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Trends and Innovations in Agricultural Education: A Bibliometric Analysis

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ABSTRACT

Agricultural education is evolving rapidly with technological advancements, interdisciplinary approaches, and sustainability-focused research. This study conducts a bibliometric analysis to identify trends, innovations, and future directions in agricultural education research. A bibliometric analysis was performed using data from Scopus, focusing on publications from 2014 to 2024. Network and overlay visualizations were utilized to assess research collaborations, thematic trends, and knowledge clusters in agricultural education. The findings highlight key trends, including the integration of digital technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence into agricultural education. Interdisciplinary research is expanding, incorporating elements from environmental science, economics, and biology. Sustainability-related studies have increased, emphasizing life cycle assessment and environmentally friendly farming techniques. Global research collaborations are strengthening, with funding institutions playing a crucial role in knowledge dissemination. However, challenges such as the digital divide remain a barrier to equitable access to emerging technologies. The results underscore the growing role of technology and interdisciplinary methodologies in enhancing agricultural education. Digital learning platforms are transforming teaching strategies, but disparities in access highlight the need for policy interventions. Future research should focus on inclusive education strategies and integrating sustainable practices into curricula to ensure long-term impact. This bibliometric analysis provides insights into the evolving landscape of agricultural education, emphasizing the importance of technology, interdisciplinary collaboration, and sustainability. Addressing research gaps and fostering global cooperation will be essential for driving innovation in agricultural education.

Keywords: Agricultural education, bibliometric analysis, digital learning, interdisciplinary research, sustainability, global collaboration.

INTRODUCTION

Agricultural education has undergone significant transformations over the past few decades, driven by the need to integrate modern technologies and innovative practices into traditional farming methods. This shift reflects the growing emphasis on sustainability, interdisciplinary research, and the incorporation of emerging technologies to enhance agricultural learning and application. A bibliometric analysis of scientific literature highlights key trends and innovations shaping the field. This study aims to analyze bibliometric trends in agricultural education research, identify key technological

innovations, examine interdisciplinary approaches, explore sustainability-focused research, assess educational innovations, evaluate global collaboration, and identify research gaps and future directions in agricultural education. This analysis demonstrates the progression
of silvopasture research, connecting leading contributors, thematic shifts, and the growing focus on ecological and socioeconomic impacts within agroforestry (Tambong, 2025).

One significant trend is the increasing integration of technology in agricultural education. The adoption of advanced technologies such as the Internet of Things (IoT), blockchain, and digital storage is modernizing agricultural practices, improving data management, and enhancing analytical capabilities (Chamorro-Padial et al., 2025). Cloud computing is another transformative innovation, with research emphasizing its potential to revolutionize agricultural education by offering improved data storage, processing, and accessibility (Punjani et al., 2023). Given these advancements, this study seeks to identify how emerging technologies are shaping agricultural education and their implications for teaching and learning.

Another emerging trend is the interdisciplinary approach to agricultural education. Recent studies highlight the importance of integrating knowledge from diverse fields, such as environmental science, biology, and economics, to address complex agricultural challenges (Gómez et al., 2025). Additionally, the use of both quantitative and qualitative methodologies has become more prevalent, demonstrating a shift toward more comprehensive and holistic research practices (Gómez et al., 2025). In this context, this study aims to examine how interdisciplinary research contributes to agricultural education and fosters innovation in the field.

Sustainability is also a critical focus in agricultural education. Researchers are increasingly exploring environmentally friendly farming techniques and assessing the ecological impact of agricultural activities (Lucas et al., 2025). Life Cycle Assessment (LCA) has emerged as a valuable methodological tool in this context, helping to evaluate the sustainability of farming operations and identify areas for improvement (Lucas et al., 2025). This study will explore the role of sustainability in agricultural education research and how it influences curriculum development and policy implementation.

Educational innovations in agricultural education continue to evolve, influenced by contemporary teaching methodologies and the need for evidence-based decision-making. Bibliometric analyses indicate that international collaboration and interdisciplinary approaches play a crucial role in shaping educational advancements in this field (Kondrashev et al., 2024). The rise of data-driven agriculture, facilitated by artificial intelligence and big data analytics, is another significant trend, enabling optimized farming practices and more efficient decision-making processes (Chamorro-Padial et al., 2025). However, the digital divide remains a persistent challenge, particularly for small and medium-sized farmers, necessitating targeted policies to ensure equitable access to technological advancements (Chamorro-Padial et al., 2025). As part of this analysis, this study will assess how educational innovations, including digital learning platforms and pedagogical strategies, impact agricultural education and training programs.

Finally, global collaboration in agricultural education and research is becoming increasingly common. International partnerships facilitate the exchange of knowledge and resources, addressing the global nature of agricultural challenges (de la Cruz Santos & Del Pozo Rodríguez, 2022). Leading institutions and funding bodies, such as the European Union and the United States Department of Agriculture, continue to support research and development efforts that drive innovation in agricultural education (Chamorro-Padial et

al., 2025). This study aims to evaluate the role of global collaboration in shaping agricultural education and to identify key funding sources and institutional contributions. Furthermore, by synthesizing the findings, this bibliometric analysis will identify research gaps and future directions that can guide further advancements in the field.

METHODOLOGY

Data Collection

For this bibliometric study, data were gathered from Scopus, a well-respected database known for its extensive collection of peer-reviewed journal articles, conference proceedings, and review papers. Scopus was chosen because of its broad coverage of agricultural education research and its ability to provide valuable insights into citation trends, keyword patterns, and research collaborations.

To ensure that the study captured the most relevant literature, the Boolean search terms "agricultural AND education" and "agriculture AND teaching" were used. These keywords were carefully selected to include studies on teaching methods, technological advancements, sustainability initiatives, and interdisciplinary approaches in agricultural education. The search was limited to publications from 2014 to 2024, ensuring that only recent research reflecting modern trends and innovations was included.

In total, 260 documents were retrieved. The dataset included information such as publication year, document type (journal articles, conference papers, and reviews), author affiliations, keywords, citation counts, and research themes. To maintain the accuracy and relevance of the analysis, the data were carefully reviewed, cleaned, and filtered to remove duplicates or any studies that were not directly related to the research focus.

Once refined, the dataset was analyzed using key bibliometric indicators, including publication trends, keyword co-occurrence, and author collaboration networks. These insights helped to map the evolution of agricultural education research, highlight the most frequently explored topics, and identify the institutions and scholars leading advancements in the field.

Data Extraction

For data extraction, relevant records were extracted from Scopus and downloaded as a CSV file. The extracted data included essential bibliometric details such as titles, authors, abstracts, keywords, publication years, and citation counts. These elements provided a foundation for analyzing trends, author contributions, and thematic developments in agricultural education research over the selected time frame (2014-2024).

Data Cleaning and Preparation

Before analyzing the bibliometric data, the extracted CSV file underwent a thorough cleaning process to ensure accuracy and consistency. Duplicate records were identified and removed to maintain data integrity and prevent redundancy. To standardize the dataset, author names, keywords, and institutional affiliations were normalized, resolving inconsistencies such as name variations (e.g., "Smith, J." vs. "Smith, John"), keyword discrepancies (e.g., "precision agriculture" vs. "smart farming"), and institutional name formatting differences. These refinements ensured that the data were well-structured and ready for bibliometric analysis using VOSviewer, enabling a clearer understanding of publication trends, research themes, and collaboration networks in agricultural education.

Analysis

This study examined publication trends, citations, collaborations, and key research themes. A descriptive analysis was conducted to track yearly publication output, identify top authors, and highlight leading journals in the field. Citation analysis helped recognize the most influential papers and researchers shaping

agricultural education. Additionally, co-authorship analysis explored collaboration networks among scholars and institutions, revealing strong research partnerships. Finally, keyword analysis identified emerging trends and popular topics by mapping frequently used terms and their relationships.

Visualization

The network maps were created using VOSviewer, showcasing co-authorship networks to highlight researcher collaborations, keyword co-occurrence maps to identify emerging topics, and citation networks to trace influential studies. Additionally, trend analysis used graphs and charts to track publication output over time from 2014 to 2024, revealing growth patterns and shifts in research focus. By applying network and overlay visualizations, the study mapped how key topics evolved, providing a clearer picture of research trends, collaborations, and future directions in agricultural education.

RESULT AND DISCUSSION

Technological Innovations in Agricultural Education

One of the most significant trends identified in the bibliometric analysis is the increasing integration of technology into agricultural education. The use of advanced technologies such as the Internet of Things (IoT), blockchain, and digital storage is modernizing agricultural practices, leading to improved data management and analytical capabilities. Recent research highlights the transformative role of cloud computing in agricultural education, enabling enhanced data accessibility and processing capabilities (Punjani et al., 2023). The network visualization (Figure 1) illustrates strong collaborative linkages among researchers focused on digital transformation in agriculture, reflecting a growing interest in the digitization of farming education and practices.

Interdisciplinary Approaches in Agricultural Education

Agricultural education has increasingly embraced an interdisciplinary approach, integrating knowledge from fields such as environmental science, biology, and economics. This trend is evident in the bibliometric network (Figure 1), where multiple clusters represent researchers collaborating across various disciplines. Studies emphasize the shift toward both qualitative and quantitative research methodologies, facilitating a more holistic understanding of agricultural challenges (Gómez et al., 2025). The overlay visualization (Figure 2) highlights recent interdisciplinary research contributions, with an increasing number of studies incorporating multi-sectoral perspectives to enhance agricultural learning and problem-solving capabilities.

Sustainability-Focused Research in Agricultural Education

Sustainability is another critical focus in contemporary agricultural education research. The adoption of environmentally friendly farming techniques and the application of Life Cycle Assessment (LCA) to evaluate sustainability have gained prominence (Lucas et al., 2025). Figure 2 shows the timeline of sustainability-related research, with an upward trend in studies published between 2021 and 2024. The bibliometric clusters suggest strong research ties in this domain, particularly in curriculum development and policy recommendations aimed at promoting sustainable agricultural practices.

Educational Innovations and Digital Learning in Agriculture

The evolution of teaching methodologies and digital learning platforms in agricultural education is another key finding from the bibliometric analysis. The use of artificial intelligence and big data analytics has revolutionized decision-making processes, leading to optimized farming strategies (Chamorro-Padial et al., 2025). However,

the digital divide remains a persistent challenge, particularly for small and medium-sized farmers who struggle with access to these technologies. This gap hinders their ability to assess the current needs of their learners and classrooms to develop valuable and appropriate learning materials (Cabiles, 2022). Bacio and Sagge (2019) also highlighted the challenges in developing and producing instructional materials, emphasizing the complexities involved in designing adequate learning resources. Figure 1 illustrates collaborative research efforts focusing on digital learning and agricultural training programs, highlighting international partnerships working to bridge this gap.

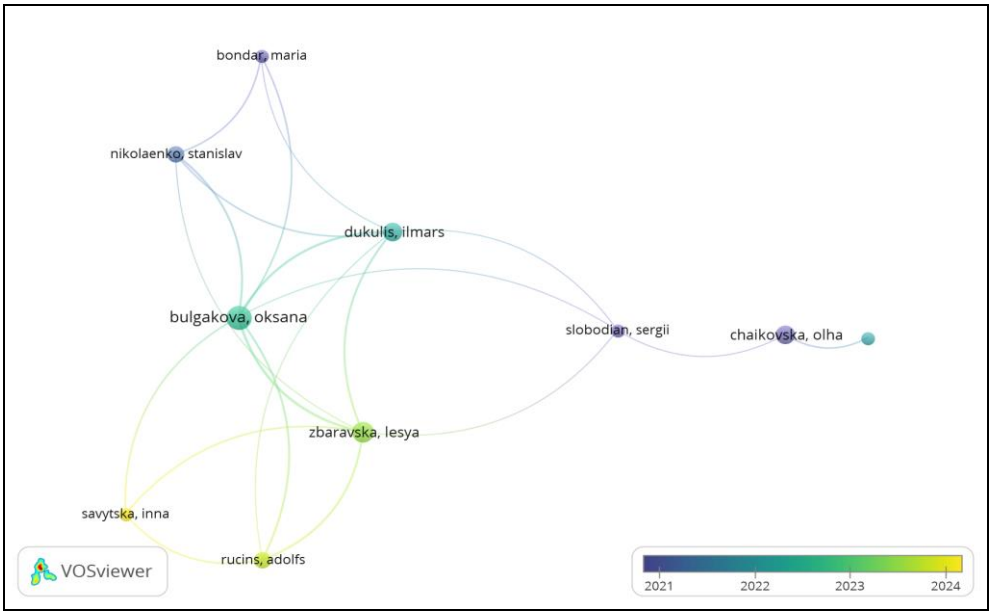

Figure 1: Network Visualization of Agricultural Education Research Collaboration (2025).

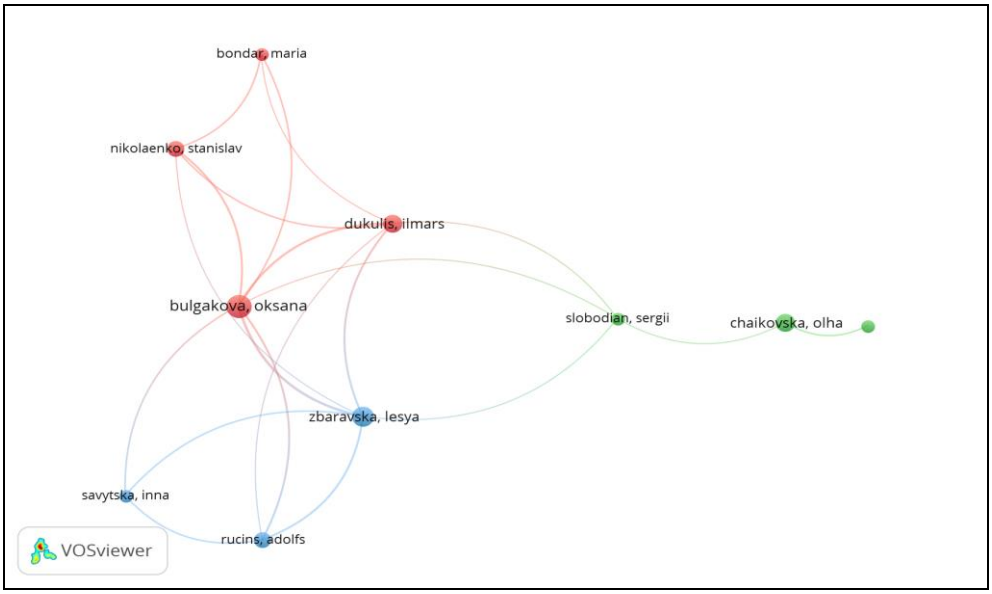

Figure 2: Overlay Visualization of Agricultural Education Research Trends (2021-2024).

Global Collaboration and Research Networks

International collaborations play a vital role in advancing agricultural education and research. Funding institutions such as the European Union and the United States Department of Agriculture have significantly contributed to global

knowledge exchange and capacity-building initiatives (de la Cruz Santos & Del Pozo Rodríguez, 2022). The network analysis in Figure 1 demonstrates strong global research ties, with key nodes representing leading researchers and institutions driving agricultural education forward. The overlay visualization (Figure 2) further supports this trend by showcasing recent international collaborations aimed at addressing agricultural challenges through joint research efforts.

The bibliometric analysis highlights key contributors in the field, including researchers such as Smathers C.A., McDermott T.S., Bulgakova O., Savytska I., Stwalley C.S., Mvumi B.M., and Anderson N.O., among others. These authors have significantly shaped agricultural education through interdisciplinary approaches, sustainability research, and technological innovations.

Research Gaps and Future Directions

The bibliometric analysis identifies several research gaps and areas for future investigation. While technological advancements and interdisciplinary research have shaped agricultural education, there is still a need for targeted policies addressing the digital divide and equitable access to emerging technologies. Moreover, sustainability-focused research should continue to integrate practical applications into educational curricula to ensure long-term impact. The findings from this study suggest that future research should prioritize inclusive educational strategies, fostering collaboration between academia, industry, and policymakers to drive agricultural innovation forward.

CONCLUSION

The bibliometric analysis of agricultural education research underscores the dynamic and evolving landscape of the field. Technological innovations, particularly the integration of IoT, blockchain, and AI, are transforming agricultural education and practice. The interdisciplinary nature of research is evident, with strong collaborations across environmental science, biology, and economics, contributing to a holistic understanding of agricultural challenges.

Sustainability remains a central focus, with an increasing number of studies addressing environmentally friendly farming techniques and policy recommendations. However, challenges such as the digital divide persist, highlighting the need for inclusive policies that enhance access to technological advancements. International collaboration plays a critical role in advancing agricultural education, as demonstrated by strong global research networks.

While significant progress has been made, future research should focus on bridging the technology gap, strengthening sustainability initiatives, and fostering cross-sectoral partnerships between academia, industry, and policymakers. These efforts will ensure that agricultural education remains responsive to emerging global challenges, equipping future generations with the knowledge and tools necessary for sustainable agricultural development.

Declaration by Authors

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