# Scientific mapping on the impact of climate change on global food security*

## Mapeo científico sobre el impacto del cambio climático en la seguridad alimentaria global

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**Abstract**

Climate change poses significant threats and risks to food security. Natural phenomena such as droughts, floods, and heatwaves affect various crops, reducing agricultural yields. Water scarcity, a direct consequence of these events, limits irrigation and impacts the viability of many crops. Additionally, pests, fungi, and bacteria thrive in these altered climatic conditions, spreading more easily and contaminating crops, leading to significant economic losses for farmers. This scientific mapping was conducted to analyze the environmental impact on food security. Tools like VOSviewer and Scopus were used to identify key research in this field. The results highlight a growing interest among communities in environmental security and the development of strategies to adapt crops and mitigate climate change impacts. However, it is essential to continue research and explore new solutions to counteract these climatic effects. Finally, an agenda for future studies is presented.

**Keywords**:Biodiversity, environmental impact, nutrition, global warming, food security, climate change, sustainability

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**Resumen**

El cambio climático conforma amenazas y riesgos en la seguridad alimentaria, fenómenos naturales como sequías, inundaciones y olas de calor afectan los diferentes tipos de cultivos, reduciendo el nivel de producción de los agricultores y cultivos, la escasez de agua, consecuencia de estos mismos eventos limita el riego y afecta la vida de muchos cultivos. Asimismo, las plagas, hongos y bacterias potenciales por las condiciones climáticas afectan, contaminan y se propagan con más facilidad generando así pérdidas económicas en los agricultores. Este mapeo científico se realizó para analizar el impacto ambiental en la seguridad alimentaria, se usaron herramientas como VOSviewer y Scopus ha permitido identificar las principales investigaciones en este campo. Por lo tanto los resultados exponen un creciente interés de las comunidades en la seguridad ambiental y cómo se desarrollan estrategias que permitan la adaptación de cultivos y mitigación de los mismos, no obstante es importante seguir haciendo las investigación y exponiendo nuevas soluciones que contrarrestan los efectos climáticos. Finalmente se presenta una agenda para futuros estudios.

**Palabras clave:** Biodiversidad, impacto ambiental, nutrición, calentamiento global, seguridad alimentaria, cambio climático, sostenibilidad.

## 1. Introduction

Climate change jeopardizes the sustainability of agriculture and global food security. In response to these shifts, farmers have resorted to excessive pesticide use, thereby disrupting soil health [1]. Moreover, evidence shows that climate change drives pathogenic evolution, increasing the risk of plant diseases [2]. Consequently, climatic impacts at the global scale threaten the stability of food supplies worldwide [1].

The nexus between food security and environmental sustainability is critically shaped by how climate variability alters microbial communities and food supply chains. Scholars have proposed innovative, methodological strategies—such as closed-loop systems—that both enhance food security and reduce greenhouse gas emissions [3]. Likewise, recent advances in nanofertilizer technology demonstrate reduced environmental contamination and improved crop productivity through enhanced nutrient uptake [4]. The United Nations' Sustainable Development Goals further underscore the dual challenges of agricultural sustainability and food security amid climate change and a growing global population [5].

Export restrictions on staple crops—such as rice—exacerbate food security risks under changing climatic conditions [6]. Rice and wheat production remain pillars of global food security, and adaptation strategies such as integrated water-resource management and renewable energy deployment have been recommended to mitigate climate impacts [7].Farmers' experiential knowledge also plays a role: more seasoned cultivators report greater awareness of climate-driven crop challenges and actively seek adaptive measures [8].

A review of the literature reveals several related bibliometric studies: Mustafa et al. [9] examined the climate–food security nexus in Malaysia; Tamasiga et al.[10]explored links between climate change, inequality, and poverty in Africa; Farooq et al. [11] and Wekeza et al. [12] assessed organic agriculture's potential for climate adaptation and its effects on food production and price volatility; and Baars et al. [13]. Lanalyzed how climate change has influenced food quality and subsequent health outcomes. However, to date there is no bibliometric literature review that systematically maps global research trends on climate change's impact on food security.

Accordingly, this paper conducts a bibliometric review of the scientific literature on climate change's impact on global food security. We address this gap by querying the Scopus database and processing results with VOSviewer to identify and classify research clusters.

The article is organized into four main sections. Section 1 details the methodology for article retrieval, selection, and analysis, including our search criteria. Section 2 presents a theoretical overview of climate change's effects on global food security. Section 3 reports the bibliometric analysis. Finally, Section 4 offers conclusions, discusses limitations, and outlines an agenda for future research on this critically important topic.

## 2. Methodology

Nalimov and Mulchenko [14] established the principles of scientometrics, a discipline that applies quantitative methods to observe the progress of science. Among its most widely used approaches are scientific mapping and bibliometrics, which enable the visualization and understanding of indicators derived from bibliographic data [15].

According to Cobo [16], bibliometric analysis is essential for assessing the impact level of scientific publications. Indicators and metrics—such as citation counts and the h-index—also make it possible to evaluate the productivity of authors, countries, and journals [17], [18]. This discipline reveals the most relevant information sources, assesses scientific advances, identifies foundations for new discoveries, and pinpoints the leading authors in a field of study [19].As a result, bibliometrics has become an indispensable tool for comprehensively understanding most scientific domains [20].

Scientific mapping is fundamental because it focuses on understanding the intellectual structure of a knowledge field through its various research components [21], [22]. This technique uncovers trends and knowledge patterns [23], [24], [25] and includes analyses such as author co-citation analysis [26], [27], document co-citation analysis [28], and co-word analysis [29], as well as network visualization techniques [30].

The popularity of these methods within the scientific community has grown markedly due to their capacity to process and analyze large volumes of information, enabling researchers to detect emerging trends in specific fields [21], [31], [32].Likewise, increasing access to

citation databases and the development of more sophisticated analytical tools have fueled this expansion [33].
The primary purpose of this analysis is to explore and understand the evolution of a particular knowledge domain—whether a broader area or a specific topic [15]. Although these methods rely on quantitative data, their ultimate aim is to reveal qualitative aspects of research [34]. To this end, we will employ bibliometric and scientific mapping analyses to meet the study's objectives.

## Database Selection

Among the various bibliographic sources, Scopus was chosen as the most appropriate for this study due to its recognized academic reputation [35]. With over 76 million documented records, Scopus stands out not only for its extensive coverage but also for the quality and precision of its indexed sources [36], [37]. Furthermore, comparative analyses have repeatedly underscored Scopus's superiority over other platforms in multiple dimensions—coverage, citation tracking, and metadata consistency—positioning it as the premier database worldwide [38], [39].

## Keyword Selection

To define the core concepts linking climate change and global food security, we synthesized terminology from key prior reviews [9], [10], [11], [12], [13]. Precise search terms are essential to capture relevant literature. Therefore, our primary search string—applied to article titles and author keywords—was:

*("food safety" OR "Food security") AND ("climate change").*

## Inclusion Criteria

**Table I,** summarizes the criteria applied during the database query to ensure relevance and methodological rigor.

**Table I.** Search parameters and inclusion criteria

| Criterion | Detail |
|---|---|
| Document type | Articles, reviews |
| Language | English |
| Time span | 2000–2024 |
| Data base | Scopus |
| Subject area | Agricultural and Biological Sciences; Environmental Science; etc. |
| Search fields | Title, Keywords |
| Lenguaje | todos |
| Keywords | "food security", "food safety", "climate change" |
| Results | 3.834 |

**Bibliometric Analysis**

For this analysis, we employed VOSviewer, an application designed for constructing and visualizing bibliometric maps [40]. VOSviewer is the tool of choice for many researchers due to its ability to manage large datasets and generate intuitive visualizations of clusters and thematic evolution within a field of study [41]. Moreover, its user-friendly interface and availability in multiple languages have made it a popular platform in the scientific community [21].

This type of procedure has proven its usefulness and contribution in various fields of knowledge, such as business management [42], [43], [44], finance [45], [46], logistics [47], [48], [49], education [50], [51], [52], social sciences [53], [54], technology [55], entrepreneurship [56], [57], economics [58], [59], [60], [61], marketing [62], [63], [64], [65], scientometrics [66], [67], [68], and sustainable development [69], [70].

## 3. Resultados

**Bibliometric Analysis**

Figure 1 presents the publication history in this field since 2015. From 2020 onward, the increase in the number of documents becomes more pronounced, reflecting sustained and growing scholarly interest in climate change and food security topics. Over the past two years, roughly 33 % of the retrieved scientific articles have been published, which likely corresponds to the escalating global concern about increasingly frequent and intense extreme climate events.

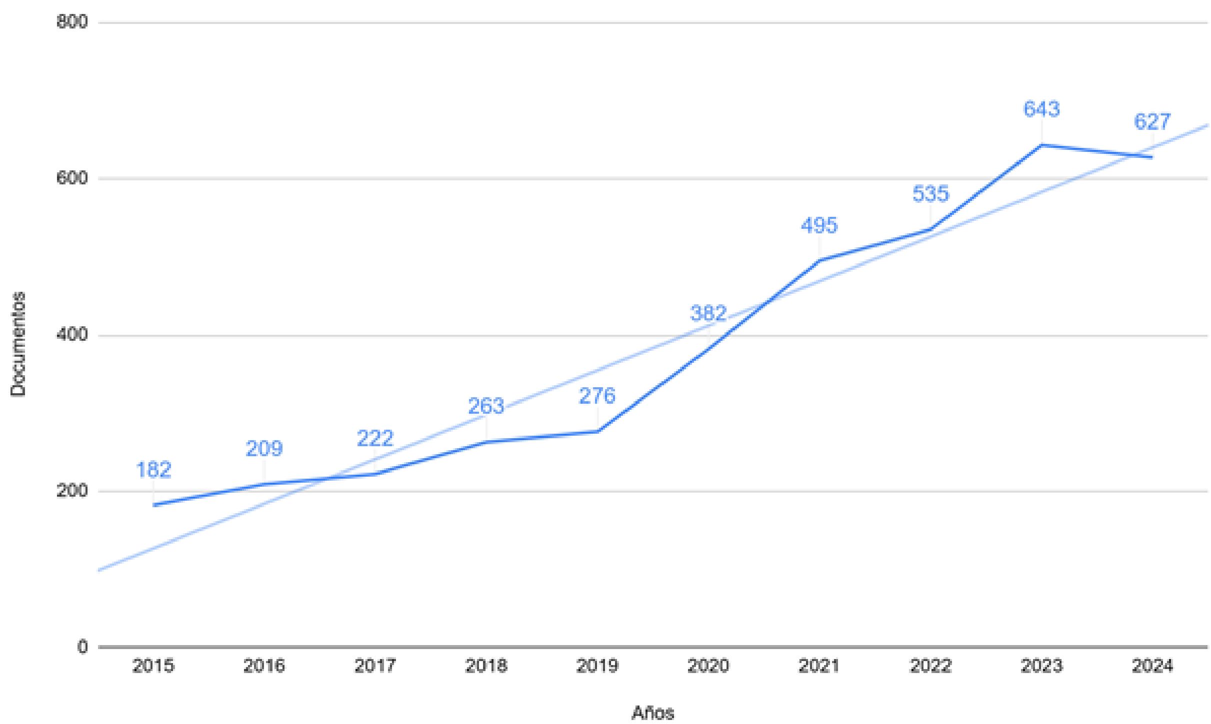


**Figure 1.** Publication trend

**Featured Authors**

Table II shows the authors with the highest number of publications in the field of climate change and food security, along with impact metrics such as h-index and total citations. The citation network comprises 16,101 authors, of whom at least 12 have published four documents and received 690 citations.

The author with the largest number of documents is Fulu Tao, affiliated with the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, with an h-index of 67, 15 published documents, and 786 citations. However, Rattan Lal of Ohio State University (USA) holds the highest h-index (142), making him the leading authority in this field.

The article titled "The carbon sequestration potential of terrestrial ecosystems" features notable contributions from Pete Smith and Rattan Lal, the two researchers with the highest h-indexes in this domain. This work aims to identify ecosystems and land areas where carbon sequestration in the terrestrial biosphere—which includes vegetation and soil—can serve as a viable mitigation strategy; it proposes shifting toward restorative land-use practices and implementing best-management practices tailored to regional conditions [71].

**Table II.** Authors ranked by number of publications

| Position | Author | Affiliation | H-index | Documents | Citations |
|---|---|---|---|---|---|
| 1 | Fulu Tao | Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences | 67 | 15 | 786 |
| 2 | Pete Smith | University of Aberdeen | 141 | 12 | 1192 |
| 3 | Rattan Lal | The Ohio State University | 142 | 12 | 915 |
| 4 | Petr Havlik | International Institute for Applied Systems Analysis | 74 | 10 | 772 |
| 5 | Eva Wollenberg | Centro Internacional de Agricultura Tropical | 37 | 10 | 690 |
| 6 | Mario Herrera | Universidad de Chile | 48 | 10 | 799 |
| 7 | Hans Van meijl | Wageningen University & Research | 37 | 8 | 963 |
| 8 | Tomoko Hasegawa | Graduate School of Engineering | 47 | 7 | 721 |
| 9 | Andrzej Tabeau | Wageningen University & Research | 33 | 7 | 792 |
| 10 | Claire Chenu | AgroParisTech | 70 | 44 | 697 |

Figure 2 presents the author citation network, in which each author's node size is proportional to their total citations. The network segregates into at least three distinct clusters, suggesting the presence of separate research communities within the field. The numerous inter-author links indicate a high degree of collaboration.

Corey Lesk emerges as the most highly cited researcher, with 2,399 citations. He is currently affiliated with the Lamont-Doherty Earth Observatory at the Columbia Climate School and the Neukom Institute at Dartmouth College. His work focuses on how extreme climate events—such as heat waves and droughts—affect global crop production, a critical area for assessing food-security risks under changing climatic conditions. Lesk's studies, conducted since 2017, have demonstrated that extreme events exacerbate agricultural system vulnerabilities and increase the risk of crop losses in key producing regions.

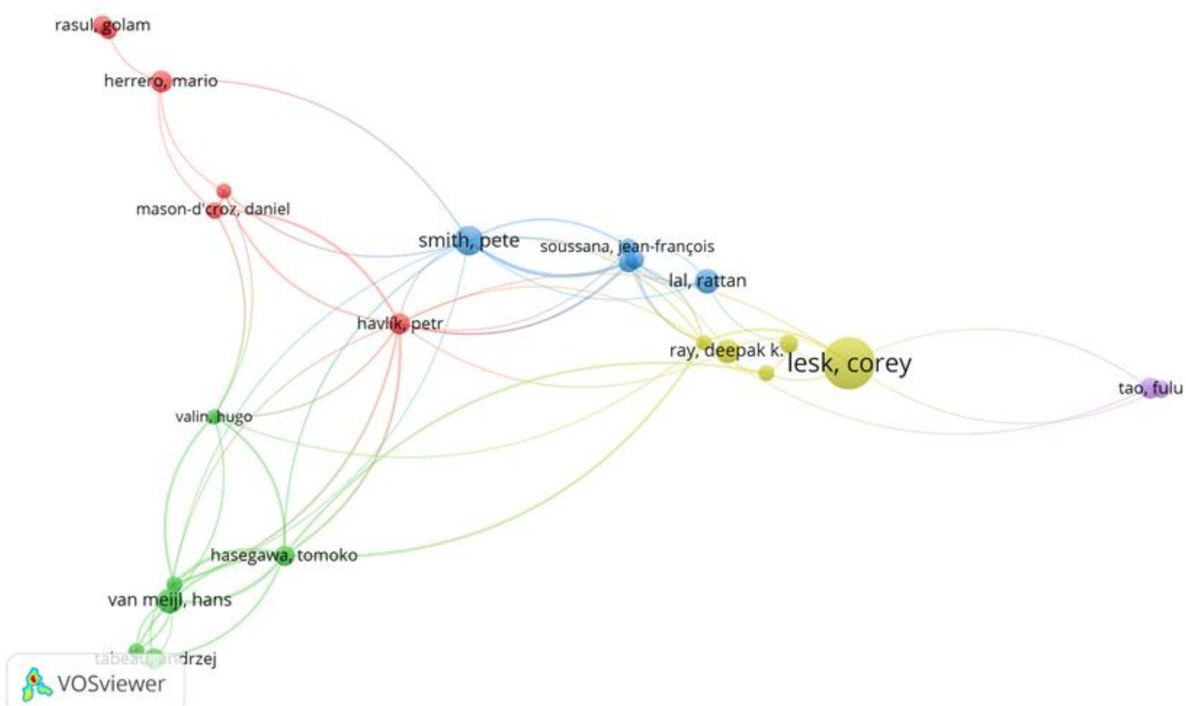


**Figure 2.** Map of Authors Highlighted by Citations

**Featured Journals**

Using VOSviewer, we analyzed 1,093 journals publishing on the impact of climate change on global food security. Of these, at least 21 journals feature five or more articles and have accumulated at least 900 citations (see Table II).Sustainability ranks first in terms of publication volume, with 190 documents. This journal covers environmental topics such as renewable energy, pollution, conservation, biodiversity, and climate change, as well as economic, sustainable development, circular economy, social, and cultural issues.

By contrast, Science of the Total Environment leads in citations, with 4,777. It specializes in pollution research—examining various pollutant types, environmental toxicology, ecology, climate-change mitigation, sustainable natural-resource management, and environmental engineering.

**Table III.** Journal ranking

| Position | Journal | Quartile / H-index / SJR 2023 | Documents | Citations |
|---|---|---|---|---|
| 1 | Sustainability | Q1 / 169 / 0.67 | 190 | 3.584 |
| 2 | Science of the total environment | Q1 /353 /2 | 157 | 4.777 |
| 3 | Snvironmental research letters | Q1 /183 / 2.13 | 81 | 3.582 |
| 4 | Food security | Q1 / 76 / 1.57 | 66 | 2.135 |
| 5 | Agricultural systems | Q1 / 134 / 1.59 | 61 | 2.183 |
| 6 | Frontiers in sustainable food systems | Q1 / 54 /0.86 | 49 | 509 |
| 7 | International journal of environmental research and public health | Q2 / 198 /0.81 | 45 | 1174 |
| 8 | Environment, development and sustainability | Q1 / 82 /0.89 | 41 | 329 |
| 9 | Plos one | Q1 / 435 /0.84 | 40 | 1773 |
| 10 | Nature food | Q1 / 57 /4.89 | 38 | 1592 |

**Featured Countries**

A total of 192 countries have contributed publications in the studied area, with an average of at least 81 documents and 9 citations per country. Among these, the United States and China stand out for their remarkable publication volume and network interconnections in agricultural topics, suggesting their leadership in both research and production within this field. This prominence can be attributed to their status as the world's leading agricultural producers and their substantial financial resources, which enable investment in advanced research to innovate agricultural practices and technologies. Such high levels of investment address the need to maintain and enhance domestic agricultural output, secure internal food availability, and strengthen export capacity. Both the United States and China have developed robust research systems that span biotechnological innovations to sustainable agriculture practices, positioning them as benchmarks for other nations in emerging trends and advancements in this domain.

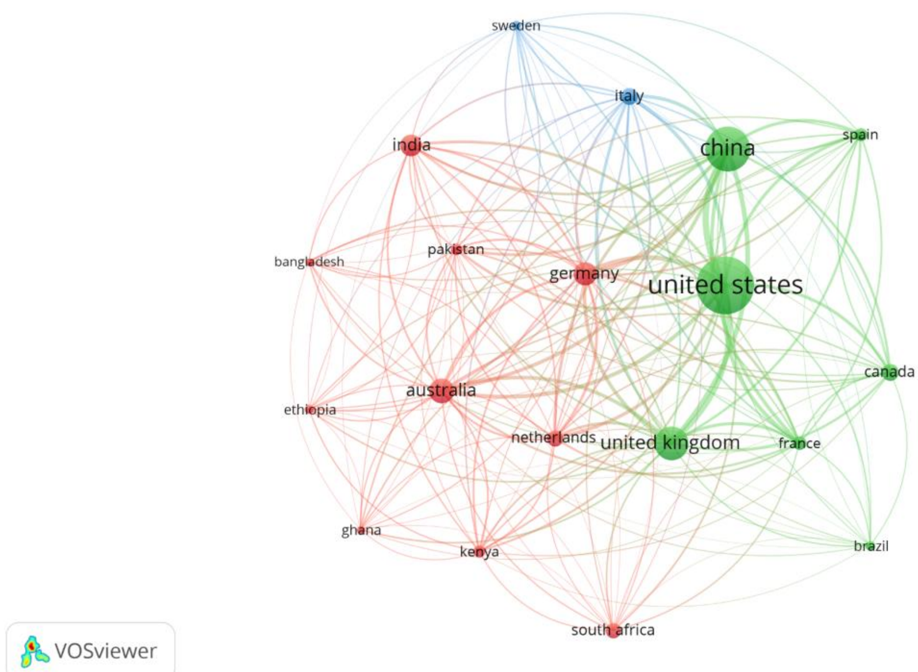


**Figure III.** Map of featured countries

**Featured Documents.**

Table IV presents the ten most-cited papers in the global research network on climate change and food security. In total, the network comprises 3,834 documents. The most-cited work is Lesk et al. [72], "Influence of extreme weather disasters on global crop production:

Natural climate solutions." This study analyzes cereal yield losses worldwide during 1964–2007 attributable to reported extreme climate events. The authors found that droughts and extreme heat can reduce cereal production by up to 10 % in the United States, with developing countries experiencing even greater losses—approximately 11 % compared to developed nations. Consequently, this paper serves as a key tool for guiding international efforts in disaster-risk reduction and adaptation of agricultural production to climate change.

The implementation of natural climate solutions—such as ecological restoration of land to avoid greenhouse-gas emissions and increase carbon storage—offers co-benefits including improved air and water quality [73]. Similarly, nanomaterials have been shown to enhance nutrient- and resource-use efficiency, thereby optimizing crop yields and reducing waste, which promotes sustainable agricultural practices [74].

Moreover, the COVID-19 pandemic exposed the need for robust public-health measures to protect the environment. The widespread use of disposable masks has created a new challenge in microplastic pollution, posing threats to ecosystems and wildlife [75]. Another critical aspect is the vulnerability of water availability under climate-change scenarios and its effects on ecosystem diversity, agriculture, energy production, and human consumption [76]. Water management is therefore fundamental to interrelated activities—hydropower generation, agricultural irrigation systems that rely on both water and electricity, and food processing—where disruptions in one can significantly impact the others [77].

In the context of global food security, direct links exist among climate change, agricultural policies, and market volatility; these factors influence both food production and access, triggering crises in various regions [78]. Furthermore, rising global temperatures negatively affect yields of the four major staple crops—wheat, rice, maize, and soy—thus threatening the capacity to feed the world's population [79]. Land-use changes also have significant repercussions for biodiversity, climate, and water resources, highlighting the importance of sustainability policies such as conservation and adoption of responsible agricultural practices to mitigate environmental impacts [80].

**Table IV.** Top 10 Most-Cited Documents

| Position | Title/reference | Citations |
|---|---|---|
| 1 | Influence of extreme weather disasters on global crop production [72] | 2285 |
| 2 | Natural climate solutions [73] | 1772 |
| 3 | Temperature increase reduces global yields of major crops in four independent estimates [79] | 1743 |
| 4 | Importance and vulnerability of the world's water towers [76] | 1036 |
| 5 | A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050 [78] | 744 |
| 6 | Covid-19 face masks: A potential source of microplastic fibers in the environment [75] | 650 |
| 7 | Opportunities and challenges for nanotechnology in the agri-tech revolution [74] | 648 |
| 8 | Sustainable development and the water–energy–food nexus: A perspective on livelihoods [77] | 638 |
| 9 | Global land use changes are four times greater than previously estimated [80] | 614 |
| 10 | Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets [81] | 585 |

## Discussion of Findings

### ✓ Key Research Themes

To identify the core research themes in the field of climate change's impact on food security, we applied clustering techniques by constructing a keyword co-occurrence network. This network comprised a total of 18,048 keywords. In Figure 4, four distinct clusters are displayed:

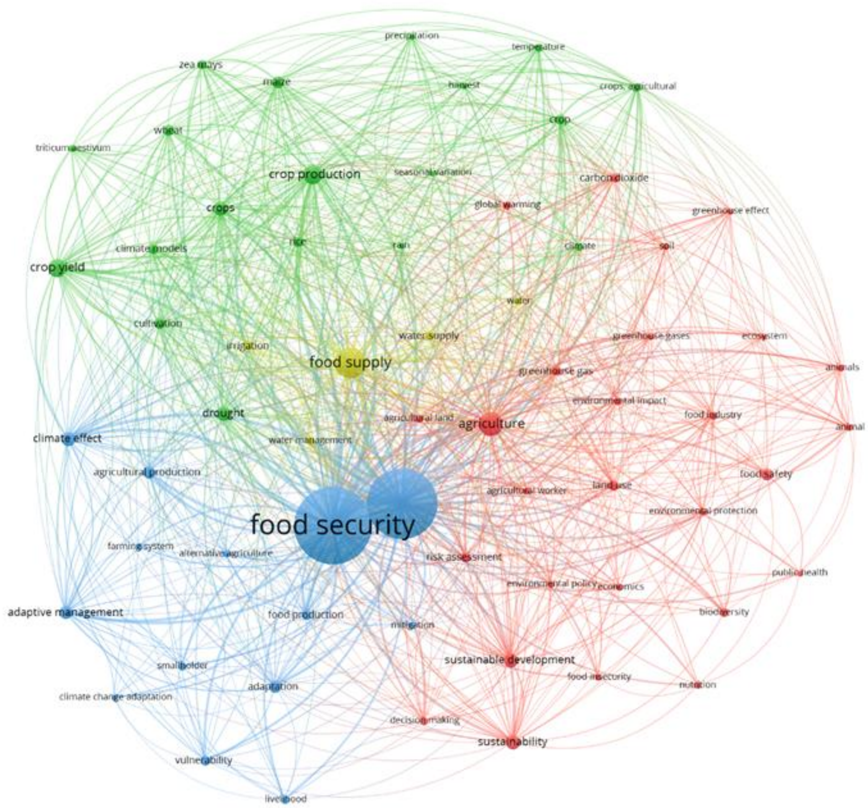


**Figure 4.** Keyword co-occurrence network

Thematic analysis based on the clusters highlights three key areas related to the impact of climate change on global food security. Cluster 1 (red) addresses climate change and its effects on sustainability, soil, and crops, aiming to understand the dynamics and challenges associated with these critical factors. Cluster 2 (green) focuses on crop types adapted to climate-change scenarios, emphasizing their importance for developing resilient agricultural strategies. Finally, Cluster 3 (blue) examines the implications of climate change on food security, outlining threats and potential solutions to ensure access to food under changing climatic conditions.

**Below is the analysis of each cluster:**

**Cluster 1: Red. Climate Change and Its Impacts on Sustainability, Soil, and Crops.**

Various strategies are proposed, including the use of ecological technologies (biofertilizers, nanofertilizers), agroecological practices, and climate-change adaptation measures. The importance of farmer education and training is emphasized, as is the role of governments in promoting sustainable agricultural practices.

Agricultural sustainability offers a solution for increasing food productivity in developing countries without harming the environment by combining the use of genetically modified biofertilizers [5]. Moreover, nanofertilizers enhance plants' resilience to climatic stress and improve nutrient-uptake efficiency, thereby reducing pollution and boosting crop yields [4]. In this context, sustainable approaches such as agroecology provide a viable framework for building climate-resilient systems and conserving natural resources by integrating scientific knowledge to address food-production challenges [82].

Climate change alters microbial communities and food-chain dynamics. One proposed strategy is to integrate more effective food-security cycles that reduce greenhouse-gas emissions within a circular-economy model—minimizing waste and maximizing the reuse of natural resources [3]. Likewise, adaptive agricultural practices—such as switching from irrigated to rainfed crops and advancing planting dates—are recommended to cope with shifting precipitation patterns [83]. Concurrently, biodiversity loss, rising pest pressures, and extreme weather events (droughts, heat waves, and heavy rainfall) have driven farmers toward environmentally harmful soil practices, including excessive pesticide and synthetic-fertilizer applications [1].

In this scenario, it is imperative for governments to enact policies that incentivize sustainable agribusiness, advancing farm mechanization alongside eco-friendly technologies [84]. Additionally, farmer training on microbial inoculants is crucial, as these inputs increase soil biomass and carbon content, enhance agricultural productivity, and reduce greenhouse-gas emissions [85]. Over time, research has also demonstrated that women's participation in decision-making significantly influences climate-adaptation efforts, empowerment, and the resilience of farming communities [86].

**Cluster 2: Green. Crop Types Adapted to Climate-Change Scenarios.**

This cluster explores the challenges facing global food security due to climate change and unsustainable agricultural practices, highlighting the negative impacts on staples such as rice, wheat, and maize. Various mitigation strategies are proposed, including the adoption of sustainable farming practices, the development of crop varieties resilient to adverse conditions, and the use of biotechnology to enhance food quality and yield.

Export restrictions can cause severe food-security problems by significantly reducing global food supplies, triggering shortages and price spikes that disproportionately affect the most vulnerable countries [6]. Meanwhile, climate change further undermines the production of essential crops—especially rice—posing an additional threat to food security. In response, strategies such as integrated water-resource management systems and renewable-energy deployment have been recommended to mitigate these effects [7]. Rice is also noted as a climate-friendly option because it generates lower greenhouse-gas emissions compared to other staples [87].

Wheat, one of the world's most important cereals, has likewise suffered under evolving climatic stresses. Experienced farmers are aware of these challenges and actively seek adaptive measures [8]. Wheat cultivation additionally struggles with soil salinity and inefficient water management, underscoring the urgent need for sustainable agronomic practices to secure future yields [88].

The growth and development of various crops—including rice—has been significantly enhanced by soil phosphorus-solubilizing bacteria, which increase plant tolerance to multiple stressors [89]. Adapting crops to adverse conditions also requires breeding flood-tolerant varieties and implementing more efficient irrigation systems [90]. Furthermore, the introduction of exogenous genes into wheat has been advanced as a strategy to bolster food security by improving nutritional quality and resistance to diseases and pests—critical factors for sustaining this essential cereal [91].

**Cluster 3: Blue. Impact of Climate Change on Food Security.**

Climate change threatens agricultural production and food security through factors such as increased pathogen prevalence, soil degradation, droughts, and heat waves. Crops like quinoa, wheat, and rice occupy a vital place due to their adaptability to diverse climates, which makes them resilient and enduring over time. Various strategies to combat climate change—such as sustainable practices, “greening” agriculture, and agroforestry—underscore the crucial role of farmers and the care they apply to different crop types.

Climate change poses a significant challenge to agricultural sustainability and food security. Consequently, many farmers have resorted to excessive pesticide use, causing soil imbalances and negative effects on agricultural ecosystems [1]. Additionally, factors like humidity and temperature favor pathogen growth, increasing plant disease incidence and threatening both food production and global biodiversity [2]. Meanwhile, rising world population intensifies food demand, leading to soil overexploitation. Cereals such as wheat, rice, and quinoa therefore emerge as key options for ensuring food security, given their ability to adapt to adverse climatic conditions and their nutritional importance for future generations [92].

Ancient cereals—quinoa, wheat, and rice—play an essential role in combating climate change thanks to their tolerance for extreme conditions and high nutritional value, making them well-suited to environmental challenges while contributing to food security [93]. A recent study highlights the potential of Aegilops tauschii, a plant that prevents soil erosion and fixes essential nutrients such as nitrogen, thereby benefiting surrounding crops and improving their nutritional profile [94]. Quinoa, renowned for its nutritional value and drought tolerance, shows remarkable adaptability in arid climates, making it a key crop for addressing food security challenges under water stress [95].

Plants adapted to variable climatic conditions—such as certain legumes and fruits—can play a crucial role in mitigating climate change due to their adaptability, low water requirements, and minimal need for intensive management [96]. In parallel, sustainable agricultural practices—like “greening” agriculture—aim to replace external inputs by enhancing nutrient recycling and other strategies to reduce environmental impact, thereby contributing to food security [97]. Farmers are essential to the transition toward sustainable systems, as their responsibility extends beyond maintaining production to implementing responsible pesticide and fertilizer management, balancing productivity with environmental stewardship [3].

As a result of the cluster-content analysis, the following research agenda is proposed:

**Table V.** Research Agenda

| Cluster | Theme | Reference |
|---|---|---|
| Cluster Theme Reference Climate change and its effects on sustainability, soil, and crops | Assess the impact of emerging technologies—such as artificial intelligence and the Internet of Things (IoT)—on optimizing and sustaining the food supply chain. | [3] |
| | Evaluate the environmental and economic impact of the widespread adoption of climate-smart crops. | [96] |
| Crop types adapted to climate-change scenarios | Evaluate effective microbial consortia that combine different species to maximize agronomic and environmental benefits. | [85] |
| | Conduct detailed local and regional studies to better understand how climate change affects different crop types—such as rice—across varied agroecological zones. | [7] |
| | Explore crop-adaptation strategies to improve and stabilize yields—especially under low-production conditions—by integrating innovative approaches that optimize resource use and enhance the resilience of agricultural systems to climatic stress. | [98] |
| Impact of climate change on food security | Assess risks and perform life-cycle analyses within food supply chains to identify critical vulnerability points, improve resource-use efficiency, and mitigate environmental impacts associated with food production and distribution. | [3] |
| | Examine the long-term effects of sustainable agricultural practices across diverse regions and socioeconomic contexts to understand how local conditions influence climate-adaptation strategies and inform the development of tailored solutions. | [86] |

## Conclusions

This study conducted a scientific mapping of the global literature on food security and climate change. To this end, records available in the Scopus database were analyzed using bibliometric tools such as VOSviewer and Bibliometrix. The analysis identified, among other factors, the most prominent countries, the authors with the highest citation counts and publication volumes, and the journals with the greatest impact in this field.

The intersection of climate change, food security, and ecological systems underscores the urgent need to implement sustainable and integrated strategies, taking into account the effects of extreme climate events on agricultural production—particularly in developing countries—and the potential of natural solutions and nanomaterials to mitigate these impacts.

Moreover, the COVID-19 pandemic revealed new environmental challenges, such as microplastic pollution, which affect ecosystems and demand appropriate management measures. Water availability is key for interconnected activities—agriculture, energy generation, and food processing—highlighting its sustainable management as a global priority.

Land-use changes, rising global temperatures, and volatility in agricultural markets represent critical threats to world food security. Therefore, concerted action is required that integrates sustainable agricultural policies, ecological restoration, and innovative technologies to ensure the resilience of both food systems and the environment.

The thematic cluster analysis highlights three key areas for addressing the impact of climate change on global food security. The focus on sustainability, soil, and crops (Cluster 1) provides a comprehensive understanding of the associated challenges. Research on climate-resilient crop varieties (Cluster 2) emphasizes the need to develop robust agricultural strategies. Finally, analysis of threats and solutions to guarantee food access (Cluster 3) underscores the importance of implementing concrete measures to confront the consequences of climate change on food security. These findings offer a solid foundation for the design of global policies and strategies.

The results of this review also identified several priority research lines. Advances in emerging technologies—artificial intelligence and the Internet of Things (IoT)—together with the deployment of climate-smart crops, are transforming the sustainability and efficiency of food supply chains. At the same time, effective microbial consortia present new opportunities to maximize agricultural benefits in a sustainable manner.

Life-cycle analysis and risk assessment in food chains, alongside environmental and economic impact studies, are essential for guiding more sustainable agricultural policies and practices. Long-term evaluations and local to regional studies on climate-change effects in different crops—such as rice—enable the adaptation of strategies to specific conditions and diverse socioeconomic contexts.

Adaptations in crop management to stabilize yields under low-production scenarios underscore the importance of integrating technology, scientific research, and sustainable practices to face global challenges in food security and agricultural sustainability.

Finally, despite the methodological rigor applied, this study presents several limitations that may serve as opportunities for future work. First, although the chosen database is widely recognized and validated at a global level, some relevant studies may not be indexed in Scopus. Future research could incorporate additional sources to broaden the scope of the review.

Second, although the methodological approach and tools employed are validated by the scientific community and follow a systematic framework, it would be important to compare results with other methods and platforms. This would advance greater standardization in bibliometric research.

Lastly, the inherent bias of researchers must be considered. While the systematic procedure relies on quantitative techniques, the interpretation and analysis of results depend on qualitative judgment, which may introduce subjectivity. Addressing this aspect in future studies could further strengthen the robustness of the findings.

## Declaration on the Use of Artificial Intelligence

The authors declare that the use of artificial intelligence tools in this work was strictly limited to two tasks: (i) translating the original text, written in Spanish, into English, and (ii) assisting with style correction and grammatical improvement of the translated manuscript. At no point were AI tools employed for generating, analyzing, or interpreting data, nor for drafting the scientific content of the manuscript. The final review, validation, and approval of the translation and stylistic adjustments were carried out by the authors to ensure the accuracy, coherence, and fidelity of the text.

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