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OPTIMIZING RESOURCES IN AGRICULTURE: A BIBLIOMETRIC ANALYSIS OF ECONOMIC STRATEGIES AND TECHNOLOGICAL ADVANCEMENTS

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Abstract

This paper investigates the optimization of resources and activities in agriculture, focusing on increasing efficiency and productivity through modern technologies and resource management practices. Precision agriculture, crop rotation, and integrated pest management are highlighted as key methods for improving yields while minimizing environmental impacts. Bibliometric analysis was conducted on 1,366 academic publications using tools such as citation analysis and keyword co-occurrence analysis. The results show a significant growth in research on economic optimization in agriculture, with sustainability and technological advancements driving the field. Key areas of focus include resource efficiency, automation, and multi-objective optimization, with water management emerging as a critical topic. The study provides insights into the evolving research landscape, emphasizing the integration of advanced technologies such as AI, IoT, and machine learning in future agricultural practices. Although bibliometric methods offer valuable assessments, the limitations of these approaches, such as citation biases, should be considered when interpreting results. The analysis underscores the growing importance of sustainable agricultural practices and resource optimization in addressing global challenges like climate change and resource scarcity

Key words: *resources, efficiency, productivity, technologies, agriculture*

INTRODUCTION

The optimization of resources and activities on farms, whether crop and/or livestock production, is an important process to increase agricultural efficiency and productivity. This process of optimization involves the rational use of the resources used, including land, seeds, fertilizers, equipment, but especially water, all to maximize yield and profitability by reducing costs and environmental impact.
Integrating modern technologies as they have been developed and refined, such as precision agriculture, has become a key aspect of optimization. New technologies allow crop monitoring and management using sensors and data, and enable farmers to adjust resources in real time according to their specific needs. Other aspects practiced to reduce excessive pesticide use and contribute to soil revitalization are crop rotation and integrated pest management. In addition, economic optimization involves financial planning including cost analysis, identifying opportunities to diversify production and accessing new markets. In a nutshell, optimization not only supports environmental sustainability but also ensures the long-term economic viability of farms.
With the mechanization of agriculture and its industrialization, resource inputs have increased exponentially to increase yields. In this respect, farmers, but especially researchers, have tried to create models for optimizing crop technologies so as to rebalance the effect-effort balance, or more specifically to achieve the optimal correlation between production and resources used.
Bibliometric analysis is a quantitative method used to measure and evaluate scientific research, its impact and collaboration between researchers. The term was introduced by Pritchard (1969), describing the use of statistics to analyse books and other forms of written communication. The main purpose of bibliometric analysis is to schematize research in a field, assess scholarly impact and identify trends and gaps in the field.
Methods and tools used include citation analysis, co-citation and keyword co-occurrence analysis. Citation analysis measures the number

of citations a paper receives, providing a clear quantification of its impact (Garfield, 1979). Co-citation, introduced by Small (1973), examines how frequently two papers are cited together, revealing conceptual links between them. In addition, co-authorship analysis can highlight scholarly collaborations (Newman, 2001).

Frequently used data sources include databases such as Scopus and Web of Science, which provide access to scholarly publications and impact assessment tools. Scopus is a preferred platform for citation analysis and assessment of international collaborations (Elsevier, 2023), while Web of Science allows the analysis of co-citation networks (Clarivate Analytics, 2023).

Bibliometric indicators include: the number of publications, the total number of citations and the h-index, an index that combines the productivity and impact of a researcher's work (Hirsch, 2005). While these indicators are useful, bibliometric analysis also has limitations. Dissensions in bibliometric assessments can arise due to the predominance of papers published in English and in open access journals, which may influence the frequency with which they are cited (van Raan, 2005). In addition, citations do not always reflect the quality of research, but rather its visibility.

Consequently, bibliometric analysis is a tool for evaluating academic research, providing an overview of scientific impact and collaborative networks. However, its results should be interpreted with caution, given the inherent limitations of this method.

MATERIALS AND METHODS

For this bibliometric analysis, we used the keywords "economic optimization in agriculture" in the Scopus search engine. This provided a starting point for identifying all relevant publications. Initially, the search returned a total of 1604 publications on this topic. Next, we applied a series of filters to refine the results and ensure that the study focused on the most relevant academic papers in the areas of interest.

Filtering publications

In the first stage of refining the results, we restricted the list to publications that include articles in academic journals, papers presented at conferences, books and book chapters. This filter was applied to ensure a dataset composed of papers with significant scientific impact. Other types of publications, such as technical notes or review articles, were excluded to maintain a rigorous approach.

Subsequently, we applied additional filters to focus on specific areas of interest that are directly related to economic optimization in agriculture. The selected areas were:

- Environmental sciences - to include studies related to the sustainability of resource use and the impact of economic optimization on the environment;
- Agricultural and Biological Sciences - the main area addressing agricultural practices and technologies underlying economic optimization;
- Engineering - to cover technical aspects and innovations that can contribute to resource optimization;
- Energy - covering the essential role of energy in agriculture, including energy efficiency solutions;
- Business, Management and Accounting - to examine the economic, management and planning dimensions of optimization in agriculture;
- Economics, Econometrics and Finance - this area was selected to understand the economic modeling and financial viability studies of different strategies used both in agricultural practices and in informing decisions;
- Multi-disciplinary - we included this category to capture publications that do not fall strictly within a single field, but make contributions to a holistic understanding of the topic.

Applying these filters reduced the number of publications to 1366 relevant papers, which will be analyzed in detail in this chapter. After refining the results, the 1366 publications represent a significant selection of papers exploring economic optimization from diverse perspectives, ranging from technological innovations and management practices to energy solutions and economic models. A detailed analysis of these papers can contribute to an integrated understanding of economic optimization in agriculture and its impact on sustainability and efficiency in the agricultural sector.

RESULTS AND DISCUSSIONS

The number of publications on economic optimization in agriculture has shown significant growth between 2012 and 2022 (Figure 1). Initially, there was a gradual increase in the number of publications from 2012 to 2016, indicating an emerging interest in the topic. The pace of growth accelerated from 2017 onwards, reaching 181 publications in 2020. This can be attributed to advancements in technology and the digitalization of agriculture, which have created new opportunities for optimizing resources and production. The COVID-19 pandemic and its impact on supply chains and agricultural systems have also fueled research on more resilient solutions. Additionally, global issues such as climate change, sustainability, dwindling resources, and EU regulations have contributed to the increased focus on economic optimization in agriculture. The growing need for research is driven by the implementation of policies supporting sustainable agriculture and the reorganization of agricultural practices to align with these policies.

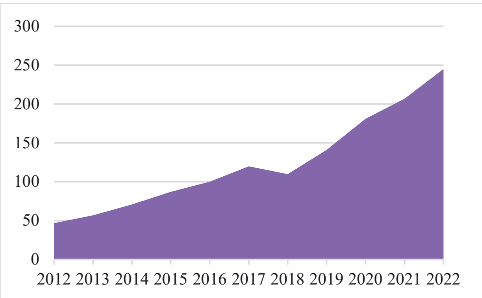

Figure 1. The evolution in number of publications in the period 2012-2022
Source: own processing based on data extracted from Scopus

Analysis of the number of publications shows that economic optimization in agriculture has become increasingly important in scientific literature. The steady increase in the number of publications over the last decade, especially after 2017, reflects the growing concerns about the efficiency and sustainability of agriculture in the face of global challenges. This trend suggests that the topic will continue to be widely explored in the years to come, given the ongoing need to optimize agricultural resources and processes.

The top 10 journals with the highest number of publications related to economic optimization in agriculture is dominated by Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, which includes 77 publications. This is followed by Journal of Cleaner Production with 54 publications and Science of the Total Environment with 41 publications. Other relevant journals include Agricultural Water Management with 38 publications and IOP Conference Series: Earth and Environmental Science, along with Agricultural Systems, both with 33 publications each. Journal of Environmental Management stands out with 29 publications, while Sustainability (Switzerland) and Water (Switzerland) contributed with 24 and 22 publications respectively. Finally, Computers and Electronics in Agriculture published 19 papers. These journals are essential sources of research on economic optimization in agriculture. The 10 journals contain a total of 370 publications (Table 1). This number represents about 27.09% of the total 1366 publications on economic optimization in agriculture.

Table 1. Ranking of journals by number of publications

Journal title	Publication number	Percentage of total (%)
Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering	77	5.64
Journal of Cleaner Production	54	3.95
Science of the Total Environment	41	3
Agricultural Water Management	38	2.78
IOP Conference Series: Earth and Environmental Science	33	2.42
Agricultural Systems	33	2.42
Journal of Environmental Management	29	2.12
Sustainability (Switzerland)	24	1.76
Water (Switzerland)	22	1.61
Computers and Electronics in Agriculture	19	1.39
Total	370	27.09

Most research publications in the field of economic optimization in agriculture consist of scientific articles, which account for about 81.7% of all publications, with a total of 1116 articles. Conference papers follow, representing approximately 14.2% of the total, with 194 publications. These findings suggest that a significant portion of research and findings in this field are initially presented and discussed at academic conferences. Book chapters constitute about 3.5% of the total publications, with 48 chapters. These chapters often explore specific topics in greater detail within a broader or interdisciplinary context and are commonly found in reference works. Books have the smallest share, with only 8 publications, making up about 0.6% of the total. This indicates that while there is interest in the field, research in the area is primarily published in shorter formats like articles and conference papers, as opposed to longer works like treatises or books.

The 8 books identified as part of the bibliometric analysis related to economic optimization in agriculture cover a wide range of topics relevant to sustainable development and agricultural efficiency at the global and regional level. Here is a brief overview of each paper:

- *Biogas Systems in China* (Deng et al., 2014) - This book analyzes the use of biogas in China, highlighting the economic and environmental benefits of this system for agriculture. It is an important resource for energy optimization and reducing dependence on conventional energy sources in agriculture.
- *Climate Smart Agriculture in South Asia: Technologies, Policies and Institutions* (Hossain & Awasthi, 2019) - This paper focuses on the implementation of climate smart agriculture in South Asia, discussing technologies and policies aimed at optimizing agricultural resources and reducing the impact of climate change on production.
- *The Economy in Romania and the Need for Optimization of Agricultural Production Structures* (Popescu, 2017) - This book discusses the need for optimization of agricultural production structures in Romania, highlighting the importance of economic adjustments to increase the efficiency and competitiveness of agriculture in the Romanian economic context.
- *Modeling and Optimization of Biomass Supply Chains: Top-down and Bottom-up Assessment for Agricultural, Forest and Waste Feedstock* (Gonzalez-Sanchez & Elbersen, 2016) - This paper addresses the modeling and optimization of biomass supply chains, with a focus on the assessment of agricultural, forest and waste feedstock. It is particularly relevant for developing sustainable and economical solutions in agriculture.
- *Plant Genetic Resources, Inventory, Collection and Conservation* (Engels & Ramanatha Rao, 2002) - This book explores the management of plant genetic resources, with a focus on inventory, collection and conservation, which are essential aspects for optimizing agricultural production and maintaining the genetic diversity necessary for sustainable agriculture.
- *Process Management in Spinning* (Chakraborty, 2018) - This paper presents information on process management in the textile industry, with direct applications in streamlining production in textile fiber-related agriculture, such as cotton and other technical crops.
- *Specifications of Photovoltaic Pumping Systems in Agriculture: Sizing, Fuzzy Energy Management and Economic Sensitivity Analysis* (Alahmed & Cherkaoui, 2020) - The book discusses the specificities of photovoltaic systems in agriculture, providing solutions for their efficient energy management and economic sensitivity analysis. It is a relevant work for optimizing energy resources on modern farms.
- *Structural Change, Productivity, and Climate Nexus in Agriculture: An Eastern European Perspective* (Csaki & Forgacs, 2021) - The paper addresses the relationship between structural change, productivity, and climate change in agriculture, focusing on the Eastern European perspective. It analyzes how structural adaptations can lead to more efficient and sustainable agriculture.

Keyword link analysis

This paper discusses the central terms and their link strength in the scientific literature on economic optimization in agriculture. The terms "agriculture" and "optimization" are the most central, indicating that these topics are frequently correlated with other topics in the literature. The term "Economics" and related terms such as "economic and social effects" and "sustainable development" are also central, highlighting the importance of economic aspects and social effects in the context of sustainable agriculture. Additionally, the terms "water supply" and "water management" are central in discussions on optimizing water resources in agriculture, particularly considering the increasing droughts in recent years.

The total link strength of a term represents the strength of its relationships with other terms in the network, indicating its centrality and importance in the field (Table 2 and Figure 2).

Table 2. Links between terms and total strength of links

Terms	Links	Total strength of links
Agriculture	441	8104
Optimization	439	7448
Economics	427	3132
Economic and social effects	426	3455
Sustainable development	423	3276
Article	416	3931
Water supply	399	3376
Decision making	397	2675
Water management	396	3693
Crops	391	2534

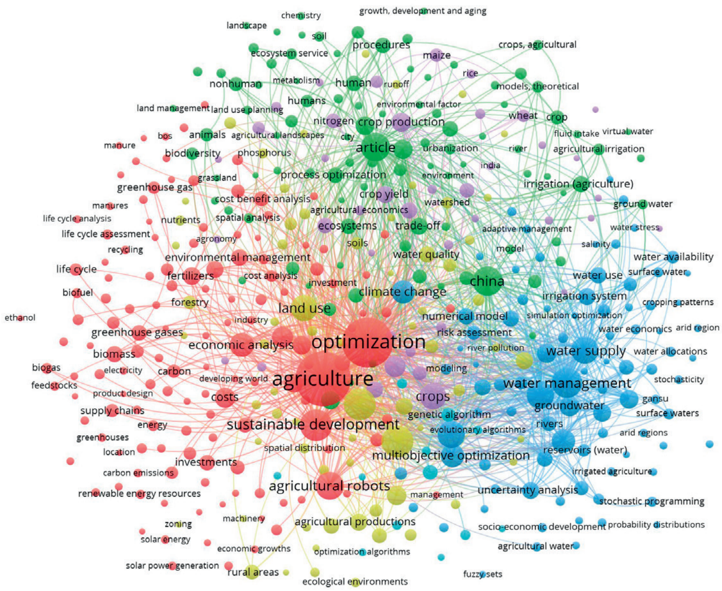

Figure 2. Map of links between terms
Source: own processing with VOS Viewer based on data extracted from Scopus

The future of research in economic optimization in agriculture will be driven by advanced technologies like deep learning, machine learning, and the Internet of Things (IoT). These technologies will play a crucial role in the transformation of agriculture towards precision agriculture. They enable real-time data collection and analysis, allowing for automated decision-making on farms. Precision agriculture will be achieved through the use of autonomous cars and drones equipped with IoT sensors, which will monitor soil and plant health. Deep learning will be utilized for problem recognition and management, including detecting crop diseases, monitoring environmental factors, and optimizing irrigation. This integration of technology and smart solutions in agriculture will enable farmers to maximize crop yields and minimize resource losses. Sustainability and resource efficiency in agriculture are also of growing concern, with issues related to water resource management and multi-objective optimization being key areas for research. Overall, the future of agricultural research will be characterized by the integration of advanced technologies and the focus on sustainability (Figure 3).

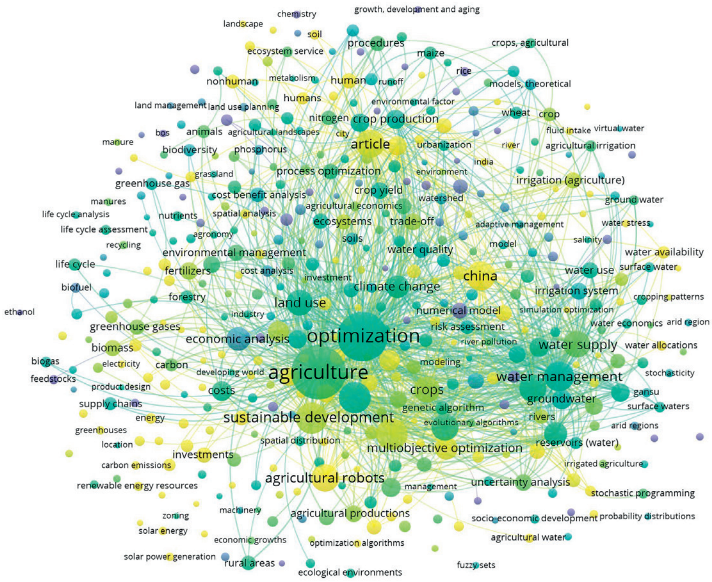

Figure 3. Map of terms by year of publication
Source: own processing with VOS Viewer based on data extracted from Scopus

Research in water resources is crucial due to climate pressures and global water scarcity. The future of agriculture depends on efficient water management, which will be supported by research in irrigation, water harvesting, and reuse technologies. To address limited water and space resources, innovative systems like vertical farms and controlled environment farming will be developed for more sustainable and efficient agriculture.

Multi-objective optimization and predictive models will play a significant role as well. We can expect a deeper integration of these methods into agricultural processes. Multi-objective models enable decisions that optimize multiple criteria simultaneously, such as crop yield, costs, and environmental impact. Advanced optimization algorithms will provide tailored solutions for different regions and climatic conditions. Moreover, advanced predictive models will be developed to anticipate extreme events like floods and droughts, with suggestions for optimal preventive measures. Integration with machine learning technologies will allow real-time updates based on new data, enhancing the accuracy and reliability of these models.

The future of agriculture will largely be focused on automation, with the aim of reducing manual labour and increasing efficiency through the use of autonomous machines, robots, and artificial intelligence. Agricultural robotics will play a significant role in transforming the sector, with robots being utilized for tasks such as planting, harvesting, and plant care. Additionally, there will be a growing emphasis on sustainability and reducing carbon footprints, leading to an increase in research into regenerative agriculture practices. These practices, like carbon sequestration and resource recycling, will become mandatory in efforts to minimize environmental impact. Achieving carbon neutrality will be a key objective for farmers, and agriculture will be at the forefront of implementing initiatives to reduce greenhouse gas emissions. Integrated digital platforms will also become more prevalent in the agricultural industry, aggregating data from various sources such as IoT, drones, and predictive modelling. This real-time information will enable farmers to make data-driven decisions on planting, fertilizing, and harvesting.

CONCLUSIONS

The bibliometric analysis carried out, based on 1366 publications, highlighted the main research directions in economic optimization in agriculture. Based on the distribution of terms, co-occurrences and clusters identified, we can draw the following conclusions supported by concrete figures:

- Sustainability and natural resource management: cluster 1, the largest, contains 138 terms and is centred on sustainability. Terms such as agriculture (with 441 links and a total strength of 8104) and sustainable development (423 links, strength of 3276) highlight the importance of research on sustainability in agriculture. Research focuses on the efficient use of resources, especially water and land, to meet the challenges of climate change.
- Emerging technologies and automation in agriculture: Cluster 6, which includes 12 terms, focuses on advanced technologies such as genetic algorithms (274 links, total strength of 765) and machine learning (97 links, strength of 147). These terms show a growing interest in agricultural automation through artificial intelligence and optimization algorithms. This line of research is supported by advances in deep learning and artificial neural networks, which enable more accurate decision-making and optimization of complex agricultural processes.
- The economic and social importance of decisions in agriculture: Cluster 4 (68 terms) is centred on the economic efficiency and social impact of decisions in agriculture. Terms such as economics (427 links, strength 3132) and economic and social effects (426 links, strength 3455) emphasize that research focuses on the economic and social analysis of agricultural decisions, assessing their impact on costs, efficiency and regional development.
- Multi-objective optimization and increasing productivity: Cluster 5, with 40 terms, reflects efforts to maximize agricultural productivity. The terms crops (391 links, strength 2534) and crop yield (290 links, strength 967) show a significant focus on improving the yield and efficiency of agricultural crops. In addition, the term multi-objective optimization (292 links, strength 803) indicates the use of advanced optimization techniques to balance cost, yield and sustainability in agriculture.
- Water resources management and strategic decision making: Cluster 3 (88 terms) is centred on water resources management and decision making. The terms water supply (399 links, strength 3376), water management (396 links, strength 3693) and decision making (397 links, strength 2675) emphasize that optimizing water use is a crucial topic in agriculture.

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