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Classic publications in food security research: A bibliometric analysis

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Abstract

The article presents classic publications in the field of food security from 1993 to 2022 using bibliometric methods. Data come from the Science Citation Index Expanded (SCI-EXPANDED) of the Web of Science database. The results show that the years 2010 and 2011 stand out as the most prolific, with a total of three classic articles receiving the highest citations. The articles show that agricultural intensification does not necessarily lead to increased yields but rather contributes to environmental degradation through deforestation, biodiversity loss, and ultimately climate change. The articles highlight the adoption of ecologically friendly methods, natural solution, and technology-based and sustainable agricultural practices to reduce the impact of climate change and address food insecurity. However, linking agricultural intensification to biodiversity conservation and hunger and the effectiveness of different adaptation models in the increasing variability of extreme events remain complex issues that require further research in the future. Similarly, machine learning research can be used to address food insecurity, especially in crop or plant, and forestry tree breeding, precision agriculture, and so forth.

KEYWORDS

classic articles, climate change, global food security, Web of Science Core Collection

1 | INTRODUCTION

Food security remains one of the most pressing global topics that has attracted the attention of international organizations, policy-makers, and scientific research (Skaf et al., 2020). It is estimated that nearly 1 billion people are undernourished because of chronic food insecurity and that food demand is expected to increase by at least 50% by 2050 (Godfray et al., 2010; Nelleman et al., 2009). The impacts of climate change are having significant negative impacts on food production and food security worldwide because of rising global temperatures, changing weather patterns, and other environmental disruptions. Consequently, the focus has been on transforming food systems, taking into account greenhouse gas emissions (GHG), freshwater resources, biodiversity, and soil quality to achieve sustainability (Bock et al., 2022; Von Braun et al., 2021). In this article, we review classic publications with more than 1000 citations in the field of food security, which suggests that they are impactful articles that contribute to the research field. Previously, Garfield (1976) pointed out that classic articles are articles that have been cited 100 or more times; recently, articles with at least 1000 citations from the Web of Science Core Collection are also referred to as classic articles (Ho, 2018; Long et al., 2014; Yeung & Ho, 2018). We report the characteristics of classic articles, publication outputs, journals, life citation histories, and other attributes of the classic articles based on the Web of Science categories in the Science Citation Index Expanded (SCI-EXPANDED).

2 | DATA SOURCES AND METHODS

Data for this study were collected on November 10, 2023, by extracting information from the online databases of the Science Citation Index Expanded (SCI-EXPANDED). According to the latest Journal Citation Reports (JCR) released by Clarivate on June 28, 2023, there is a total of 9637 journals categorized under 178 Web of Science categories in SCI-EXPANDED.

In 2011, the "front page" including title, abstract, and author keywords as a filter was proposed to improve search strategy when using the terms of Topic (TS) in the Web of Science Core Collection for the bibliometric study (Wang & Ho, 2011). The "front page" filter can avoid introducing unrelated publications for bibliometric analysis. In recent years, a significant difference was found in a wide range of bibliometric studies using the "front page" as a filter, for example, research topics: Fenton oxidation for soil and water remediation (Usman & Ho, 2020), insomnia (Jallow et al., 2020), Q fever (Farooq et al., 2022), and temporomandibular disorders (Al-Moraissi et al., 2023).

To ensure thorough search coverage, we employed the use of quotation marks ("") and the Boolean operator "or" to guarantee the inclusion of at least one search keyword in the TOPIC field (title, abstract, author keywords, and *Keywords Plus*) from 1991 to 2022.

The search keywords used were "food security." To have more accurate analysis results, uncommon terms, namely, "grain security," "security of food," "food securities," "security of grain," "security of foods," "foodstuff security," "security of foodstuffs," "foods security," "securitization of food," "food securitization," and "foodborne security," and some terms missed spaces in the database, namely, "food securityand," in SCI-EXPANDED were also considered. The asterisk (*) represents any group of characters, including no character. Furthermore "food security*" was used to check out articles containing "food security ("or "food security)."

In 2014, Ho's research group introduced the term "classic articles," defining it as any article garnering a total of 1000 citations or more from the Web of Science Core Collection. The citation count is calculated from the publication year of the article until the conclusion of the latest recorded year, denoted as TC_{year}, where $TC_{year} \geq 1000$ citations (Long et al., 2014).

A total of 43 documents with 1000 citations or more from the Web of Science Core Collection containing search keywords in terms of TS (topic) were searched out from 2004 to 2019 in the SCI-EXPANDED database. In order to enhance the search strategy for the bibliometric study using the terms of Topic (TS) in the Web of Science Core Collection, the "front page" filter has been found to be effective in a wide range of topics in the SCI-EXPANDED (Ho et al., 2024; Wang & Ho, 2011). The search for documents containing the specified keywords on their "front page" yielded a total of 29 classic documents with $TC_{2022} \geq 1000$ citations, which accounted for 67% of the 43 initially identified documents. The search was conducted in the category of SCI-EXPANDED, spanning the years 1991 to 2022. It is worth noting that all citations from the original text have been preserved in this revised version. The complete records of documents from SCI-EXPANDED, along with the corresponding citation counts for each year, were downloaded into Microsoft 365 Excel. Manual coding was conducted to further enhance the data analysis process (Ho et al., 2024; Li & Ho, 2008). The journal's impact factors (IF_{2022}) were obtained from the Journal Citation Reports (JCR) published in 2022.

Affiliations from England, Scotland, and Wales were reclassified as being from the United Kingdom (UK).

The total number of citations of a document in the Web of Science Core Collection is updated from time to time. Ho's group proposed citation indicators:

C_{year}: the number of citations from Web of Science Core Collection in a particular year (e.g., C_{2022} describes citation count in 2022) (Ho, 2012).

TC_{year}: the total citations from Web of Science Core Collection received since publication year till the end of the most recent year (2022 in this study, TC_{2022}) (Wang et al., 2011).

CPP_{year}: average number of citations per publication ($CPP_{year} = TC_{year}/TP$); TP: total number of publications (Ho, 2013).

The advantage of using TC_{year} and C_{year} is that they are immutable and ensure repeatability compared with the citation index of the Web of Science Core Collection (Fu et al., 2012).

3 | RESULTS AND DISCUSSION

3.1 | Characteristics of document types

A total of 29 classic documents were identified in the SCI-EXPANDED from 2004 to 2017, among three document types including 18 articles (62% of 29 documents), 11 reviews (38%), and one book chapter 3.4%). Reviews ($CPP_{2022} = 2239$ citations) had a CPP_{2022} value 1.2 times higher than that of articles ($CPP_{2022} = 1922$ citations). This value was higher than some classic topics: apoptotic (0.98 times) (Jallow et al., 2021), *Helicobacter pylori* (0.82 times) (Suk et al., 2019), and cervical cancer (0.43 times) (Tantengco & Ho, 2023). The classic review entitled "Food security: The challenge of feeding 9 billion people" (Godfray et al., 2010) was the most frequently cited document in food security research with a TC_{2022} of 6170 citations. "Climate change and food systems" (Vermeulen et al., 2012) was the only classic book chapter with a TC_{2022} of 1023 citations. The book chapter was also categorized to be a review in the Web of Science Core Collection. Godfray et al. (2010) in their article discuss the importance of food system sustainability given the myriad challenges facing the planet including the impacts of climate change due to greenhouse gas emission, increasing human activities, and urbanization. An integrated global strategy is proposed that takes into account land, water, environment, and energy aspects to ensure sustainable and equitable food security by closing the yield gap, increasing production limits, reducing waste, and improving dietary habits to a high proportion of food derived from the most efficient sources. Similarly, Vermeulen et al. (2012) in their article discuss the interaction between food systems and climate change, particularly, in achieving sustainable production while controlling greenhouse gas emission and conserving water supplies to end world hunger. The article shows that achieving this outcome requires reforms in the social and natural sciences related to food production with a focus on achieving environmental and social justice outcomes, including improving incomes and livelihoods. Both classic articles demonstrate the need for synergistic actions and an integrated approach in addressing food security, climate change adaptation, and mitigation in food systems by developing policies that make food systems more resilient to climate change and reduce greenhouse gas emissions (GHG).

The contributions of various document types were different, with articles being the most commonly used document type in the research topic (introduction, method, results, discussion, and conclusion). The classic articles were chosen for a deeper analysis in research topics, including cervical cancer (Tantengco & Ho, 2023), apoptotic (Jallow et al., 2021), and *H. pylori* (Suk et al., 2019). Among the 18 classic articles, English was the only language.

3.2 | Publication outputs

A relationship between total number of classic articles in a year (*TP*) and their average number of citations per publication ($CPP_{year} = TC_{year}/TP$) by the years in a topic as a unique indicator was presented (Jallow et al., 2021; Suk et al., 2019). The 18 classic articles were published between 2004 and 2017. The average TC_{2022} was 1922 citations with a maximum of 4296 citations. Figure 1 shows the distribution of these 18 classic articles over the years and their CPP_{2022}. No classic article was identified after 2017. In terms of classic articles in food security research, the years 2010 and 2011 stand out as the most prolific, boasting a total of three classic articles respectively. In 2011, there were three articles that garnered the highest CPP_{2022} score of 3135 citations. Notably, the year 2017, with just two articles, achieved a CPP_{2022} of 2647 citations, whereas the year 2004, with two articles, recorded a CPP_{2022} of 2566 citations, demonstrating their significant impact on the field.

3.3 | Web of Science Categories and Journals

A total of 9649 journals were categorized under 178 Web of Science categories in SCI-EXPANDED in 2022. The 18 food security-related classic articles were published in nine journals across nine Web of Science categories in SCI-EXPANDED. The characteristics of the Web of Science categories based on their average number of citations per publication (CPP_{year}), the average number of authors per publication (*APP*), and the number of journals in a category as basic information of the journals in a research topic were proposed (Giannoudis et al., 2021). Table 1 shows the nine categories. The category of multidisciplinary sciences with 73 journals published the most 11 classic articles, which represent 61% of 18 classic articles. Comparing the categories in Table 1, articles published in the category of imaging science and photographic technology had the greatest CPP_{2022} of 4253 citations, whereas articles in the category of plant

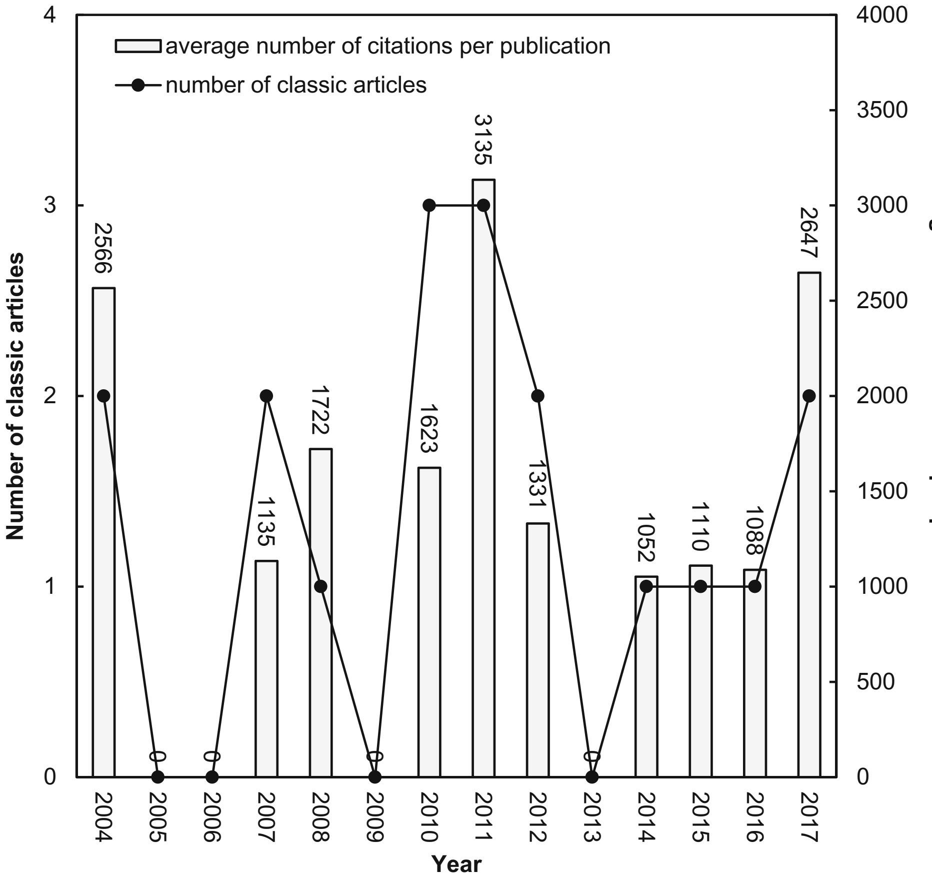

FIGURE 1 Number of classic articles and average number of citations per publication by year.

TABLE 1 Nine Web of Science categories published the classic food security articles.

Web of Science category	*TP* (%)	*No. J*	*APP*	CPP_{2022}
Multidisciplinary sciences	11 (61)	73	17	2139
Environmental sciences	5 (28)	274	5.4	1737
Meteorology and atmospheric sciences	2 (11)	94	4.0	1135
Biodiversity conservation	1 (5.6)	64	8.0	1098
Ecology	1 (5.6)	169	8.0	1098
Genetics and heredity	1 (5.6)	172	30	1307
Imaging science and photographic technology	1 (5.6)	28	6.0	4253
Plant sciences	1 (5.6)	238	3.0	1088
Remote sensing	1 (5.6)	33	6.0	4253

Abbreviations: *APP*, average number of authors per publication; CPP_{2022}, average number of citations per publication (TC_{2022}/TP); *No. J*, number of journals in a category in 2022; *TP*, number of classic articles.

sciences had a CPP_{2022} of 1088 citations. The *APP* ranged from 30 authors in the category of genetics and heredity to 3.0 authors in the category of plant sciences. It should also be noticed that journals could be classified into two or more categories in Web of Science, for instance, *Remote Sensing of Environment* was listed in environmental sciences, remote sensing, imaging science, and photographic technology; thus, the sum of percentages was higher than 100% (Ho, 2014).

Among the 11 journals, eight journals (73% of 11 journals) contained one classic article. Ho proposed the characteristics of the journals based on their CPP_{year} and the *APP* as basic information of the journals in a research topic (Ho, 2021). It has been applied in classic articles in cervical cancer (Tantengco & Ho, 2023). Table 2 shows the 11 journals that published the classic food security articles. The *Nature* published the most four classic articles, which represent 22% of 18 classic articles. Comparing the 11 journals in Table 2, articles published in the *Remote Sensing of Environment* had the greatest CPP_{2022} of 4253 citations, whereas articles in the *Nature Climate Change* had a CPP_{2022} of 1052 citations. The *APP* ranged from 33 authors in the *Nature* to 2.0 authors in the *Environmental Research Letters*. The top two journals in the 73 journals in the category of multidisciplinary sciences: *Nature* ($IF_{2022} = 64.8$) with four classic articles and *Science* ($IF_{2022} = 56.9$) with three articles had the highest journal impact factor.

TABLE 2 The 11 journals published the classic food security articles.

Journal	*TP* (%)	IF_{2022}	*APP*	CPP_{2022}	Web of Science category
Nature	4 (22)	64.8	33	2072	Multidisciplinary sciences
Proceedings of the National Academy of Sciences of the United States of America	3 (17)	11.1	13	1961	Multidisciplinary sciences
Science	3 (17)	56.9	3.3	2661	Multidisciplinary sciences
Nature Communications	1 (5.6)	16.6	5.0	1370	Multidisciplinary sciences
Frontiers in Plant Science	1 (5.6)	5.6	3.0	1088	Plant sciences
Nature Genetics	1 (5.6)	30.8	30	1307	Genetics and heredity
Remote Sensing of Environment	1 (5.6)	13.5	6.0	4253	Environmental sciences Remote sensing Imaging science and photographic technology
Global Environmental Change-Human and Policy Dimensions	1 (5.6)	8.9	5.0	1063	Environmental sciences Environmental studies Geography
Environmental Research Letters	1 (5.6)	6.7	2.0	1218	Environmental sciences Meteorology and atmospheric sciences
Biological Conservation	1 (5.6)	5.9	8.0	1098	Biodiversity conservation Ecology Environmental sciences
Nature Climate Change	1 (5.6)	30.7	6.0	1052	Environmental sciences Environmental studies Meteorology and atmospheric sciences

Abbreviations: *APP*, average number of authors per publication; CPP_{2022}, average number of citations per publication (TC_{2022}/TP); IF_{2022}, journal impact factor in 2022; *TP* (%), total number of classic articles and the percentage of all number of classic articles.

The *Nature Climate Change* ($IF_{2022} = 30.7$) with one classic article was the top journal in the 94 journals in the category of meteorology and atmospheric sciences.

3.4 | Citation history of the classic articles

Classic articles might not always have a high impact on a research topic (Jallow et al., 2021; Suk et al., 2019). It is necessary to understand the citation history of the classic articles. The citation histories of the top 18 classic articles are shown in Figure 2. Thirteen of the 18 articles were published after 2009, and the other five were published before 2009. Figure 2 shows that one of the articles "Google Earth Engine: Planetary-scale geospatial analysis for everyone" recorded a sharp increase in citations throughout the period since its publication in 2017. This article might have a high impact in WOS category of imaging science and photographic technology. In addition, classic author Lobell D. B published two classic articles. Therefore, we discuss all classic articles and show their contribution in the field of food security (Table 3).

3.4.1 | Solutions for a cultivated planet (Foley et al., 2011)

This paper discusses the interaction between agriculture, food, and the environment systems, emphasizing that to achieve global food security food production and environmental conservation must be addressed simultaneously. This article received the highest citations and can be considered the most popular article in food security. Since its publication in the last decade (from 2011), the annual citations increased significantly, with a slight decrease in 2022. This

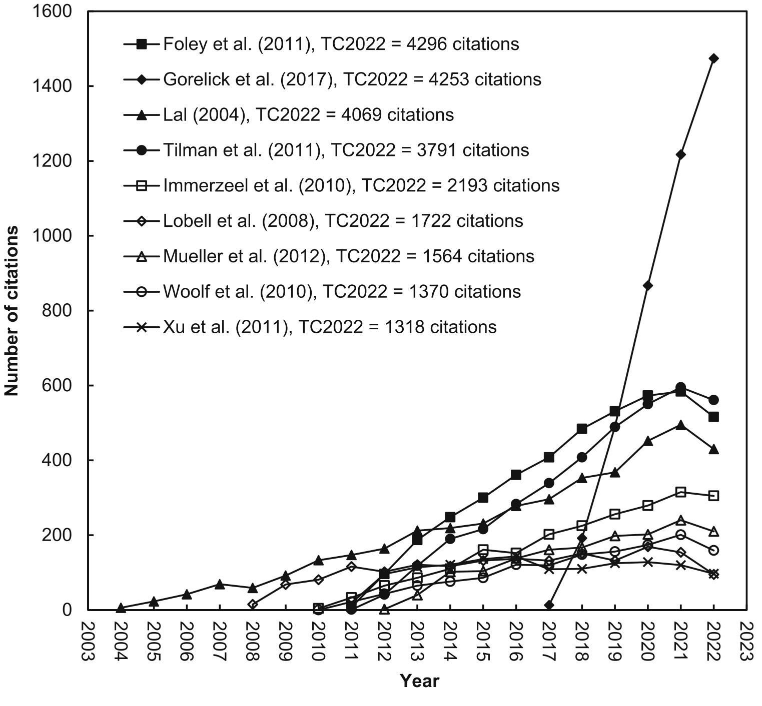

FIGURE 2 Citation histories of the top nine classic food security-related articles.

TABLE 3 The 18 classic food security articles.

Rank (TC_{2022})	Rank (C_{2022})	Article title	Country	Reference
1 (4296)	3 (516)	Solutions for a cultivated planet	USA, Canada, Sweden, Germany	Foley et al. (2011)
2 (4253)	1 (1474)	Google Earth Engine: Planetary-scale geospatial analysis for everyone	Switzerland, USA	Gorelick et al. (2017)
3 (4069)	4 (430)	Soil carbon sequestration impacts on global climate change and food security	USA	Lal (2004)
4 (3791)	2 (561)	Global food demand and the sustainable intensification of agriculture	USA	Tilman et al. (2011)
5 (2193)	8 (305)	Climate change will affect the Asian water towers	Netherlands	Immerzeel et al. (2010)
6 (1722)	17 (95)	Prioritizing climate change adaptation needs for food security in 2030	USA	Lobell et al. (2008)
7 (1564)	9 (210)	Closing yield gaps through nutrient and water management	USA, Canada	Mueller et al. (2012)
8 (1370)	10 (159)	Sustainable biochar to mitigate global climate change	USA, UK, Australia	Woolf et al. (2010)
9 (1318)	15 (97)	Genome sequence and analysis of the tuber crop potato	China, Peru, India, Russia, Chile, UK, Poland, Italy, USA, Argentina, Ireland, New Zealand, Denmark, Netherlands	Xu et al. (2011)
10 (1307)	14 (103)	Genome-wide association studies of 14 agronomic traits in rice landraces	China, USA	Huang et al. (2010)
11 (1218)	16 (96)	Global scale climate - crop yield relationships and the impacts of recent warming	USA	Lobell and Field (2007)
12 (1,110)	7 (315)	Managing nitrogen for sustainable development	USA, France	Zhang et al. (2015)
13 (1,098)	13 (110)	Global food security, biodiversity conservation and the future of agricultural intensification	Germany, USA	Tscharntke et al. (2012)

TABLE 3 (Continued)

Rank (TC_{2022})	Rank (C_{2022})	Article title	Country	Reference
14 (1,088)	5 (367)	Using deep learning for image-based plant disease detection	Switzerland, USA	Mohanty et al. (2016)
15 (1,063)	18 (45)	Effects of climate change on global food production under SRES emissions and socio-economic scenarios	UK, Austria, Spain, USA	Parry et al. (2004)
16 (1,052)	11 (157)	A meta-analysis of crop yield under climate change and adaptation	UK, Colombia, USA, Australia	Challinor et al. (2014)
17 (1,051)	12 (112)	Global food security under climate change	Italy, USA, Austria	Schmidhuber and Tubiello (2007)
18 (1,041)	6 (319)	Natural climate solutions	USA, UK, Brazil, Australia, Sweden, Netherlands	Griscom et al. (2017)

Note: TC_{2022}, the total number of citations from Web of Science Core Collection since publication year until the end of 2022; C_{2022}, the total number of citations in 2022 only; Rank, rank in all 18 food security-related articles.

article offers three critical messages: (a) aiming to close yield gaps without necessarily agricultural expansion—maximize production on existing agricultural croplands to avoid deforestation and other environmental degradation; (b) increasing resource efficiency use by minimizing unsustainable use of water, nutrients, and chemicals on land; and (c) reducing food waste—by shifting away from producing food for livestock feeds, bioenergy, and other non-food applications. The article proposes ecologically friendly ways to reverse the effects of greenhouse gas emissions, biodiversity loss, and unsustainable water withdrawals.

3.4.2 | Google Earth Engine: Planetary-scale geospatial analysis for everyone (Gorelick et al., 2017)

This article ranked second (TC_{2022}) and had a significant increase in citations for all the period of study. Compared with the first article, this article did not have enough time to accumulate citations, but it gained relatively more citations in just 6 years after publication, which shows its impact. We expect this article to be cited more in the future (Figure 2). This is a novel article that discusses the application of the Google Earth engine in multiple plenary-scale geospatial analyses such as food security, deforestation, drought, disaster, water management, and environmental protection. It discusses the platform of the Google Earth engine—how to access and analyze data, the data catalog—based on 2D gridded raster bands in a lightweight image container, system architecture, data distribution models, efficiency performance and scaling, and its applications in various disciplines. This article highlights the capabilities the Google Earth engine provides to access and compute data and information related to societal challenges by facilitating the tracking, monitoring, and management of the environment and other resources. This article provides an important foundation for application and integration with other technologies, including other artificial intelligence tools to address agricultural challenges.

3.4.3 | Soil carbon sequestration impacts on global climate change and food security (Lal, 2004)

This article ranked third (TC_{2022}) and saw a significant increase in citations for the first 4 years since its publication. It reached 69 annual citations in 2007 and then fell to 59 citations in 2008 before picking up again from 2009 to 2021, with 495 citations in 2021 and finally falling to 430 citations in 2022. The work of Lal (2004) recorded an upward trend of citation from 2004 to 2022 with a slight decline in 2008 and 2022, respectively. This article discusses strategies for increasing food production by improving soil quality to address food insecurity. This requires the use of technologies based on recommended management practices (RMP) to increase crop yields on a global scale by improving soil fertility through improving soil organic matter stock, which requires the use of sustainable agricultural technologies for water and nutritional management. Using cases from Africa, it demonstrates how the destruction in soil matter leads to a decline in crop yields and thus to food insecurity and environmental degradation. It showcases how carbon sequestration reverses the situation by improving and sustaining agronomic productivity, including offsetting fossil-fuel emission by 0.4 to 12 Gt/year or 5% to 15% of global emissions.

3.4.4 | Global food demand and the sustainable intensification of agriculture (Tilman et al., 2011)

This article ranked fourth (TC_{2022}), experiencing a significant increase in citations in the first 10 years since its publication, reaching 595 annual citations in 2021 and finally a slight decrease to 561 citations in 2022. This article warns of the threat of land clearing and habitat fragmentation, leading to biodiversity loss, and global greenhouse gas emissions thereby damaging marine, freshwater, and terrestrial ecosystems. Using quantitative assessments, it forecasts global crop demand in 2050 and assesses the likely impact of land clearing, nitrogen fertilizer use, and greenhouse gas emission on meeting global crop demand. It shows that from 2005 to 2050, global demand for calories would increase by 100% and global demand for crop proteins would increase by 110%. It highlights a trajectory that adopts and transfers technologies to lower-yielding countries, improves their soil fertility, creates more efficient nutrient use, and minimizes land clearing, providing a promising path to more environmentally sustainable agricultural intensification and a more equitable food supply.

3.4.5 | Climate change will affect the Asian water towers (Immerzeel et al., 2010)

This article ranked fifth (TC_{2022}), experiencing an increase in citations in the first 5 years since its publication. It reached 161 annual citations in 2015, then fell to 152 citations in 2016, and then rose again before falling slightly to 305 in 2022. The article discusses the impact of climate change on water availability and food security in Asia using a case study of water sources such as the Brahmaputra, Indus, Yangtze, and Ganges basins. The article highlights that climate change impacts vary significantly across catchment areas based on population size and irrigated agriculture. It shows that the Brahmaputra and Indus basins are likely to be more severely affected as a large proportion of the population relies on them for irrigation, threatening the food security of an estimated 60 million people.

3.4.6 | Prioritizing climate change adaptation needs for food security in 2030 (Lobell et al., 2008)

This article ranked sixth (TC_{2022}), with a total of 1722 citations over the study period. The article experienced slight fluctuations in citations over the study period. Lobell et al. (2008) discuss the adaptation priority needs for food security by 2030 to reverse the impacts of climate change. It highlights that adaptation needs differ across regions with the types of crops because of differences in biophysical resources, management, and other factors. For example, the adaptation needs in South Asia and Southern Africa for sorghum and maize crops require attention. The article notes that identifying less impacted crops and then switching from severely affected to less affected crops may be a viable adaptation option.

3.4.7 | Closing yield gaps through nutrient and water management (Mueller et al., 2012)

This article ranked seventh (TC_{2022}) and has seen an increase in citations since publication, up to 240 citations in 2021, and decreased to 110 citations in 2022. Mueller et al. (2012) highlight that the most important future challenge will be to meet future food demand without endangering the environment. The article shows that yield variability depends largely on fertilizer use, irrigation, and climate and that opportunities exist to reduce environmental degradation, including eliminating over-use of nutrients while increasing maize, wheat, and rice production to about 30%. In this article, high fertilizer application rates were observed in high-income countries and some rapidly developing countries. Likewise, South Asia, East Asia, and parts of the USA have more irrigated areas, illustrating that simultaneously increasing nutrient application and irrigated areas could close yield gaps in areas of underproduction, demonstrating the importance of nutrient and water management for sustainable intensification. However, the study reports that efforts must be accompanied by a reduction in agriculture's global environmental footprint and a halt to agricultural expansion.

3.4.8 | Sustainable biochar to mitigate global climate change (Woolf et al., 2010)

This article ranked eighth (TC_{2022}) and has seen an increase in citations since its publication, peaking at 201 citations in 2021 and decreasing slightly to 156 citations in 2022. This article reports that the use of biochar has the potential to help in mitigating climate change and found that the impacts of biochar are on average a quarter greater than other alternative methods such as bioenergy, particularly in areas with poor soil growing biomass because biochar use is characterized by more efficient use of water and crop nutrients. However, the article highlights that a combination of methods can be used, such as bioenergy in regions with fertile soil, where coal emissions can be offset, and biochar in poor soil, where biomass grows. The article concludes by emphasizing that the use of biochar must be guided by well-developed guidelines and sustainability protocols to effectively mitigate climate change.

3.4.9 | Genome sequence and analysis of the tuber crop potato (Xu et al., 2011)

This article ranked ninth (TC_{2022}). The article experienced slight fluctuations in citations over the study period. This article shows that potato is a non-grain crop that plays an important role in global food security. The article discusses genome revolution, haplotype diversity, and inbreeding depression. The article highlights that after sequencing a unique doubled monoploid potato clone to address the challenges associated with high heterozygosity in genome assembly, a high-quality draft potato genome sequence was created that uses a combination of data to provide new insights into the evolution of the eudicot genome, which is a new resource for use in breeding.

3.4.10 | Genome-wide association studies of 14 agronomic traits in rice landraces (Huang et al., 2010)

This article ranked 10th (TC_{2022}). The article experienced slight fluctuations in citations over the study period. This article shows that genome-wide association studies (GWAS) of rice landraces can be used to map multiple traits, provide a wealth of sequence polymorphisms, and enable the detection of structural variations, which is important in global food security. Using a novel data imputation method, 14 agronomic traits were examined in the Oryza sativa indica subspecies population, and the loci identified by GWAS explained an average of 36% of the phenotypic variance. This highlights that integrating GWAS and second-generation genome sequencing can provide a powerful complementary strategy to a classical biparental gross mapping for dissecting complex traits in rice, and this study is a foundation for valuable genes and alleles from the world geomplasm collection for cultivar improvement. However, future research could explore the structural variations of low-coverage genome sequencing in more detail by combining information across landraces whose haplotypes are smaller.

3.4.11 | Global scale climate–crop yield relationships and the impacts of recent warming (Lobell & Field, 2007)

This article ranked 11th (TC_{2022}) and discussed that the impact of climate change as a result of human activities has had significant negative impacts on the global production of major crops. Although the use of technology increased yields over the study period, increasing seasonal temperatures and precipitation depending on the location of each crop explained the 30% annual variation in global average yields of major crops. However, although the effects of warming may have been reduced by the fertilizing effect of increased carbon dioxide levels, the extent of the impact was not known.

3.4.12 | Managing nitrogen for sustainable development (Zhang et al., 2015)

This article ranked 12th (TC_{2022}) and experienced a significant increase in citations during the study period. This article has been cited 1110 times in 8 years since it was published. We expect this article to be cited more in the future (Figure 3). The article discusses the effective means of increasing crop productivity while reducing environmental degradation. By assessing the historical pattern of agricultural nitrogen use efficiency (NUE) to meet global food demand in 2050, the article reports that although nitrogen use can be useful to address the challenges of food insecurity, environmental degradation, and climate change, it requires cultural, social, and economic incentives, knowledge of barriers to non-adoption, and best management practices that vary regionally to effectively implement NUE. The article shows that the average global NUE value in crop production must improve from 0.4 to 0.7 to meet food security and environmental challenges in 2050 and that crop production will increase by 60% to 100% between 2007 and 2050 to meet global food demand. It highlights that improvement requires the development of global and national targets for NUE, technology transfer, agricultural innovation, robust international collaboration, and investment in research, extension, and human resource development.

3.4.13 | Global food security, biodiversity conservation, and the future of agricultural intensification (Tscharntke et al., 2012)

This article ranked 13th (TC_{2022}) and discussed a dichotomy that exists between conventional agricultural intensification, which relies on high-input agriculture, and low-input pro-poor

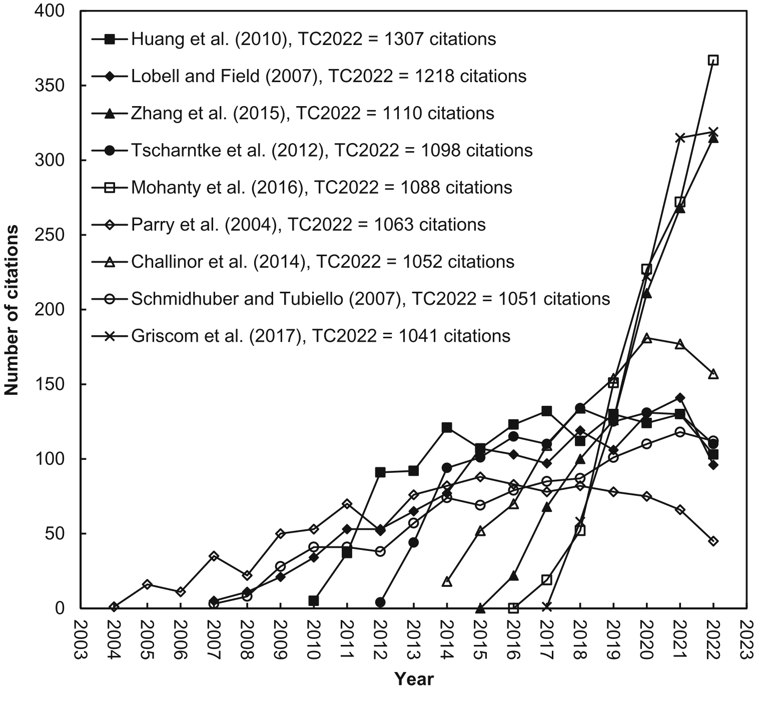

FIGURE 3 Citation histories of the top 10 to 18 classic food security-related articles.

agriculture, which relies more strongly on biodiversity and associated ecological processes. It shows that small and diversified farms rather than large farms show greater productivity per area and that food security policies must target an increase of agro-ecological capacity and environmentally friendly and sustainable techniques to manage diversified cropland, avoid pesticide use, and integrate soil fertility strategies by both organic and non-organic fertilizers. It concludes that conventional intensification disrupts biodiversity and degrades environmental quality, with implications for the sustainability of food production, and argues for exploring further mechanisms to balance human and ecological needs.

3.4.14 | Using deep learning for image-based plant disease detection (Mohanty et al., 2016)

This article ranked 14th (TC_{2022}) and recorded a significant increase in citations for all the period of study and gained relatively more citations in just 6 years of its publication, signaling its impact in the field. This article uses artificial intelligence technologies, particularly deep learning models, to detect plant diseases that pose a threat to food security. Using smartphone-assisted disease diagnosis, a deep convolutional neural network evaluated 54,306 images of diseases and healthy plant leaves collected under controlled conditions to identify 14 crop species and 26 diseases. The trained model showed an accuracy of 99.35%, highlighting the effectiveness of this approach. The article calls for image data from smartphones to be supplemented by location, time, and other additional information to increase the accuracy of future research.

3.4.15 | Effects of climate change on global food production under SRES emissions and socio-economic scenarios (Parry et al., 2004)

This article ranked 15th (TC_{2022}) and examined the effects of climate change on global food production under the Special Report on Emission Scenario (SRES) and socio-economic scenarios. The results show that regional variations in crop yields will increase, leading to significant price increases and increased hunger in low-income countries under SRES, due to the impacts of climate change. It is estimated that variations caused by climate change will account for more than 50% of mean climate change signals by 2080, that climate change is likely to heighten differences in cereal yields between developed and developing countries compared with previous periods, and that developed countries will have to compensate developing countries for the decline in production. The article highlights the need to explore ways and technologies to adapt to a more uncertain world as crop failure will be significant in some regions.

3.4.16 | A meta-analysis of crop yield under climate change and adaptation (Challinor et al., 2014)

This article ranked 16th (TC_{2022}) and had a significant increase in citations in the first 6 years since its publication, reaching 181 annual citations in 2020. It then decreased to 177 citations in 2021 and 157 citations in 2022, respectively. This article examines the impacts of climate change on yields and adaptation effects. The results show that without adaptation, more losses are expected for wheat, rice, and maize in both temperate and tropical regions. For example, adaptation increased yields between 7% and 15%, and more adaptation effectiveness was seen for wheat and rice than maize. However, the article argues that although adaptations are likely to be helpful, there remains some uncertainty about their impacts and effectiveness, demonstrating the need to report yield variability along with underlying assumptions about climate variability.

3.4.17 | Global food security under climate change (Schmidhuber & Tubiello, 2007)

This article ranked 17th (TC_{2022}) and reviewed the potential impacts of climate change on food security showing that climate change will impact all four dimensions of food security: (i) food availability, (ii) access to food, (iii) stability of food supplies, and (iv) food utilization. The article shows that the importance of each dimension and the overall impact of climate change will vary regionally and over time, depending on the country's socio-economic status, and will place the greatest burden on low-income countries in Africa and to a lesser extent South Asia by 2080. It concludes by showing that the way in which the impact of climate change will be felt depends on the future policy environment for the poor and on investments in technology, transport, and communication infrastructure, as well as investments in sustainable agricultural practices.

3.4.18 | Natural climate solutions (Griscom et al., 2017)

This article ranked 18th (TC_{2022}) and experienced a significant increase in citations throughout the study period suggesting its impact on the field of food security. We expect this article to be cited more frequently in the future. This article discusses the importance of natural solutions in combating the impacts of climate change. The article prioritizes natural solution and shows that natural solution can achieve 37% cost-effectiveness in curbing carbon dioxide emissions and a 66% reduction in global warming to below 2°C by 2030. The other benefits of natural solution, when implemented effectively, include water filtration, flood buffering, soil health, habitat biodiversity, and improved climate resilience.

3.5 | Future research agenda

Based on classic publications in food security discussions, we present the key points or themes that were raised and the future research agendas.

3.5.1 | Food security and agricultural intensification

This cluster collects articles that discuss the role of agricultural intensification in combating food insecurity. The findings show that agricultural intensification does not necessarily lead to increased yields but rather contributes to environmental degradation through deforestation, biodiversity loss, and ultimately climate change. The findings emphasize on closing yield gaps and adopting more sustainable solutions to address the challenges of food insecurity, for example, (a) the adoption of ecologically friendly methods—implementing food production and environmental conservation at the same time, avoiding pesticide use, and so forth

(Foley et al., 2011; Tscharntke et al., 2012); (b) technology deployment and technology transfer to low-income countries can help close yield gaps and increase yields, thereby reducing land clearing (Tilman et al., 2011); (c) close yield gaps through use of nutrients and water management (Mueller et al., 2012); and (d) increase efficiency use of nitrogen, which is essential for the growth and development of crops to increase yields (Zhang et al., 2015). However, linking agricultural intensification to biodiversity conservation and hunger remains a complex issue that requires further research in the future.

3.5.2 | Investment in natural solutions to the effects of climate change

In this cluster, articles highlight the importance of natural solutions to deal with the impacts of climate change, which is a threat to food security, for example, (a) sustainable biochar production to mitigate global climate change (Woolf et al., 2010) and (b) soil carbon sequestration to mitigate carbon emissions (Griscom et al., 2017; Lal, 2004). Finding effective natural solutions to the impacts of climate change will continue to be a research agenda in the future, particularly in low-income countries.

3.5.3 | Climate change adaptation needs

This cluster collects articles that discuss adaptation needs, which can vary significantly by regions depending on the socio-economic status and policy environment. Climate change will increase the dependence of low-income countries on imports, for example, in countries such as Sub-Saharan Africa and, to a lesser extent, South Asia (Schmidhuber & Tubiello, 2007). Therefore, the need for adaptation is influenced by various factors including (a) infrastructure development, (b) sustainable agricultural practices, and (c) technological progress. Although a number of studies have highlighted the importance of adapting to climate change, uncertainty remains about the effectiveness of different adaptation models given the increasing variability of extreme events. This area could form a future research agenda to provide further information on the adaptation models.

3.5.4 | Technology and food security

This cluster collects articles that talk about the application of technology to address the challenges of food insecurity. In areas such as plant disease detection, phenotyping, and plant or crop breeding (Huang et al., 2010; Mohanty et al., 2016; Xu et al., 2011). Given the advancements in technologies, such as machine learning, further research can be carried out on ways to address food insecurity, particularly in crop or plant, and forestry tree breeding, precision agriculture, and so forth.

4 | CONCLUSION

This article presents the classic publications on food security from 1993 to 2022 using bibliometric methods. The articles discuss practical solutions that can enhance global food security while addressing the causes of food insecurity such as the impacts of climate change, environmental degradation, and biodiversity loss. The category of multidisciplinary sciences with 73 journals published the most 11 classic articles, which represent 61% of 18 classic articles. Articles published in the category of imaging science and photographic technology had the greatest CPP_{2022} of 4253 citations, whereas articles in the category of plant sciences had a CPP_{2022} of 1088 citations. The *APP* ranged from 30 authors in the category of genetics and heredity to 3.0 authors in the category of plant sciences. In general, this article documented the most productive authors, institutions, and countries as well as their publication impact and contributions in the field of food security.

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