

Mapping the Nexus between Food Wastage, Food Security, Environmental Sustainability and Economic Growth: A Bibliometric Analysis

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ABSTRACT

Food wastage is a critical global challenge adversely impacting food security, environmental sustainability, and economic development. Despite growing academic interest, research integrating these interconnected dimensions remains fragmented. Therefore, this study systematically maps the intellectual structure and evolving trends of this multidimensional nexus. Adopting a systematic literature review approach guided by the PRISMA framework, 120 peer-reviewed articles published between 2015 and 2024 were selected and analyzed using VOSviewer software. Bibliometric techniques were applied to evaluate keyword co-occurrence, citation patterns, journal sources, and geographical contributions. The analysis reveals three primary research streams: the interplay between food loss and food security, the environmental footprints of food wastage, and the implications for economic growth and resource efficiency. Findings underscore a distinct scholarly shift toward circular economy models and sustainable supply chain management. Furthermore, the results highlight the urgent need for integrated policy frameworks that simultaneously address consumer behavior, post-harvest losses, and resource utilization to achieve the UN Sustainable Development Goals. Ultimately, this study provides a comprehensive overview of the sustainable food systems landscape, bridging theory and practice while identifying interdisciplinary gaps to guide future research.

Keywords: Food Wastage, Food Security, Environmental Sustainability, Economic Growth, Sustainable Food Systems, Bibliometric Analysis

INTRODUCTION

Food wastage has become one of the most significant worldwide issues impacting the food system, environmental sustainability, and economic growth (Koutras et al., 2024). Global estimates show that of all the food produced for human consumption, approximately 1.3 billion metric tons of food is lost or wasted each year throughout the food supply chain, between production and consumption (FAO, 2011; UNEP, 2024). This food waste is a significant problem that undermines food security and enhances environmental destruction and economic inefficiencies (Cattaneo et al., 2021). Against the backdrop of increased population growth and a rising shortage of natural resources worldwide, food wastage mitigation has developed as a key element towards achieving the Sustainable Development Goals, particularly the achievement of zero hunger, responsible consumption, and environmental protection (United Nations, 2015; UNEP, 2024). The current literature recognizes food waste as it occurs at various steps of the food supply chain, that is, food production, post-harvest management, processing, distribution, and food consumption, wherein each process incurs high economic costs and advocates

inefficient utilization of natural resources, that is, land, water, and energy (WHO, 2023; Koutras et al., 2024).

Empirical evidence indicates that food wastage reduction would significantly contribute to the efficient use of resources and increase food access and affordability to vulnerable groups (Thyberg & Tonjes, 2016). Food wastage is a paradox of food systems in the context of global food security; as millions of people are hungry and malnourished worldwide, millions of edible foods are thrown away every year (WHO, 2023; Santeramo & Lamonaca, 2021). Studies have shown that reducing food wastage plays an important role in improving food security by increasing food availability and maximizing the use of agricultural resources (Cattaneo et al., 2021). Moreover, sustainability results and environmental pressure could be further increased by effective food waste management through recycling, redistribution, and circular economy methods (Koutras et al., 2024).

Moreover, food wastage and its connection to economic growth have gained increasing scholarly interest in recent years (Golinska et al., 2023). Unproductive food systems not only create losses for producers, retailers, and consumers of food, but also increase the costs incurred during food production and distribution. Few researchers have stressed that policies inherent in curbing food wastage can lead to economic efficiency, sustainable agricultural practices, and long-run economic growth. Although this subject is becoming an increasingly popular area of scholarly research, the current literature is still fragmented and scattered across various fields. This has, in turn, necessitated a systematic mapping of the intellectual framework of the research that has been able to connect food wastage to food security, environmental sustainability, and economic growth (Golinska et al., 2023; Santeramo & Lamonaca, 2021).

Food wastage has become an important international topic, which can be explained by its complex impacts on food security, environmental sustainability, and economic development (Koutras et al., 2024). Although large amounts of food are wasted each year, food insecurity and malnutrition affect millions of people (FAO, 2023; UNEP, 2024). This inequality highlights the inefficiencies of the global food system, and the viability of current food production and consumption trends is a matter of concern (Cattaneo et al., 2021; Santeramo & Lamonaca, 2021). Existing studies have been conducted on different aspects of food wastage, including the reasons behind food wastage, environmental consequences, and the implication of food wastage on food security (Baybars, et al., 2024).

Research Questions

1. How has the scientific literature on food wastage, food security, environmental sustainability, and economic growth evolved during 2010–2022?
2. What are the major research themes and intellectual structures within the literature on food waste and its relationship with food security and environmental sustainability?
3. Which authors, institutions, and countries have contributed the most significantly to the development of research in this field?
4. What are the emerging research trends and future directions in studies linking food wastage with sustainability and economic development?

Research Objectives

1. To analyze the growth and development of academic publications related to food waste and sustainability between 2010 and 2022.
2. To identify the major research themes, clusters, and intellectual structures within the literature using bibliometric techniques
3. Examine the most influential authors, journals, institutions, and countries contributing to research in this field.

4. To map citation patterns and co-occurrence networks to understand the knowledge structure of a research area.
5. To highlight emerging research trends and provide recommendations for future research on food waste, food security, environmental sustainability, and economic growth.

Bibliometric analysis is a powerful approach to research that allows the definition of research trends, influential publications, and emerging themes in a particular area (Donthu et al., 2021). In this regard, this study will conduct a bibliometric review of the literature published between 2015 and 2024 to review the developing nexus of food wastage, food security, environmental sustainability, and economic growth. In addition, there has been little research on interdisciplinary relationships between food wastage, food security, environmental sustainability, and economic growth using superior bibliometric visualization software. These linkages are crucial for finding new research groupings, collaboration networks, and directions for future research. Therefore, this study addresses these gaps by conducting a comprehensive bibliometric analysis to map the intellectual structure and research evolution of the nexus between food wastage, food security, environmental sustainability, and economic growth.

LITERATURE REVIEW

Food wastage is considered one of the most important factors underlying many anthropogenic activities, especially in developing countries. Food waste is a major issue that causes problems in the entire waste management system. Recent empirical research has studied food wastage at various levels of the supply chain and in various geographic setups. Several studies have focused on consumer and household behavior, which is characterized by a lack of awareness of the effects of food waste and the necessity of specific interventions in social marketing (Hao et al., 2022; Wani et al., 2023). Other studies have investigated food loss during production and post-harvest stages, reporting high losses and their direct effects on food security and the livelihoods of farmers (Paraschivu et al., 2022; Saputro et al., 2021). The quantitative measures of the environmental footprints of food wastage are also increasing and encompass greenhouse gases, land, and water consumption (Cattaneo et al., 2021; Malahayati and Masui, 2021). Moreover, modeling has been used in macroeconomic research to investigate the impact of decreasing food wastage on economic growth, poverty reduction, and optimal patterns of resource utilization worldwide (C.M., 2022; Lekavicius et al., 2023).

Thyberg et al., (2022) presented the estimation of food loss at primary stage production of consumer's cereals in agricultural sector, in Poland and analyse effects of food loss on environmental situation and confirming food security. Food loss is a severe global issue, especially in developed nations; as in the EU, approximately 20% of the produced food is wasted annually. However, food loss occurs throughout the food chain, from the initial production to operations and storage post-harvesting, processing, distribution, and consumption. In this study, data were collected using the mass balance method and a direct questionnaire survey by collecting data from 246 farms and seven macro-regions. This study related to the quantity of production lost as consumer cereals in Poland, and it was observed that food loss at different stages of production annually was responsible for the emission of CO₂.

Malahayati & Masui (2021) focused on the preliminary findings of an Indonesian case study by analyzing the effects of a reduction in food wastage on the environment and economy. This article emphasizes food wastage because food above 20 Mt is wasted in Indonesia annually, and approximately 50% of the food is wasted during production processing on farms. This is an alarming condition because Indonesia must secure national food stocks with a rising population and declining agricultural land every year. The Indonesian government is trying to focus on increasing agricultural productivity, especially for food crops; however, a major issue is the lack of existing literature on this topic, as there is a deficiency of literature on economic modelling involving national reports, research, and statistics, as well as future projects on the effects of reducing food wastage.

However, in this article, the effects of on-farm food loss reduction on the economy and the environment were evaluated using computable general equilibrium (CGE). The authors compared two policy sets by the Indonesian government, such as improvements in yield and production of some agricultural products (crops, horticulture, cereals, and dairy) and reductions in food loss. Hence, the findings showed that a combination of improvements in yield and reductions in food loss helped to raise Indonesia's GDP as compared to the business-as-usual (BAU) scenario until 2030. Additionally, the results showed that focusing on food loss reduction is a better policy than focusing on raising productivity and production, and it helps to decrease greenhouse gas emissions from agriculture. It was concluded that comparing these policies, a fall in food loss is more economical and profitable than government policies that only focus on improving production.

Cattaneo et al., (2021) critically elaborated the influence of fall in food wastage on environment objectives. The authors indicated that the major purpose of this study was to examine whether a reduction in food wastage may significantly contribute to improving sustainable food systems. According to the authors, by employing a stylized analytical framework, it was found that reducing food wastage enhances the efficiency of resource utilization for land and water and reduces the quantity of GHG emitted per unit of food consumed. If damage to the environment and a fall in food wastage occur, the actual outcome of the environment improves. It was found that when food waste (consumer level) is reduced, it has a better impact on environmental outcomes but not assured in food loss reduction (farm to retail) and conditional linking derived mechanism for price transmission and the environmental effects of a food wastage reduction. Barrera and Hertel (2021) emphasized the various income-level effects of worldwide food wastage on production, food prices, and utilized resources.

Mobaseri et al., (2021) analysed the impacts of reduction in food wastage on environment by applying system dynamics approach. The findings of the study exposed that the demand for food and consumption of energy grew annually. Under the above conditions, the amount of pollution emissions will increase until 2031. The results of this study showed that an improvement in the productivity of energy and a reduction in food wastage under population growth indicated that the following strategies would be more effective in managing energy and pollution. Al-Rumaihi et al., (2020) described the effects of environmental assessment of food wastage by managing it through two composting methods. Therefore, food wastage is considered a major factor that increases global and greenhouse gas (GHG) emissions (Slorach et al., 2020). Conrad and Blackstone (2020) concluded that food waste was also a waste of micronutrients and theoretically filled the nutritional gaps for a large number of populations. It was recommended that more dimensions should be added to obtain more results related to food waste and environmental sustainability.

Becerra-Sanchez & Taylor (2020) elaborated techniques for reducing post-harvest food loss and improving food security for high-quality sweet corn. This study highlighted the main issues faced by post-harvest challenges for sweet corn and elaborated on four methods for improving post-harvest quality in this popular fresh-cut vegetable. Seberini (2020) emphasized the definitions of key concepts and losses in various stages of the food chain, highlighting their impacts on the environment, economy, and society. The article presented proposed solutions as well as those already applied to reduce food waste. In 2018, approximately 14 million metric tons of food waste was generated in Slovakia, of which 2.1 million metric tons were municipal waste. Sarkodie et al., (2019) estimated environmental sustainability by applying ARDL models, related with GHGs emissions, food, biomass energy and economic development. Racz et al., (2018) illuminated the economic, environmental, and ethical influence of food wastage on friendliness and other industries worldwide. Throwing away food items in the trash created an alarming phase in the economy. The findings of this study showed positive and significant impacts of food wastage management on environmental sustainability and economic growth.

Dou et al., (2018) described the effects on environmental sustainability, safety and feasibility of Food wastage as livestock food. Basically, food wastage is a burning issue that creates challenges for food security, resources, environmental matters, and climatic changes. Irani et al., (2018) focused on the management of food security by FLW by employing data from small to big.

Marais et al., (2017) explored the major components that impact food wastage and environmental sustainability by sampling 517 students from Stellenbosch University, residing in 7 selected residences, as well as gathering input from 6 food service managers and 63 catering personnel. The study was based on cross-sectional data and descriptive analysis (interviewer-administered questionnaires and electronic survey). Food wastage was much higher than the normal level; therefore, it was concluded that students and management faculty need better communication skills to improve the environment by reducing food wastage. Paritosh et al., (2017) described the exponential growth in food wastage, which is imposing severe impacts on society, such as health risks, environmental pollution, and scarcity of dumped land. Anaerobic digestion was considered an eco-friendly and favorable solution for food wastage management, energy, and nutrient production, which contributed to the global requirement of raising energy. Thyberg & Tonjes (2016) explored how the modernization of the food system, encompassing factors such as industrialization, urbanization, globalization, and economic growth, impacts food waste generation. They identified gaps in the literature by creating policies to reduce food wastage and obstacles, consisting of (1) filling gaps in data, (2) introducing strategies for quantifying the socioeconomic and environmental impacts of food wastage reduction, (3) understanding the scale effects, and (4) discovering the impacts of transitions globally.

Lekavicius et al., (2023) described that food wastage basically, multi-dimensional worldwide issue, with environmental, social, and economic dimensions which related to sustainable development. In the present study, the authors analyzed the social, economic, and environmental pollution effects that reduce food wastage in the EU. The evaluation of food wastage fall scenarios covers all stages of the supply chain from early production to the final consumption of households. Applying the economy-wide model as a social accounting matrix (SAM) model, the influence of the scenarios was examined for the entire economy. Many scenarios investigated positive socioeconomic impacts in terms of a slow increase in GDP and employment levels. The multicriteria study highlighted that overall benefits are obtained by reducing food wastage in the food service sector. Policymakers are recommended to focus on reducing food wastage in food production and consumption and to ensure positive socioeconomic effects.

Darma et al., (2022) emphasized the influence of economic recession of Covid-19 on food security in Indonesia, considering four key aspects: accessibility, availability, stability and utilization of food. Sheikh et al., (2022) documented a negative relationship existed among food wastage, food access and environment and had positive relation with food availability and food security on economic growth. Magazzino et al., (2021) highlighted that municipal solid waste became a threatening issue which linked with economic growth and urban people and if this waste not discarded properly, it may cause harmful and poisonous discharge mixed in soil. Petrariu et al., (2021) demonstrated the effects of policies implemented in the WEFW sectors, while also considering the quality of entrepreneurial activity from the perspective of economic performance. This study has paved the way for policymakers to address a research gap in the WEFW relationship and provide an assessment of economic and entrepreneurial performance. The article concludes that significant trade-offs exist among different sectors because of the varying degrees of development in each nation. Pawlak & Kołodziejczak (2020) established a relationship in the scale of undernourishment and random features that described the agricultural sector within identified clusters of underdeveloped nations. The results revealed that the most significant challenges in maintaining food security were observed in underdeveloped nations, with a large part of the agricultural sector sharing in the GDP, contrary to some situations that hindered agricultural production and lacked infrastructure.

Manap & Ismail (2019) found that starvation and malnutrition have adverse effects on health, leading to decreased productivity and thereby gradually affecting the overall growth of the economy. Onime (2019) documented that Nigeria was undergoing a notably high population growth rate, attributed to a pronounced increase in birth rates coupled with a declining death rate. Tinta et al., (2018) examined the possibility of regional integration to accelerate economic growth and achieve food security by leveraging the advantages of global value chains. These findings highlight the need to enhance and promote regional integration to unlock the potential for each country to transition from discontinuous to sustained growth.

Thyberg & Tonjes (2016) concluded that minimizing food wastage is a significant tool for reducing pressure on food production and fulfilling increasing demand. Food wastage is an important social, economic, nutritional, and environmental issue. Sandaruwani & Gnanapala (2016) elaborated on the relationship between food wastage and its effects on sustainable hotel operations and explained the challenges and problems linked with the operation of food waste sustainable management practices in hotels. The research found it to be a positive move towards improving the hotel industry, as it promotes the development of plans and strategies to reduce food waste in the context of an environmentally friendly and sustainable model that will also increase financial profitability. According to Halloran et al., (2014), the most common way of managing food wastage is its destruction, making energy recovery its primary method of deployment. However, growing technological progress has significantly increased the competence in transforming food waste into biogas and compost, which increases the recycled nutrients throughout the food chain supply system.

RESEARCH METHODOLOGY

This study employed a systematic literature review (SLR) combined with bibliometric analysis to examine the nexus between food wastage, food security, environmental sustainability, and economic growth. The data collection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses framework to ensure a transparent and systematic selection of studies (Page et al., 2021). Bibliographic information was mainly obtained from the Dimensions database, which is a full-fledged peer-reviewed academic database. Bibliographic information was mostly accessed through the Dimensions database, which lists all peer-reviewed academic records. Having implemented the selection and exclusion criteria, the final list of relevant articles was selected and exported to be analyzed using the VOS viewer software for bibliometric analysis.

The databases used to identify the relevant publications were Scopus and Web of Science, which index high-quality peer-reviewed academic publications. Such combinations of keywords, such as food wastage, food waste, food security, environmental sustainability, environmental footprints, and economic growth, were considered the search strategy. Only peer-reviewed journal articles were included to maintain consistency and quality of the datasets, and they had to be written in English.

Based on the PRISMA framework, the literature selection process involved four steps: identification, screening, eligibility, and inclusion. First, a wide range of publications was determined using databases. Duplicate records were eliminated, and titles and abstracts were screened to remove irrelevant studies. The remaining articles were evaluated according to a predetermined set of inclusion criteria, which yielded the final dataset for the bibliometric analysis.

Bibliometric Analysis and Visualization

This study used VOSviewer, one of the most popular tools for the creation and visualization of bibliometric networks, to analyze and visualize the bibliometric data. The software enables the depiction of associations between authors, nations, institutes, and keywords in a research field.

Three visualization techniques were used in the analysis:

The relationships between the authors, institutions and keywords were analyzed using network visualization.

Overlay Visualization: used to show how research topics change over time.

Density visualization aids in raising awareness of the most concentrated research areas and developing themes.

Bibliometric analysis concentrates on co-authorship analysis, the concept of keyword co-occurrence, citation analysis, and citation country collaboration networks. The methods allow one to gain a deeper understanding of the intellectual framework, prominent research topics, and new tendencies in the literature on food waste and sustainable food systems.

This study combines systematic review processes with bibliometric mapping methods to provide a full picture of the changing research environment and to present the future challenges of interdisciplinary research in food sustainability.

Systematic Literature Review

In the current era, interest in such methodologies has been growing, as they support the analysis of the development of selected topics in previous literature (Aguinis et al., 2011). They also expose the most related authors and journals in a specific field of study (Borenstein & Higgins, 2013). According to Grant and Booth (2009), the methodologies used for reviewing papers are of 14 types, with some common and some uncommon steps. The most common is the "narrative" traditional literature review. It is simple and easy to tackle based on minimum choices for objectivity and lack of accuracy and reproducibility, as compared to a systematic literature review, which is a more structured and reproducible technique of reviewing. In fact, bibliometric analysis practices a set of quantitative techniques for measuring, mapping, and investigating academic literature and enhancing the review with quantitative data and indicators of bibliometric action (Roemer et al., 2015; Pilone et al., 2023).

The following are the specific reasons for conducting a systematic literature review with reference to our study:

- To probe the intensity of models based on the relationship between food wastage, food security, environmental footprints, and economic growth in a bibliometric analysis.
- To examine the journals, authors, and research articles that have been more influential in the domain of food waste, food security, environmental footprints, and economic growth by reviewing different bibliometric techniques.
- To focus on the research topics addressed in the areas of food waste, food security, environmental footprints, and economic growth? How can this literature be reviewed systematically?
- To explain the importance of existing studies in terms of how they fit together and in theory and suggest future research.
- To draw robust conclusions about big problems, questions, and principles through bibliometric analysis

First, as it draws robust and broader conclusions with the production of an unbiased summary of a particular topic; second, it helps to extract gaps, relations, contradictions, and mainly to explore the reasons for these; third, it develops and evaluates a new theory or evaluates an existing theory or theories to describe how and why individual studies fit together; fourth, it offers suggestions for practice and policy; and finally, it outlines directions based on future research.

The present systematic review adhered to the guidelines of the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (Moher et al., 2009). Bibliometric analysis helps quantitatively evaluate the

literature in a particular research field using statistical methods that guarantee a rigorous reviewing process and support researchers in understanding the progress of this specific field (Zupic & Cater, 2015). The most common method used, which supports descriptive analysis and network extraction, is the bibliometric approach that can focus on co-words, co-authors, and citation analysis, which consists of co-citation analysis and coupling in bibliographic (Aria & Cuccurullo, 2017; Cobo et al., 2011a, 2011b).

Various statistical packages are used to construct bibliometric reviews, including the Visualization of Similarities (VoS) viewer. A keyword, co-authors, analysis, and searching were used for the literature review, and the VOS viewer software was used to apply bibliometric analysis. Bibliometric analysis separates data into clusters and assigns different colors to each cluster.

There are three types of bibliometric analysis techniques through VOS viewer used in this research

- a) Network Visualization
- b) Overlay Visualization
- c) Density Visualization

Another advantage of using VOS viewer software is its ease of use and the possibility to manage a significant number of publications. More specifically, the first step was to create a research query with principal and ancillary keywords. Principal keywords, such as "food wastage" OR "food loss and waste," were used to limit the search to papers clearly focused on this specific topic, while a set of ancillary keywords, such as "attitudes," "determinants," and "behavior," was chosen to identify specific studies on wastage behaviors.

For the SLR, various databases were used to check the authenticity of articles, these included Scopus, Web of Science, and Dimensions. This present study was conducted using Dimensions, which is easily accessible in our country, instead of Scopus or Web of Science.

The query was developed using Dimensions. The reasons for choosing the dimension database are as follows: (i) it is easily accessible in our country, (ii) Dimensions provides relevant and reliable information on publications (also with bibliographic data) because great importance is assigned to the peer review procedure; and (iii) Dimensions allows direct export of data in a format supported for bibliometric analysis in the VOS viewer software. With the aim of evaluating the complete evolution of the research topic over time, no limitations to specific years were applied

Prisma Flow Chart Analysis

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart elaborates the processing of data collection and its filtration through different steps of flow chat such as identification, screening, eligibility and inclusion as shown in figure below

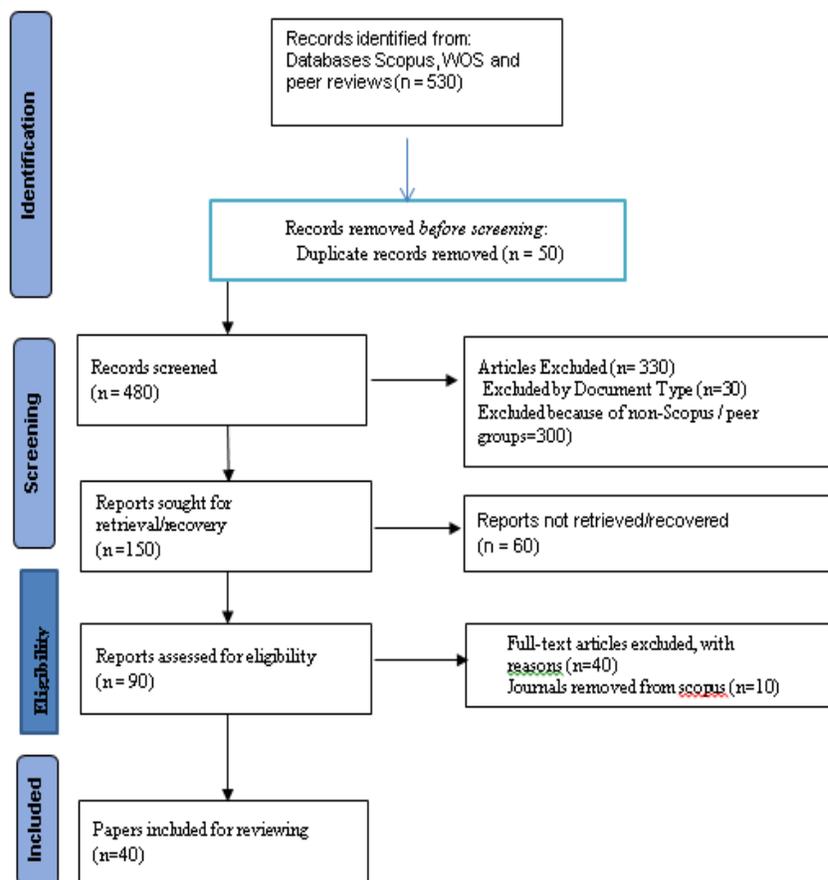


Figure 1: PRISMA Flow Chart

In the first phase of the flow chart, the search terms, search criteria, databases, and data extraction technique were chosen. The keyword to be used in the search was "food loss and waste, food security, environmental performance, " as the study aimed to identify emerging themes in food wastage, food security, environmental footprints, and economic growth.

The data were retrieved from scientific journal articles, the Scopus academic search engine and peer groups, publication years from 2009 to 2023, free-access articles, and the spheres of economics, business, and society. The identified keywords were "Food Loss and Waste," "Food Security," "Environmental Performance," and "Economic Growth." Only English was adopted as the language of journal papers. Finally, 30 articles met the selection criteria. The process of identifying and screening relevant works is depicted visually in the PRISMA diagram (Figure 1).

The articles that identified need to be screened according to the guidance of PRISMA. The main steps in the screening process were screening, retrieval, and evaluation of the eligibility of each article. Priyashantha et al., (2021) removed articles in each task that did not meet the inclusion criteria. This screening was performed manually and automatically. Articles were included using the Scopus and Web of Science (WoS) databases following automatic screening of article features by type, language, report type, and publication date; articles achieving the inclusion criteria were "empirical studies" published in "English" "journals" (2009–2023). Remaining publications, such as conference papers, chapters of books, reviews, research notes, comments in the editor, short surveys, unpublished data, and articles not published in English, were excluded. The next stage of screening involved selecting the full versions of

the articles that were retrieved for the eligibility criteria. The author manually evaluated the eligibility criteria of each article.

Table 1: Main Information about Data

Description	Results
Timespan	2009–2023
Sources	22
Range Citations Per Article	4-603
Countries	26
Authors	144

RESULTS

Bibliometric Analysis

Bibliometric analysis is used to identify and analyze large volumes of scientific data to generate a comprehensive perspective, which is collected from Scopus. The following are the three aspects of bibliometric analysis to explore data with VOS viewers:

- A. Country-Based Citation Analysis
- B. Journals/Sources Based Analysis
- C. Key Words-Based Analysis

These three aspects are explained using three techniques of the VOS viewer: network, overlay, and density visualizations.

The VOS viewer is a powerful network analysis tool that enables users, regardless of their coding or technology skills, to easily visualize data. According to the research of Van Eck and Waltman (2010), VOS viewer is an effective tool for network analysis that supports the visualization of the dynamics and structures of science, and Valenzuela, Merigó, and et al. (2017) mentioned that it is an analysis tool to conduct bibliometric analysis based on databases such as Scopus and Web of Science. Co-occurrence analysis is used to cluster essential topics in the research domain, whereas bibliographic coupling and co-citation analysis are utilized to generate an academic basis and perform developing trends in the field of green finance. The categorization of keywords according to the color range in the overlay visualization also produces perspective pictures.

Country-Based Citation Analysis

Figure 2 explains country-based citation analysis through overlay visualization, one of the techniques used for bibliometric analysis in the VOS viewer. The large spots indicate countries that have been used more frequently in research, with smaller spots indicating less frequent usage. As it focuses on connection with countries from weaker to stronger from dark blue towards yellow. The large spots indicate countries on which more research has been conducted. As scale (0 to 200) shows according to less to more frequently used country.

Figure 3 illustrates the network visualization of the countries using the VOS viewer for bibliometric analysis. It shows different colors to indicate the strength of the network connections between countries, whether stronger or weaker, or lack of relationship among countries.

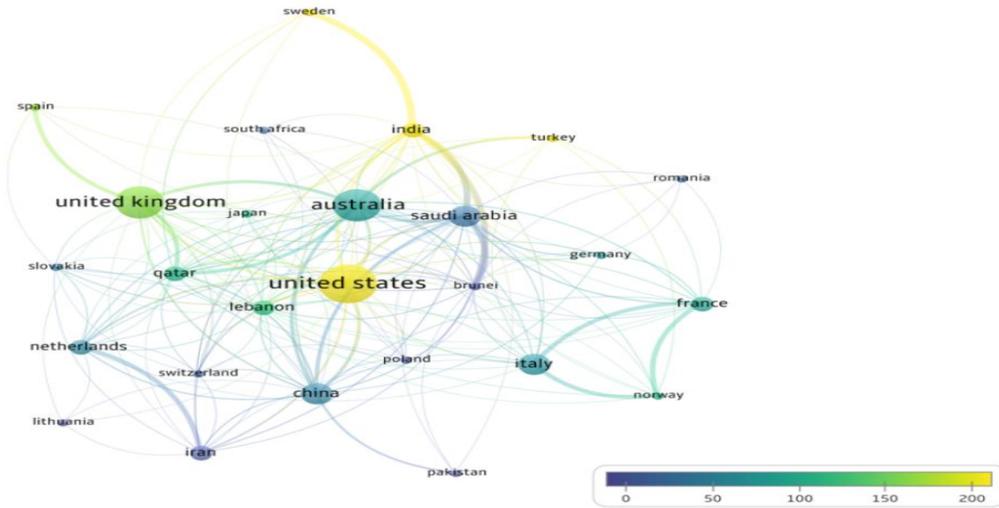


Figure 2: Country-Based Citation Analysis (Overlay Visualization)

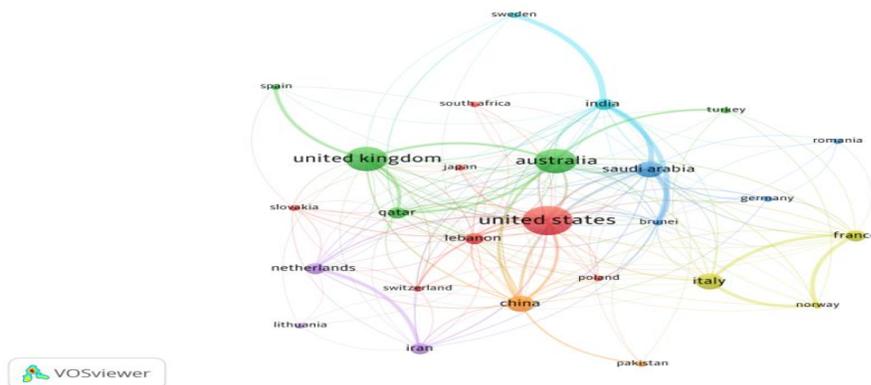


Figure.3: Country-based citation analysis (Network visualization)

Journals/Sources Based Analysis

Table 2 and Figure 4 present a list of the journals included in the bibliometric analysis, and only two journals, that is, The Science of the Total Environment and Sustainability, published a maximum of three articles each for the four sources; only two articles were retrieved from each source, and only one article was retrieved from 16 different sources. Most published articles are linked with food wastage; unsurprisingly, those that focus on environmental science, food policy, and sustainability. Not a single journal in the field of food wastage, security, and the environment has more than three papers.

In the present analysis, we regulated the threshold level by setting the minimum document number of a source to one and the minimum number of citations of a source to zero. Only sources with at least one document on the topic associated with the highest number of citations and total link strength were selected as the analysis range.

Table 2: Journals/Sources Based Analysis

JOURNALS	NUMBER OF PAPERS
The Science of the Total Environment	3
Sustainability	3
Food Policy	2
PLOS ONE	2
Agriculture & Food Security	2
Waste Management	2
Saudi Journal of Biological Sciences	1
BioMed Research International	1
Environmental Science and Pollution Research	1
Industrial Marketing Management	1
Nutrition Reviews	1
SHS Web of Conferences	1
Journal of Consumer Affairs	1
npj Science of Food	1
Energies	1
Journal of Clear Production	1
Food Security	1
Green Chemistry	1
Environmental Economics and Policy Studies	1
Resources Conservation and Recycling	1
Agriculture	1

Figure 4: Sources/Journals Bases Analysis (Network Visualization)

In the Overlay Visualization Sources/Journals-based analysis, we divided the expressions into various colors to rank the keywords based on their occurrence and count of average annual publication. The occurrence of the keywords in the document is represented by button size. Specifically, the range of dark blue to near purple indicates that this keyword has been researched for a long time. Recent publications are indicated by keywords that lie in the range of green to light blue, closer to yellow.

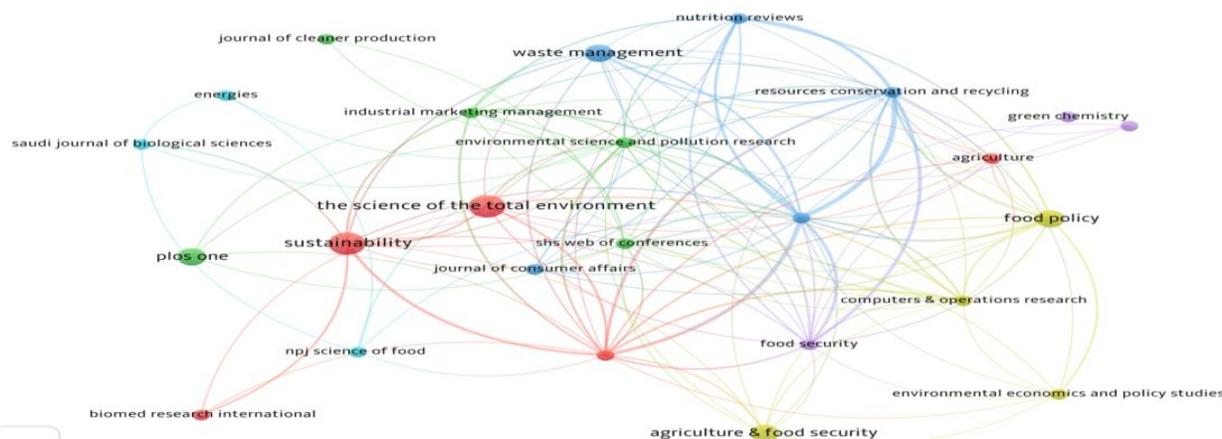


Figure 4 Sources

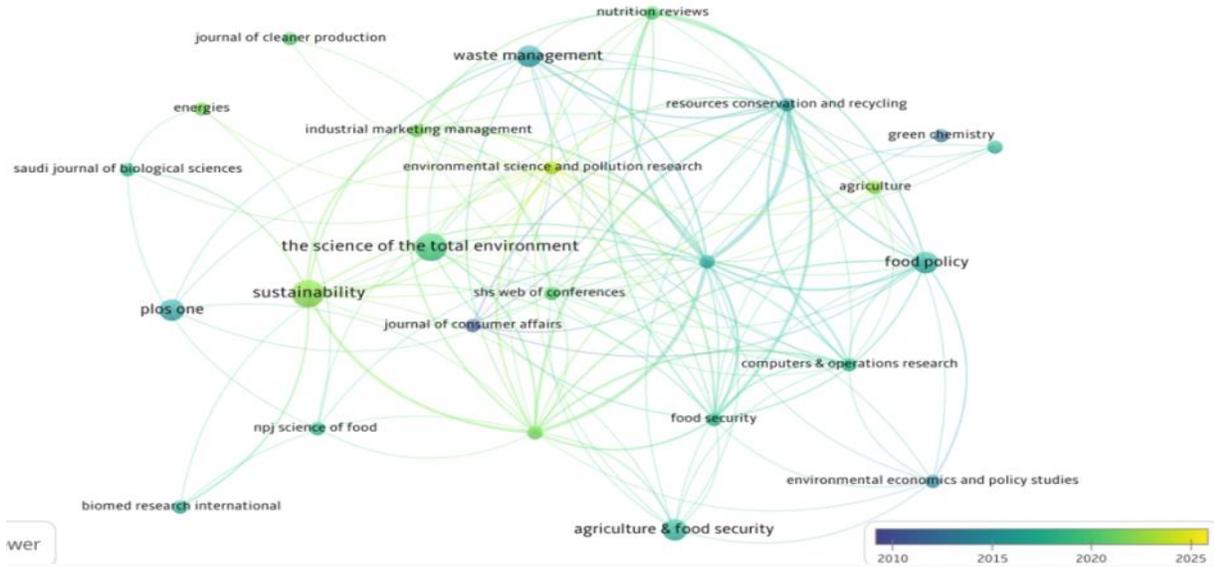


Figure 5: Sources/Journals Based Analysis (Overlay Visualization)

Key Words Co-Occurrence Analysis

Keywords-based bibliometric analysis was conducted using VOS viewers, and all three methods—network, overlay, and density visualization—were used in the following section.

Network Visualization

Network visualization was conducted using the keywords shown below with colorful clustering of common variables of the given article to obtain more comprehensive and appropriate best results. The figures below show the bibliometric analysis under network visualization with different (maximum minimum) numbers of keywords included in the figures. The size of the circles in these diagrams indicates the frequency with which the keywords appear, which is greater than that of the small circles.

Figure 6: Clustering within Articles as Revealed by Common Word Analysis (Network Visualization) (14 keywords)

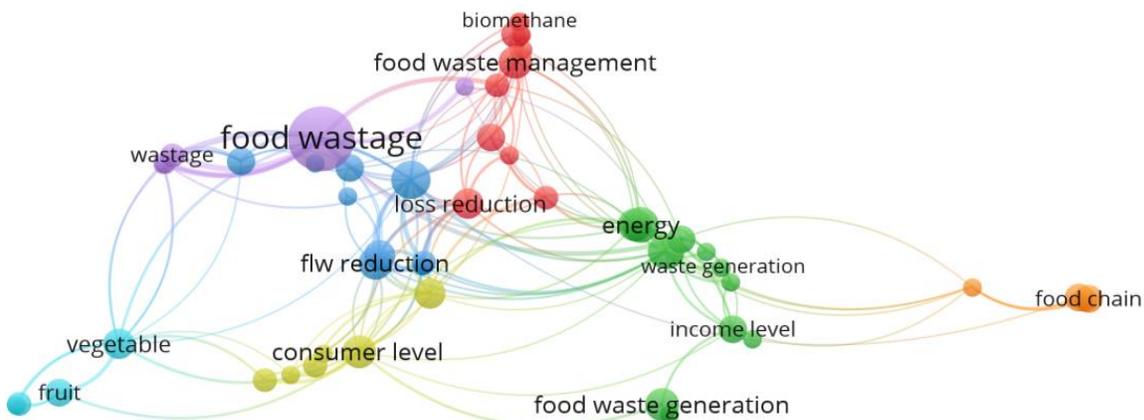


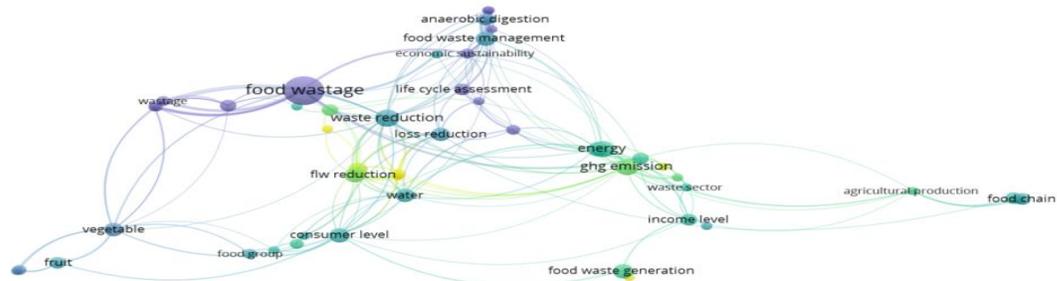
Figure 7: Network Visualization According to Keywords



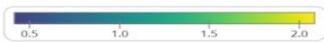
Figure.8: Network Visualization According to the Keywords (61 words)



Figure 9: Overlay Visualization Keywords Analysis (20 keywords)



VOSviewer



CONCLUSION

This study explored the nexus of food wastage and food security, environmental sustainability, and economic growth based on a systematic literature review and bibliometric analysis. The synthesis of the existing academic literature was used to realize the intellectual framework and research trends in this area. Bibliometric procedures and systematic literature review identified the most powerful research themes, authors, and journals in the field of food waste and sustainability.

The review findings reveal that food wastage is a multidimensional international problem with significant implications for food security, environmental sustainability, and economic development. A major percentage of food produced globally is lost or wasted during different stages of the food supply chain, such as production, warehousing, processing, distribution, and ultimate consumption. Such inefficiencies not only decrease the availability of food but also exert pressure on natural resources, including land, water, and energy, and play a role in greenhouse gas emissions and environmental degradation.

The literature reviewed in this study observes that food security is negatively correlated with food wastage. Food loss occurs at high rates, diminishing the supply and accessibility of food resources, especially in the developing world, where food insecurity has been a significant issue. By reducing food wastage, universal access to food would also increase significantly through the goal of zero hunger in global sustainable development.

Moreover, the environmental impacts of food wastage were determined by the study as one of the most significant research themes. The loss of food also leads to a high environmental footprint, including greenhouse gas emissions, excessive use of freshwater, biodiversity degradation, and strain on agricultural lands. Consequently, food wastage can be minimized to enhance resource utilization and curb the environmental losses caused by food production systems.

The correlation between food wastage and economic growth has also emerged as an important dimension in literature. The different studies that have been conducted have proved that economic benefits can be brought about through reducing food wastage, which in turn results in higher productivity, increased efficiency in resources as well as low cost in the food supply chain. Effective food management practices can also help create employment, enhance economic welfare, and promote sustainable economic growth.

In general, this paper adds to the body of research by providing a systematic mapping of food wastage, food security, environmental sustainability, and economic growth. The analysis of the literature and determination of research trends make this study valuable to researchers, policymakers, and other stakeholders in the field of managing sustainable food systems.

POLICY RECOMMENDATIONS

The results of this study show that policy recommendations can be offered to resolve issues related to food wastage and establish sustainable food systems.

First, governments should strategize and implement concerted programs to reduce food waste, which should include the food supply system. Food wastage occurs at different stages, including production, post-harvest treatment, processing, distribution, and consumption. Therefore, national policies that target all aspects of the supply chain are needed to minimize food waste and improve food supply.

Second, policymakers should promote the creation and adoption of technological solutions and modern waste management systems to control food waste. Technologies that can help ensure a significant reduction in environmental impact and generate new economic value include the technological processes of anaerobic digestion, biofuel, and the transformation of food waste into feed that can be provided to

livestock. The emergence of these technologies would improve waste management systems and make resource use sustainable.

Third, awareness campaigns and education programs should be introduced to instill responsible food consumption behavior among households, businesses, and institutions. Consumer behavior is an influential determinant of food wastage, which is observed to be especially high in developed countries, where a large proportion of wastage occurs at the time of consumption. Raising awareness of the economic, social, and environmental effects of food wastage can alter consumption patterns and reduce the amount of waste produced.

Fourth, governments are supposed to facilitate collaboration between food supply chain stakeholders, including farmers, manufacturers, retailers, the hospitality industry, and consumers. With the right coordination of such actors, the efficiency of supply chains can be improved, and food loss in the production and distribution processes can be reduced to a minimum. Another area that may be important in promoting sustainable food waste management is public-private partnerships.

Finally, policymakers should include food waste reduction in national sustainability policies and development programs. Reducing food wastage may make a direct contribution to achieving multiple sustainable development goals, particularly those related to food security, responsible consumption and production, and climate action.

Although this research presents substantial facts about the relationship between food wastage, food security, environmental sustainability, and economic growth, there are research gaps that require further investigation. More research should be conducted as empirical research to quantitatively establish the impacts of decreasing food wastage on food security and environmental sustainability. The literature available is largely theoretical or review-based; thus, more empirical evidence is needed to guide policymaking.

REFERENCE

- Abiad, M. G., & Meho, L. I. (2018). Food loss and food waste research in the Arab world: A systematic review. *Food Security*, 10(2), 311–322.
- Aguinis, H., and Ramani, R. S., & Alabduljader, N. (2011). What do you see? What do you get? Enhancing methodological transparency in management research. *Organizational Research Methods*, 14(2), 306–332.
- Al-Rumaihi, A., McKay, G., Mackey, H., & Al-Ansari, T. (2020). Environmental impact assessment of food waste management using life cycle assessment. *Journal of Cleaner Production*, 266, 121932.
- Apostolidis, C., Brown, A., & Chakraborty, R. (2021). Leveraging mobile applications for food waste reduction and sustainable consumption. *Sustainability*, 13(14), 7885.
- Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975.
- Baig, M. B., Gorski, I., & Khan, N. (2019). Food waste in Saudi Arabia: Causes, consequences and policy implications. *Journal of Cleaner Production*, 232, 708–719.
- Barrera, C., & Hertel, T. (2021). Global food waste across income levels: Implications for food security and the environment. *Food Policy*, 98, 101987.
- Baumeister, R. F. (2013). Writing a literature review. In M. J. Prinstein (Ed.), *The portable mentor: Expert guide to a successful career in psychology* (pp. 119–132). Springer.

- Baumeister, R. F., & Leary, M. R. (1997). Writing narrative literature reviews. *Review of General Psychology*, 1(3), 311–320.
- Becerra-Sanchez, F., & Taylor, M. (2020). Post-harvest loss reduction strategies and food security improvement. *Postharvest Biology and Technology*, 168, 111244.
- Bem, D. J. (1995). Writing a review article for psychological bulletin. *Psychological Bulletin*, 118(2), 172–177.
- Bisangwa, E. (2019). Global food waste and implications for food security. *International Journal of Food System Dynamics*, 10(4), 361–372.
- Borenstein, M., & Higgins, J. (2013). Meta-analysis and systematic review methods. *Research Synthesis Methods*, 4(1), 1–6.
- Cattaneo, A., Sánchez, M., Torero, M., & Vos, R. (2021). Reducing food loss and waste: Five challenges for policy and research. *Food Policy*, 98, 101974.
- Cobo, M. J., López-Herrera, A., Herrera-Viedma, E., & Herrera, F. (2011a). Science mapping software tools: Review and analysis. *Journal of the American Society for Information Science and Technology*, 62(7), 1382–1402.
- Cobo, M. J., López-Herrera, A., Herrera-Viedma, E., & Herrera, F. (2011b). An approach for detecting, quantifying, and visualizing the evolution of research fields. *Journal of Informetrics*, 5(1), 146–166.
- Cole, M., Augustin, M., Robertson, M., & Manners, J. (2018). The science of food security. *NPJ Science of Food*, 2(1), 1–8.
- Conrad, Z., & Blackstone, N. T. (2020). Drivers of consumer food waste and implications for environmental sustainability. *Resources, Conservation and Recycling*, 162, 105053.
- Cooper, H. (2003). Editorial: Organizing knowledge syntheses. *Psychological Bulletin*, 129(1), 3–9.
- Darma, R., et al. (2022). COVID-19 economic recession and food security challenges in Indonesia. *Sustainability*, 14, 5678.
- Dou, Z., et al. (2018). Food waste for livestock feeding: A review. *Journal of Environmental Management*, 227, 1–8.
- Engström, R., & Carlsson-Kanyama, A. (2004). Food losses in food service institutions. *Food Policy*, 29(3), 203–213.
- FAO. (2013). *Food wastage footprint: Impacts on natural resources*. Food and Agriculture Organization of the United Nations.
- Fami, H., et al. (2021). Household food waste and food security in urban areas. *Sustainability*, 13, 12345.
- Fonseca, J. (2014). Household food waste behavior and environmental implications in Lisbon. *Waste Management*, 34(1), 1–8.
- Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types. *Health Information & Libraries Journal*, 26(2), 91–108.
- Gustavsson, J., et al. (2011). *Global food losses and food waste*. FAO.

- Halloran, A., Clement, J., Kornum, N., Bucatariu, C., & Magid, J. (2014). Addressing food waste reduction in the food chain. *Trends in Food Science & Technology*, 40(2), 194–208.
- Hao, Y., et al. (2022). Consumer behavior and food waste in urban restaurants. *Sustainability*, 14(8), 4567.
- Irani, Z., & Sharif, A. M. (2016). Food security and food supply chain management. *International Journal of Production Economics*, 181, 1–6.
- Irani, Z., et al. (2018). Food loss reduction and supply chain management strategies. *International Journal of Production Economics*, 203, 94–102.
- Kader, A. A. (2009). Handling of horticultural perishables to reduce losses. *Postharvest Biology and Technology*, 52(3), 333–339.
- Lekavičius, V., et al. (2023). Socio-economic and environmental impacts of food waste reduction in the European Union. *Sustainability*, 15, 889.
- Magazzino, C., et al. (2021). Municipal solid waste and economic growth nexus. *Waste Management*, 120, 1–10.
- Manap, N., & Ismail, N. (2019). Food security and economic growth nexus. *International Journal of Economics and Financial Issues*, 9(3), 1–6.
- Marais, M., et al. (2017). Student food waste behavior and environmental sustainability. *Sustainability*, 9, 215.
- Moher, D., et al. (2009). Preferred reporting items for systematic reviews and meta-analyses (PRISMA). *PLoS Medicine*, 6(7), e1000097.
- Mobaseri, S., et al. (2021). Food waste reduction and environmental impacts: A system dynamics approach. *Journal of Cleaner Production*, 282, 124514.
- Mousa, H. (2020). Food security, food donation and food redistribution policies. *Food Policy*, 92, 101875.
- Munesue, Y., et al. (2015). Food waste and food security challenges globally. *Agricultural Systems*, 138, 1–12.
- Paraschivu, M., et al. (2022). Food loss and waste and sustainability challenges. *Sustainability*, 14, 789.
- Paritosh, K., et al. (2017). Food waste management through anaerobic digestion. *Renewable and Sustainable Energy Reviews*, 73, 1094–1104.
- Pawlak, K., & Kołodziejczak, M. (2020). Agricultural sector and food security. *Agricultural Economics*, 66(6), 285–296.
- Petrariu, R., et al. (2021). Water-energy-food-waste nexus and economic performance. *Sustainability*, 13, 5432.
- Pilone, V., et al. (2023). Bibliometric analysis of sustainability research trends. *Sustainability*, 15, 567.
- Priyashantha, K., et al. (2021). Systematic literature review methods in management research. *Sustainability*, 13, 1234.
- Rącz, G., et al. (2018). Economic and environmental implications of food waste. *Sustainability*, 10, 1–15.

- Roemer, R., et al. (2015). Bibliometrics and research evaluation. *Library Trends*, 63(3), 636–658.
- Rutten, M. (2013). Economic impacts of reducing food waste. *Food Policy*, 41, 56–67.
- Santeramo, F. G. (2021). Food loss and waste and food security. *Food Policy*, 98, 101–110.
- Santeramo, F. G., & Lamonaca, E. (2021). Food loss, waste, and food security dynamics. *Food Policy*, 102, 102–111.
- Sarkodie, S. A., et al. (2019). Environmental sustainability, energy consumption, and economic development nexus. *Science of the Total Environment*, 657, 1331–1341.
- Seberini, A. (2020). Food waste: Causes and solutions. *Sustainability*, 12, 1–12.
- Slorach, P., et al. (2020). Environmental sustainability of household food waste management. *Resources, Conservation and Recycling*, 154, 104–115.
- Swietlik, K. (2018). Economic growth and food security relationship. *Agricultural Economics*, 64(6), 1–8.
- Thyberg, K., & Tonjes, D. (2016). Drivers of food waste generation. *Resources, Conservation and Recycling*, 106, 110–123.
- Thyberg, K., et al. (2022). Food loss at primary production and environmental impacts. *Sustainability*, 14, 1–15.
- Valenzuela, L., Merigó, J. M., et al. (2017). Bibliometric analysis of management research. *Management Decision*, 55(10), 1–14.
- Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer. *Scientometrics*, 84(2), 523–538.
- Wang, X., et al. (2021). Food waste management and sustainability. *Journal of Cleaner Production*, 314, 128–139.
- Wani, S. A., et al. (2023). Consumer food waste behavior and sustainability. *Sustainability*, 15, 3210.
- Kostakis, I., Papadaki, S., & Malindretos, G. (2024). Analyzing the relationship between consumers' and entrepreneurs' food waste and sustainable development using a bibliometric approach. *Frontiers in Sustainability*, 5, 1373802.
- Golinska-Dawson, P., Werner-Lewandowska, K., Kolinska, K., & Kolinski, A. (2023). Impact of market drivers on the digital maturity of logistics processes in a supply chain. *Sustainability*, 15(4), 3120.
- Santeramo, F. G., & Lamonaca, E. (2021). Food loss–food waste–food security: a new research agenda. *Sustainability*, 13(9), 4642.
- Thyberg, K. L., & Tonjes, D. J. (2016). Drivers of food waste and their implications for sustainable policy development. *Resources, Conservation and Recycling*, 106, 110–123.
- United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. New York: UN.
- United Nations Environment Programme. (2024). *Food waste index report 2024*. Nairobi: UNEP.
- World Health Organization. (2023). *The State of Food Security and Nutrition in the World 2023: Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum* (Vol. 2023). Food & Agriculture Org.

- Baybars, M., Demircan Keskin, F., Kazançoğlu, İ., & Kazançoğlu, Y. (2024). Decoding the Nexus: A Bibliometric Review on Sustainability, Circular Economy, and Consumer Food Waste. *Sustainability*, 16(11), 4408.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, 372.
- Food and Agriculture Organization. (2011). *Global food losses and food waste: Extent, causes and prevention*. Rome: FAO.
- 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.
- Cattaneo, A., Sánchez, M. V., Torero, M., & Vos, R. (2021). Reducing food loss and waste: Five challenges for policy and research. *Food Policy*, 98, 101974.
- Zhao, Y., et al. (2022). COVID-19 impacts on food waste and food security. *Food Security*, 14, 123–135.
- Zupic, I., & Čater, T. (2015). Bibliometric methods in management research. *Organizational Research Methods*, 18(3), 429–472.