

Enhancing rice resilience and sustainability: A bibliometric analysis of innovations for food security and environmental conservation

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Abstract. This study delivers a critical bibliometric examination of the innovative strategies employed to boost the resilience and sustainability of the rice supply chain. As one of the most vital cereal crops globally, understanding the nuances of the rice supply chain and its broader implications for food security is paramount. This study establishes the intrinsic connection between the rice supply chain and Sustainable Development Goals (SDGs), specifically SDG 2 (Zero Hunger) and SDG 15 (Life on Land). This study systematically scrutinises the academic literature from reputable journals and databases. Through rigorous bibliometric analysis, we identified salient themes, trends, and seminal contributions related to enhancing the resilience and sustainability of the rice supply chain. Our study yields crucial insights into the strategies and initiatives employed to confront challenges in the rice sector, underlining the sector's role in promoting food security and sustainable agricultural practices with a particular emphasis on environmental conservation efforts. The comprehensive synthesis and analysis of diverse academic publications offer valuable information for policymakers, researchers, and stakeholders seeking to craft effective interventions and policies. These initiatives will enhance the food security and sustainability of rice production. Our findings emphasise the need to integrate innovation in rice.

1 Introduction

Rice is still a strategic commodity, often considered the main food commodity. The Indonesian government pays great attention to rice commodities through policy interventions aimed at protecting rice producers and consumers through food security programs. A country's food security is seen from its availability, accessibility, safety, and sustainability [1]. Food security is included in the Sustainable Development Goals (SDGs). The Sustainable Development Goals (SDGs) serve as a guiding framework, directing international efforts to

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eradicate poverty, maintain ecological balance, and safeguard the well-being of all individuals by 2030 [2–5]. The set of 17 goals presented here exemplifies the collective resolve of countries worldwide, as they address pressing issues ranging from food insecurity and public health to education and sustainable infrastructure development. Within the framework of aspirations worldwide is Sustainable Development Goal 2 (SDG 2), which focuses on overcoming poverty, improving the quality of life, and regional development, or what is commonly referred to as "Zero Hunger."

SDG 2, which seeks to eradicate hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030, emphasises the importance of strengthening agricultural methods to ensure their resilience and sustainability. Rice, a fundamental dietary component for more than 50% of the world's population, is at the heart of this narrative. Dynamic methods and technologies associated with rice cultivation and management can have a significant impact not only on aspects of food security but also on the field of environmental conservation. The importance of advances in rice research cannot be denied, as they have the potential to contribute to the achievement of Sustainable Development Goal 2 and have a significant impact on socio-economic dynamics, especially in regions where rice has food and cultural importance.

Furthermore, SDG 15, which preserves diverse forms of life on land, requires targeted efforts to protect, restore, and promote the conservation and sustainable use of terrestrial and other ecosystems. Goal 15 focuses on managing forests sustainably, halting and reversing land and natural habitat degradation, combating desertification, and stopping biodiversity loss. All these efforts aim to ensure that the benefits of land-based ecosystems, including sustainable livelihoods, will be enjoyed for generations.

Research and innovation in sustainable food systems have recently become the focus of public policy in several countries [6]. Building food security must be balanced by applying the concept of food sovereignty, which is realised by aligning and maximising competence between political resources, environmental resource capacity, and environmental diplomacy [6,7]. On the other hand, the population continues to increase throughout the year, posing a challenge for the government to increase food security. In 2045, Indonesia's population is estimated to reach 321.4 million people and will rank fifth after China, India, Nigeria, and the United States [9].

There has been an increase in research interest regarding the link between rice cultivation, resilience, and sustainability since the enactment of SDG 2. Exploring the potential for innovation and practice in the field of rice cultivation, with the aim of increasing resilience and sustainability, is something that needs to be done, a topic of great interest in academic circles. Applying these innovative strategies has the potential to bring about significant change and has a broad impact, especially in areas where rice cultivation is widespread.

To further explore the complex network of connections, this research focused on conducting a thorough bibliometric analysis. This analysis examines explicitly emerging research directions related to rice, including resilience, sustainability, and broader implications for SDG 2 and 15. This study focuses on the extensive body of literature in the Scopus database. This aim includes two main aspects: first, to identify the main research themes in the field, and second, to carry out a critical evaluation of the contributions made by pioneering scholars in a particular field of study. We aimed to amplify the complex and varied meanings of rice using an analytical lens. In addition to its well-known nutritional benefits, rice also serves as a symbol of innovation, demonstrating its capacity to drive sustainable agricultural progress and reshape the global development narrative in the years to come.

2 Methodology

To pursue our objective, a methodical bibliometric approach was utilised to investigate the current research trends pertaining to this particular field [9–12]. The primary data utilised in this study were obtained from the Scopus database on 3 September 2023. The extensive scope of this database, comprising more than 25,100 titles sourced from a consortium of approximately 5,000 publishers, establishes it as a dependable resource for comprehensive scholarly enquiry. The search was conducted using a calibrated approach, focusing on keywords such as "rice," "resilience," "sustainability," "food security," and "environmental conservation." The inclusion of an additional criterion pertaining to language restricted the scope of the search to articles written in English. Implementing this strategic methodology resulted in the creation of a comprehensive collection of 1,852 articles that closely aligned with the central theme of our research. The workflow of data extraction is shown in Figure 1.

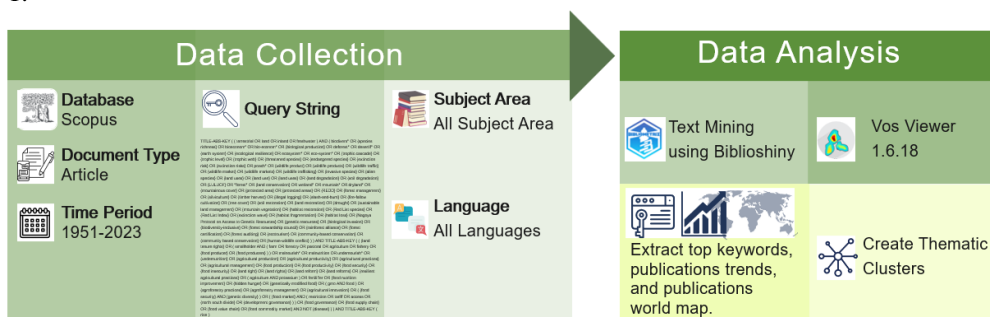


Fig. 1. Workflow steps of search query formulation for data extraction.

In the data handling phase transition, the researchers utilised the Biblioshiny tool, which is integrated within the R programming environment. R, renowned for its exceptional capabilities in bibliometric analytics, effortlessly enables the classification, analysis, and interpretation of identified patterns within our dataset [13,14].

A comprehensive methodology was adopted for data interpretation. This encompassed a variety of analytical methods, including tracking yearly fluctuations in research publications and visualising the geographical distribution of research contributions. Text mining techniques were used to analyse commonly used terminologies to identify prominent research areas. Moreover, a thorough examination of authorship sheds light on key figures in the field and maps out collaboration patterns. The citation landscape was thoroughly examined to assess the impact of these articles on the academic community.

The complex network of connections between authors, nations, and key terminologies was visually represented using VOSviewer [15,16]. Visual representations have the ability to simplify intricate data, emphasising the collaborative nature and central themes within research focused on rice.

The analytical journey concluded with the initiation of the refinement stage. During this phase, the dataset was subjected to pruning to remove redundant and overarching terms. The primary objective of this meticulous curation was to enhance the lucidity and accuracy of our findings.

The research approach was driven by the goal of providing a comprehensive overview of the current research trends, focusing on the resilience and sustainability of rice. Our particular emphasis was on innovative strategies addressing food security and environmental conservation.

3 Results and Discussion

Based on an extensive dataset covering the period from 1951 to 2023, a discernible trend can be observed in the level of academic involvement pertaining to the objectives outlined in Sustainable Development Goal (SDG) 2. This particular goal emphasises eradicating hunger, attaining food security, enhancing nutrition, and promoting sustainable agricultural practices.

A comprehensive analysis was conducted on a substantial number of 1,834 documents selected from a diverse range of 779 sources, including scholarly journals, books, and other academic publications. The annual growth rate of 7.1% reflects the enduring academic enthusiasm. The documents, which have an average age of 8.25 years, present a diverse collection of both foundational and contemporary research findings. The collection of scholarly articles, which has an average citation count of 27.77 per document, highlights the significance and impact of these research findings among academic circles.

Upon dissecting the corpus of these documents, a wide range of topics became apparent. The dataset consists of 8,159 "Keywords Plus (ID)", likely derived from the referenced works' titles, abstracts, and keywords. In addition, scholars have identified 4,790 unique author keywords, providing insight into the fundamental themes and paradigms emphasised in their respective investigations. The level of international collaboration in this field is notable, as indicated by the presence of approximately 34.41% of papers that feature co-authorships across national borders. This highlights the significance of food security and sustainable agriculture worldwide.

Categorising documents according to their respective types enables a more detailed understanding of scholarly endeavours. Most of the document pool, consisting of 1,340 items, comprises articles that serve as evidence for the extensive number of peer-reviewed contributions. Conference papers comprising 224 entries serve as tangible representations of the dynamic exchanges and widespread dissemination of research findings within academic symposiums. The inclusion of 92 reviews highlights the necessity and effort to consolidate and critically evaluate the current body of literature. Moreover, the presence of 122 book chapters suggests the existence of comprehensive scholarly work focused on the diverse dimensions of SDG 2. The performance summary of the Biblioshiny results is illustrated in Figure 2.

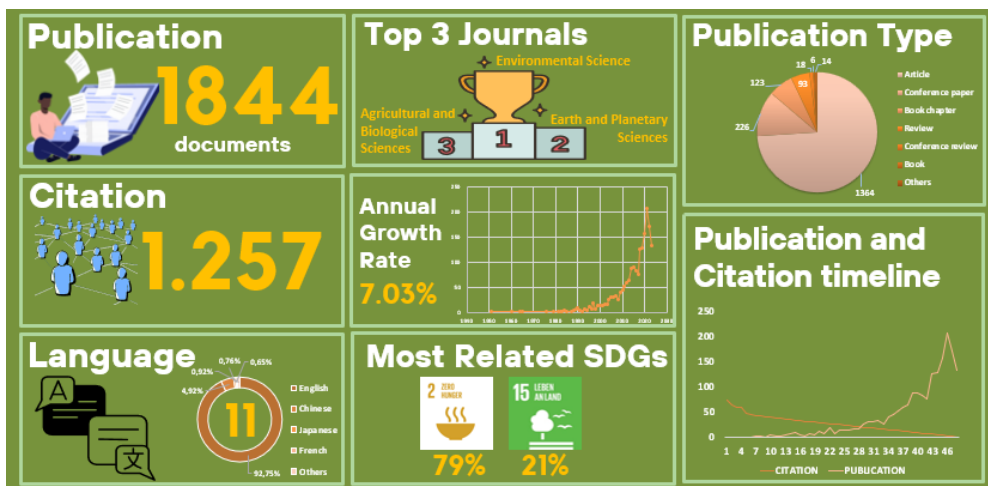


Fig. 2. Abstract assortment of general bibliometric qualities of the rice publications to SDG 2 and SDG 15.

The dataset, spanning the years 1951 to 2023, documents a captivating trajectory in academic pursuits of Sustainable Development Goal 2 (SDG 2). The preliminary stage, spanning multiple decades, may indicate the establishment of fundamental research and early acknowledgement of subjects. However, the era following 2015 demonstrates a significant paradigm change. The resurgence of enthusiasm could be attributed to external influences, such as shifts in global policies or technological advancements. The continuous and abundant flow of research findings in recent years confirms the persistent and increased significance of the topics encompassed within Sustainable Development Goal 2 (SDG 2). This underscores the crucial role that SDG 2 plays in global dialogues on hunger, nutrition, and sustainable agriculture.

The annual scientific output from 1951 to 2023 provides a comprehensive depiction of the scholarly attention given to the pursuits outlined in Sustainable Development Goal (SDG) 2. This goal primarily focuses on eradicating hunger, attaining food security, enhancing nutrition, and fostering sustainable agriculture. Between 1951 and 1975, intermittent research endeavours were characterised by a limited number of published articles. This may suggest that the subject was in its early stages of development or that there were restricted opportunities for conducting research and disseminating findings. Nevertheless, starting from the latter part of the 1970s, particularly from 1979 onwards, there was an incremental yet discernible rise in the quantity of published works. The growth observed during the 1980s was gradual, yet discernible, as evidenced by the consistent increase in articles. By 1995, the number of articles had reached a notable milestone of 10.

There was a notable increase in the late 1990s, specifically in 1997, when 19 articles were recorded. This momentum persisted throughout the early 2000s, with figures consistently increasing. By 2005, the number of publications per year amounted to 29. This figure experienced rapid growth, reaching 34 publications in 2007 and further escalating to 40 publications by 2009.

The subsequent decade, namely the 2010s, witnessed a substantial surge in research endeavours. By the middle of the decade, there was a nearly two-fold increase in the annual number of articles, reaching a total of 88 by the year 2015. The pinnacle of the current decade occurred in 2018, when the number of articles reached 127, signifying a noteworthy increase compared to the low single-digit figures observed in preceding decades.

In 2020, the research community exhibited heightened enthusiasm, as evidenced by the publication of 154 articles. The pinnacle was attained in 2021, with a remarkable total of 205 articles. This may potentially indicate the culmination of collaborative endeavours across various disciplines, advancements in technology, and an increased global consciousness regarding the issues of food security and sustainability. In 2022 and 2023, there was a slight decline in the number of published articles, with 170 and 140 articles, respectively. However, it is noteworthy that these figures still demonstrate a notable level of productivity. Upon analysing this trajectory, it is possible to make several observations.

The initial period, encompassing 1951 to the late 1970s, signifies the nascent phase of scholarly enquiry pertaining to the themes associated with Sustainable Development Goal 2. The sporadic dissemination of these publications may have originated from innovative scholars and esteemed academic institutions. The next period from the 1980s to the 1990s was marked by a consistent and indisputable upward trajectory in scholarly investigations, indicating an increasing acknowledgement of the subject matters encompassed by Sustainable Development Goal 2 (SDG 2).

The decade of the 2000s witnessed a notable period of heightened research expansion, which was influenced by significant global occurrences, policy modifications, technological advancements, and augmented financial support. The decade of the 2010s experienced significant and rapid growth, with a notable increase of over ten times from the beginning to the conclusion of the period. The potential influence of formalising the Sustainable

Development Goals in 2015 and the heightened urgency surrounding global food security concerns may have played a role in this.

In recent years, there has been a notable period characterised by a substantial level of productivity, which may suggest a stage of consolidation, implementation, and enhancement of research discoveries. The data highlight the increasing importance and urgency of Sustainable Development Goal 2 (SDG 2) topics. The scholarly community has intensified its efforts, resulting in SDG 2 becoming a prominent area of academic investigation in recent times. The data that have been exported consist of a collection of terms and their corresponding frequencies, which are likely derived from a compilation of research documents about agriculture and its related topics. This dataset type is valuable for generating a word cloud, a visual representation that depicts the frequency of terms.

To conceptualise a word cloud derived from this dataset, envision a graphical depiction that possesses the subsequent attributes: the central and dominant terms within the word cloud would consist of the words "rice", "agriculture", and "land use", as they exhibit the highest frequency of occurrence. Secondary Prominent Terms: In the vicinity of the central terms, additional noteworthy terms such as "China", "climate change", "crops", "cultivation", "agricultural land", "crop production", and "food supply" exhibit considerable magnitude, thereby signifying their significance within the dataset. In addition to the aforementioned terms, secondary words such as "fertilisers", "soil", "food security", "nitrogen", "paddy field", "soils", "India", "land use change", "*Oryza*", and "remote sensing" would be discernible, albeit in a smaller font size compared to the primary terms.

Peripheral and specific terms, such as "agricultural robots", "water management", "maize", "economics", "greenhouse gas", "carbon", and "water quality", are situated towards the periphery of the word cloud. While these terms may occur less frequently, they are nonetheless crucial for comprehensively grasping the breadth and depth of research. Cultural and Geographic Indicators: The inclusion of terms such as "China", "India", and "Asia" serves as indicators of specific geographical regions that hold notable importance within the dataset. The terms mentioned above emphasise geographical areas that may serve as focal points for agricultural research or are presently encountering difficulties in food security and sustainable agriculture.

The terminology employed, such as "climate change", "methane", "carbon dioxide", "biodiversity", and "ecosystem", underscores the inherent interdependencies between agriculture and environmental variables and predicaments. Agronomic Specifics: The utilisation of precise scientific nomenclature, such as "*Oryza sativa*", "*Zea mays*", and "*Triticum aestivum*", to refer to rice, maize, and wheat, respectively, highlights the intricate and meticulous nature of the research being conducted.

The word cloud offers a concise visual representation of the key focus areas within agricultural research. This highlights the prioritisation of specific agricultural products, geographic areas, environmental obstacles, and inventive approaches.

Based on the data extracted from VOSviewer (Figure 3), the following observations can be deduced:

a. Cluster 1: The centrality of crop cultivation and agricultural practices

This cluster is predominantly zero in the overarching realm of agriculture, characterised by a strong emphasis on farming techniques and cultivation practices. Terms such as "cultivation", "land use", "crops", "crop yield", and specific crop references like "rice", "maize", and "wheat" bolster this deduction.

- 1) The dominant keyword here is "land use" with an outstanding weight of 3005, signifying its paramount importance in the studied literature. This could indicate a pivotal focus on land management and its direct impact on crop production.

4 Conclusions and recommendations

The present study conducted a thorough bibliometric analysis highlighting the increasing significance of rice in global food security and environmental preservation discussions. In the last 20 years, there has been a noticeable change in research trends, as there has been a growing focus on sustainable practices in rice cultivation and their broader environmental implications.

The results of this study demonstrate that rice, in addition to its primary function as a staple food, is leading to the development of innovative approaches to promote sustainable agricultural methods. The increasing use of vocabulary pertaining to environmental impacts and life cycle analysis within the research corpus suggests a rising recognition of the ecological footprint associated with rice cultivation. As mentioned earlier, awareness is accompanied by deliberate endeavours to mitigate the negative effects and improve the adaptability of rice ecosystems.

The global nature of the challenges faced and the collective commitment to addressing them are exemplified by collaborative research endeavours, as indicated by the wide array of sources utilised and the presence of international co-authorships. The rice research community is actively engaged in both expanding its knowledge base and cultivating collaborative partnerships to facilitate the development of impactful solutions.

Based on the results obtained, it is apparent that rice will maintain a central position in the discourse on sustainable development. In light of the global imperative to address both food security and environmental conservation, advancements in the resilience and sustainability of rice cultivation hold significant potential for shaping a sustainable trajectory for the future. The recommendation that can be made is that this research catalyses additional research and collaboration in this important area.

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