

ORIGINAL ARTICLE



When Safety Meets the Economy: Mapping Fifty Years of Research on Agricultural Labor, Occupational Health, and Economic Outcomes

Qalbin Salim Fazli¹, Mussa Isaack Delya², Erick Hironimus Kihwili³, Ghalieb Mutig Idroes⁴, Dimas Bagus Wiranatakusuma⁵ and Ghazi Mauer Idroes^{6,*}

¹Department of Plant Protection, Faculty of Agriculture, IPB University, Bogor, 16680, Indonesia; ²Tanzania Agricultural Research Institute (TARI) - Kihinga Centre, Kigoma P.O. Box 132, Tanzania; ³Tanzania Agricultural Research Institute (TARI) - Tumbi, Tabora P.O. Box 306, Tanzania; ⁴Research Fellow at Department of Economics, Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta, Bantul 55183, Yogyakarta, Indonesia; ⁵Department of Economics, Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta, Bantul 55183, Yogyakarta, Indonesia; ⁶Department of Occupational Health and Safety, Faculty of Health Sciences, Universitas Abulyatama, Aceh Besar 23372, Indonesia

* Correspondence: idroesghazi_k3@abulyatama.ac.id

Article History

Received
29 November 2025

Accepted
10 February 2026

Available Online
17 February 2026

Keywords

Agricultural economics
Economic outcomes
Occupational health
Occupational safety
Labor productivity

Abstract

Research on occupational safety in agriculture has expanded substantially over the past decades, yet its economic dimensions remain dispersed across multiple disciplinary traditions. This study aims to map the intellectual structure and thematic development of scholarly work linking agricultural labor, occupational health, and economic outcomes. Using a bibliometric approach, publications indexed in the Scopus database were systematically analyzed covering the period from 1973 to 2026. A total of 1229 peer reviewed articles and reviews were examined using bibliometrix in R and VOSviewer to identify publication trends, influential sources, leading contributors, country collaborations, keyword networks, and thematic patterns. The results reveal a sustained growth in research output, particularly after the mid-2000s, alongside a multidisciplinary publication landscape dominated by environmental, health, and agricultural economics journals. Keyword co-occurrence and thematic analyses indicate that while occupational safety and health constitute a central research focus, economic themes such as productivity, labor, income, sustainability, and policy are increasingly integrated but remain distributed across distinct clusters. This bibliometric evidence highlights the evolving recognition of occupational safety as an economic issue within agricultural systems. The study contributes by consolidating fragmented research streams into a coherent overview, offering insights for economists, policymakers, and researchers interested in labor welfare, productivity, and sustainable agricultural development.

Introduction

Agriculture continues to play a central role in global economic systems, particularly in regions where it remains a primary source of employment and income generation [1,2]. Agricultural economics has long examined issues related to productivity, farm income, labor allocation, and structural transformation as key components of rural development and food system performance [3–5]. Differences in agricultural productivity across regions have been shown to shape income disparities, labor mobility, and economic growth trajectories, highlighting the importance of understanding the multiple factors that influence agricultural performance [6,7].

Labor remains a fundamental input in agricultural production, especially in labor-intensive farming systems that dominate smallholder and family-based agriculture [8]. A substantial body of research has examined the relationship between labor availability, productivity, and household income in agricultural settings [9–11]. At the same time, working conditions in

agriculture are often characterized by physical strain, exposure to hazardous substances, and limited regulatory protection. These conditions position occupational safety and health as an integral, though sometimes implicit, component of agricultural labor dynamics [12,13].

Occupational health issues in agriculture include exposure to pesticides, machinery-related injuries, heat stress, and chronic health risks associated with long-term chemical exposure [14–18]. Empirical studies have documented the neurological and physiological impacts of commonly used agricultural chemicals, particularly organophosphates, on farm workers [19–22]. Other studies emphasize that farmers' risk perceptions, safety behaviors, and access to information significantly influence the prevalence of workplace injuries and health outcomes in agricultural settings [12,23,24]. These findings suggest that occupational health is not only a medical or regulatory concern, but also a factor with potential economic implications through its effects on labor productivity and workforce stability.

The economic and labor dimensions of agriculture are increasingly shaped by broader environmental and structural pressures [25,26]. Climate variability and environmental change have been shown to affect crop productivity, labor requirements, and exposure to occupational risks, particularly in regions already vulnerable to resource constraints [27–32]. In parallel, processes such as digitalization, mechanization, and market integration are altering the organization of agricultural work and the distribution of risks and benefits within rural economies [33,34]. These developments underscore the growing complexity of interactions between economic performance, labor conditions, and occupational health in agriculture.

Despite the relevance of these interconnections, the related scholarly literature remains dispersed across disciplinary boundaries. Research in agricultural economics has traditionally focused on productivity, income, and policy outcomes, while studies on occupational health have often emphasized toxicological, behavioral, and regulatory dimensions. Previous studies indicate that these strands of research have largely evolved in parallel, with limited explicit integration between worker health conditions and economic performance in agricultural systems [13,19,24,35]. Although individual studies address specific links between labor conditions and economic outcomes [36], there is a limited systematic understanding of how these themes are structured, connected, and developed within the broader body of research.

Bibliometric analysis provides a systematic approach to examining the intellectual structure of a research field by analyzing publication patterns, keyword co-occurrence, and thematic relationships over time. Such methods have been widely used to map interdisciplinary domains and to identify dominant, peripheral, and emerging research themes based on quantitative indicators rather than subjective interpretation [4,10]. Previous bibliometric studies have examined related topics such as agricultural sustainability, agrochemicals, occupational hazards, and agri-food systems, but these analyses have generally focused on environmental, technological, or health dimensions separately rather than explicitly integrating economic outcomes, labor dynamics, and occupational safety within a single analytical framework [35,37,38]. In this context, the present study addresses this gap by providing a unified bibliometric mapping that connects agricultural economics, labor conditions, and occupational health within the same knowledge structure.

Materials and Methods

Data Source and Search Strategy

This study employed a bibliometric research design to systematically map the intellectual structure and thematic evolution of research at the intersection of agricultural economics, labor, and occupational health. The Scopus database was selected as the primary data source due to its broad coverage of peer-reviewed journals across economics, agriculture, environmental

sciences, and social sciences, as well as its compatibility with bibliometric tools such as Bibliometrix and VOSviewer. While other major databases, such as Web of Science, also provide high-quality indexing, Scopus was chosen because it offers wider journal coverage in interdisciplinary and applied research fields relevant to this study, which is particularly important for capturing literature spanning agricultural economics, labor studies, and occupational health.

The literature search covered publications from 1973 to 2026. The time span of 1973 to 2026 reflects the full range of publications retrieved from the Scopus database after applying the search query and filtering criteria. The starting year corresponds to the earliest indexed record matching the search terms, while the most recent year represents publications already indexed online in the database at the time of data collection. A comprehensive search query was constructed using combinations of keywords related to agricultural economics and occupational health and safety. The search was initially conducted across all available fields, yielding 8,299 documents. To ensure topical relevance, the search was subsequently restricted to the title, abstract, and author keywords, which reduced the number of records to 1,371 documents.

Further screening was applied by limiting the document type to articles and reviews only, resulting in 1,253 records. Only documents at the final publication stage were retained, yielding 1,247 records. Finally, the dataset was restricted to publications written in English to ensure consistency in bibliometric processing and interpretation. This process resulted in a final dataset of 1,229 documents used for analysis.

Data Cleaning and Preparation

The filtered Scopus records were exported in comma-separated values format and processed using the Bibliometrix package in R. Data cleaning procedures included the removal of duplicate records, standardization of author keywords, and harmonization of synonymous terms. Variations in spelling and terminology, such as labor and labour or farmworker and farm workers, were unified to avoid fragmentation in keyword analysis.

Author keywords were selected as the primary unit of analysis because they reflect the conceptual focus explicitly defined by authors and are commonly used in bibliometric studies to identify research themes and intellectual linkages.

Bibliometric Analysis Tools

Two complementary bibliometric tools were employed. Biblioshiny, the web-based interface of the Bibliometrix R package, was used for descriptive analysis, thematic mapping, and thematic evolution analysis. VOSviewer was used to construct and visualize co-occurrence networks and temporal overlay maps of author keywords [37–39]. The combined use of these tools allowed for both quantitative measurement and visual exploration of the knowledge structure within the dataset.

Co-Occurrence Network and Temporal Analysis

Keyword co-occurrence analysis was conducted to identify major research themes and their interrelationships [40]. The association strength normalization method was applied, and the Louvain clustering algorithm was used to detect thematic clusters [41,42]. Network indicators, including occurrences, total link strength, average publication year, and citation metrics, were extracted directly from the VOSviewer output and used as the basis for result interpretation.

Temporal overlay visualization was applied to examine shifts in research emphasis over time. Average publication year values were used to distinguish earlier and more recent thematic developments, allowing the identification of emerging research topics.

Thematic Map Analysis

The thematic map analysis was conducted using Biblioshiny under the conceptual structure module. Author keywords were analyzed based on their centrality and density values to classify themes into motor themes, basic themes, niche themes, and emerging or declining themes. Betweenness centrality was used as the primary indicator of thematic importance, reflecting the role of keywords in connecting different research streams.

Thematic classification was based on numerical centrality and density values rather than visual inspection of the map, ensuring objectivity and reproducibility of the analysis.

Thematic Evolution Analysis

Thematic evolution analysis was performed to examine how research topics evolved across time. The dataset was divided into four temporal periods: 1973 to 2012, 2013 to 2020, 2021 to 2023, and 2024 to 2026. These periods were defined to reflect the historical development of the literature and changes in publication intensity.

The evolution analysis was based on weighted inclusion and stability indices, which quantify the strength of thematic continuity and transformation between periods. This approach enabled the identification of persistent themes as well as emerging research directions.

Analytical Strategy

The analytical strategy followed a sequential approach. First, the structural composition of the research field was identified through keyword co-occurrence analysis. Second, the relative importance and maturity of themes were assessed using thematic map analysis. Third, longitudinal changes in research focus were examined through thematic evolution analysis.

All interpretations were grounded in quantitative bibliometric indicators and aligned with the extracted results to ensure consistency between the methods, results, and discussion sections.

Results and Discussion

Descriptive Characteristics of the Bibliographic Dataset

The bibliometric dataset consists of 1229 documents published between 1973 and 2026 across 506 different sources, indicating that research related to agricultural economics and occupational safety has been disseminated in a wide range of disciplinary outlets. As presented in Table 1, the field demonstrates a steady annual growth rate of 6.56 percent, reflecting the increasing academic attention to the relationship between agricultural labor, safety, and economic considerations over time.

Table 1. Descriptive characteristics of the bibliographic dataset.

Description	Results
Timespan	1973:2026
Sources (Journals, Books, etc.)	506
Documents	1229
Annual Growth Rate %	6.56
Document Average Age	9.3
Average citations per doc	25.3
References	10338
DOCUMENT CONTENTS	
Keywords Plus (ID)	5847
Author's Keywords (DE)	3554
AUTHORS	
Authors	4009
Authors of single-authored docs	237

AUTHORS COLLABORATION	
Single-authored docs	254
Co-Authors per Doc	3.52
International co-authorships %	29.62
DOCUMENT TYPES	
Article	1127
Review	102

The documents have an average age of 9.3 years and receive an average of 25.3 citations per document, suggesting that this topic has gained considerable scholarly recognition and influence. A total of 10338 references were cited within the dataset, showing that the research area is supported by an extensive and well-established knowledge base.

In terms of conceptual content, the dataset includes 5847 Keywords Plus and 3554 Author Keywords, which points to a high degree of thematic diversity within the literature. The authorship pattern further highlights the collaborative nature of research in this area. A total of 4009 authors contributed to the publications, with an average of 3.52 co-authors per document. Only 254 documents were written by a single author, indicating that studies in this field commonly involve teamwork and interdisciplinary cooperation. In addition, 29.62 percent of the publications involve international co-authorship, demonstrating that concerns related to occupational safety and its economic implications in agriculture are shared across countries.

As also summarized in Table 1, the dataset is dominated by research articles totaling 1127 documents and supported by 102 review papers. This composition reflects both the presence of empirical investigations and the existence of comprehensive reviews, which together signal the maturity and depth of this research field.

Annual Scientific Production

Figure 1 illustrates the annual growth of scientific publications related to agricultural economics and occupational safety over a period of more than five decades. The publication trend shows that research activity in this field remained very limited from 1973 until the early 2000s, with only a small number of articles published each year.

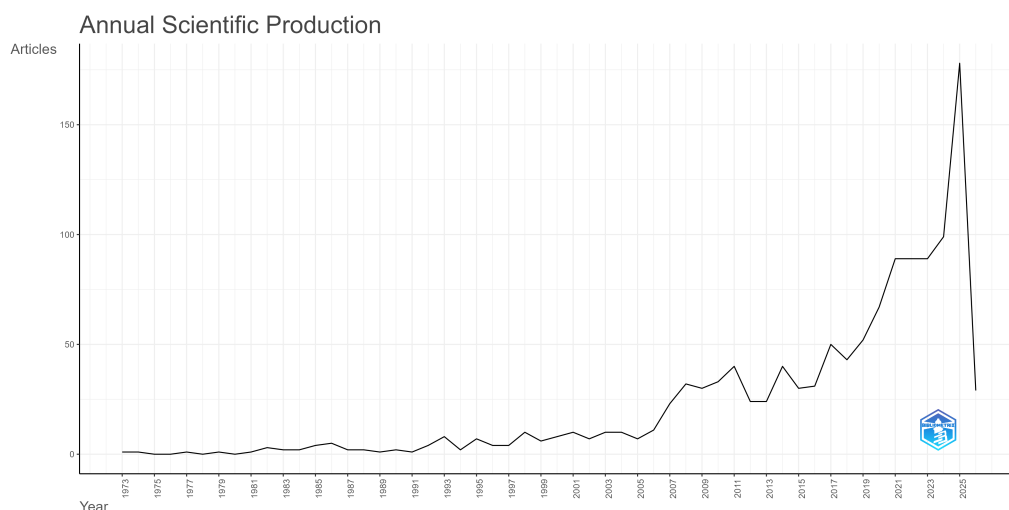


Figure 1. Annual scientific production of publications related to agricultural economics and occupational safety from 1973 to 2026.

A noticeable increase begins to appear after 2005, indicating growing academic interest in issues linking agricultural labor, safety, and economic considerations. This upward trend becomes more pronounced after 2015, where the number of publications rises sharply and reaches its peak in the early 2020s. The surge in recent years suggests that the economic

implications of occupational safety in agriculture have become an increasingly important topic within the scientific community.

The rapid escalation of publications after 2015 also reflects a shift in research priorities, where occupational safety in agriculture is no longer viewed solely from a health perspective but is increasingly associated with productivity, income, sustainability, and policy concerns. This pattern indicates that the field has transitioned from a niche research area into a broader multidisciplinary discourse that attracts attention from scholars in economics, labor studies, and development policy.

The sharp decline observed in the final year is likely due to incomplete indexing of publications for the current year rather than an actual decrease in research output.

Most Relevant Sources and Publication Outlets

Figure 2 presents the most relevant journals contributing to publications in the field of agricultural economics and occupational safety. The distribution of sources shows that this research topic is published across a wide range of disciplinary outlets, reflecting its multidisciplinary nature.

Several leading journals in environmental and public health studies, such as Journal of Environmental Management, Science of the Total Environment, International Journal of Environmental Research and Public Health, and Journal of Agromedicine, appear prominently among the top sources. This indicates that occupational safety in agriculture has traditionally been approached from environmental and health perspectives.

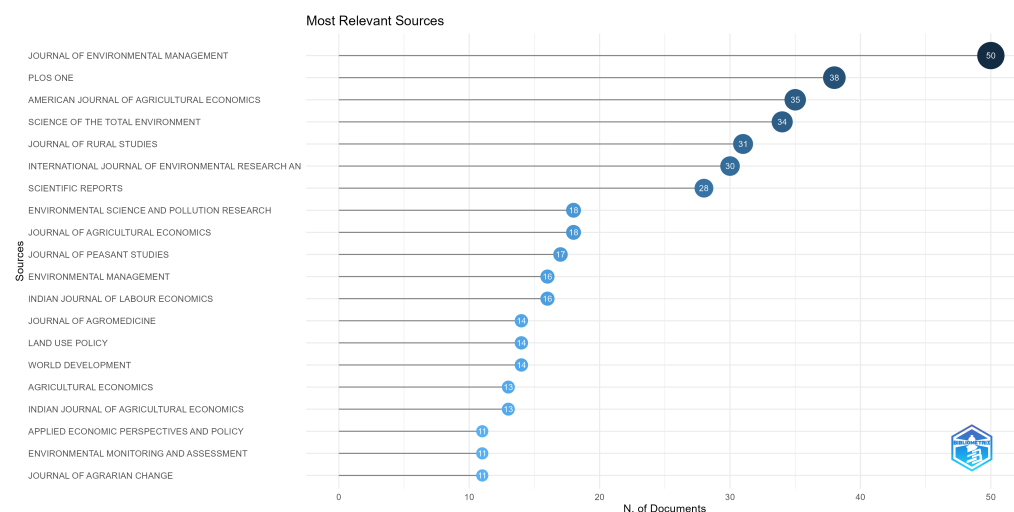


Figure 2. Most relevant sources publishing research on agricultural economics and occupational safety.

At the same time, the presence of well-established journals in agricultural economics and development studies such as American Journal of Agricultural Economics, Journal of Agricultural Economics, Agricultural Economics, Applied Economic Perspectives and Policy, Indian Journal of Labour Economics, World Development, Journal of Rural Studies, and Land Use Policy demonstrates that economic analysis has become an increasingly important dimension of this research field.

The coexistence of environmental health journals and agricultural economics journals within the top publication outlets suggests that studies on occupational safety in agriculture are gradually moving beyond purely medical or safety concerns toward broader discussions involving productivity, labor economics, policy implications, and rural development. This pattern

highlights the growing recognition that occupational safety issues in agriculture have significant economic consequences that warrant attention from both health scientists and economists.

Author Productivity

Figure 3 presents the most relevant authors contributing to the body of literature on agricultural economics and occupational safety. The distribution of publications among authors indicates that no single researcher overwhelmingly dominates the field. Instead, contributions are spread across several scholars, each providing a modest but meaningful number of publications.

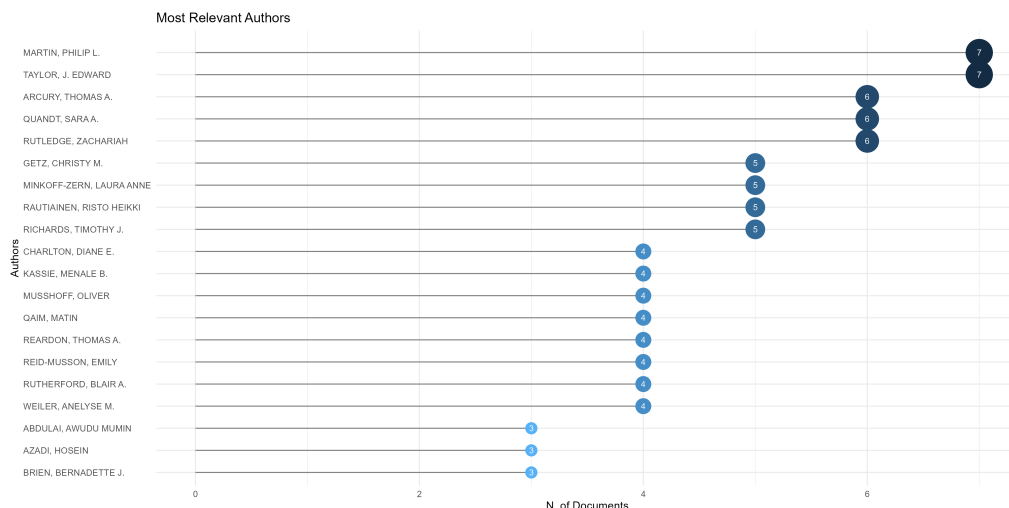


Figure 3. Most relevant authors contributing to research on agricultural economics and occupational safety.

Authors such as Martin, Philip L., and Taylor, J. Edward appear as the most productive contributors, each with seven publications, followed by Arcury, Thomas A., Quandt, Sara A., and Rutledge, Zachariah, with six publications. The presence of these authors reflects the interdisciplinary nature of the field, where expertise in agricultural labor, rural studies, public health, and agricultural economics intersect.

The diversity of leading authors also suggests that research on occupational safety and its economic implications in agriculture is not concentrated within a single academic network or discipline. Instead, it is distributed among scholars working in labor economics, rural development, agromedicine, and environmental health. This dispersed authorship pattern reinforces the multidisciplinary character of the research area and indicates that the topic is approached from multiple analytical perspectives rather than from a single dominant framework.

Country Contribution and International Collaboration

Table 2 shows the distribution of scientific production by country in the field of agricultural economics and occupational safety. The United States leads the publication output with 718 documents, followed by China with 370 and India with 273 publications. Other notable contributors include the United Kingdom, Australia, Canada, Germany, and several developing countries such as Ethiopia, Ghana, Nigeria, Kenya, and Bangladesh.

Table 2. The country's scientific production in research on agricultural economics and occupational safety.

Country	Freq
USA	718
China	370
India	273
UK	146
Australia	93

Canada	88
Germany	88
Ethiopia	74
France	63
Netherlands	62
South Africa	59
Italy	55
Ghana	48
Pakistan	45
Nigeria	42
Switzerland	42
Kenya	41
Bangladesh	30
Japan	29

This distribution indicates that research on occupational safety and its economic implications in agriculture is not limited to high-income countries but is also a significant concern in developing regions where agricultural labor plays a central role in livelihoods and rural economies.

The pattern of international collaboration presented in Figure 4 reveals a complex global research network characterized by several interconnected clusters. Countries such as the United States, China, and the United Kingdom occupy central positions in the collaboration network, as indicated by their high betweenness and PageRank values. These countries act as major hubs that connect different research communities across regions.

Interestingly, the collaboration clusters show strong linkages between developed countries and developing nations, particularly in Africa and Asia. For example, Germany, Italy, France, and the Netherlands are closely connected with countries such as Ethiopia, Ghana, Kenya, and South Africa. Similarly, the United States and China demonstrate collaboration ties with South and Southeast Asian countries, including Pakistan, Bangladesh, Indonesia, and Thailand.

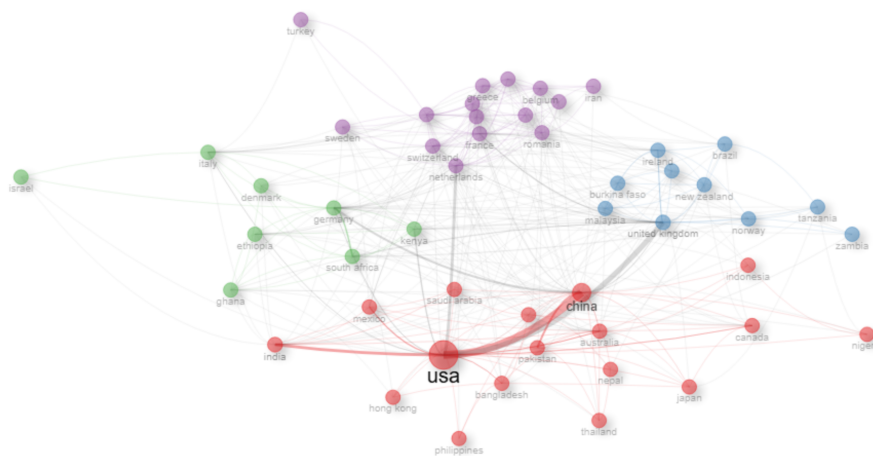


Figure 4. An international collaboration network among countries in agricultural economics and occupational safety research.

This network structure suggests that issues related to occupational safety and economic outcomes in agriculture are addressed through international research partnerships, where countries with advanced research capacity collaborate with regions where agricultural labor risks are more prevalent. The presence of multiple clusters rather than a single dominant network also indicates that the field is shaped by diverse regional research priorities and socioeconomic contexts.

Co-occurrence of Author Keywords and Thematic Evolution

The co-occurrence network of author keywords presented in Figure 5 reveals the structural composition of research themes linking agricultural economics, labor, and occupational health and safety. The network is formed by highly connected keywords with strong total link strength and high occurrence frequency, indicating dominant conceptual concentrations in the literature.

The most central keyword in the network is agriculture, with 116 occurrences and a total link strength of 136, indicating its foundational role in connecting various research themes. Other highly connected keywords include climate change with 53 occurrences and a total link strength of 85, food security with 45 occurrences and a total link strength of 69, farm labor with 44 occurrences and a total link strength of 44, agricultural productivity with 33 occurrences and a total link strength of 32, and sustainable agriculture with 25 occurrences and a total link strength of 34. These keywords form the main structural backbone of the knowledge network.

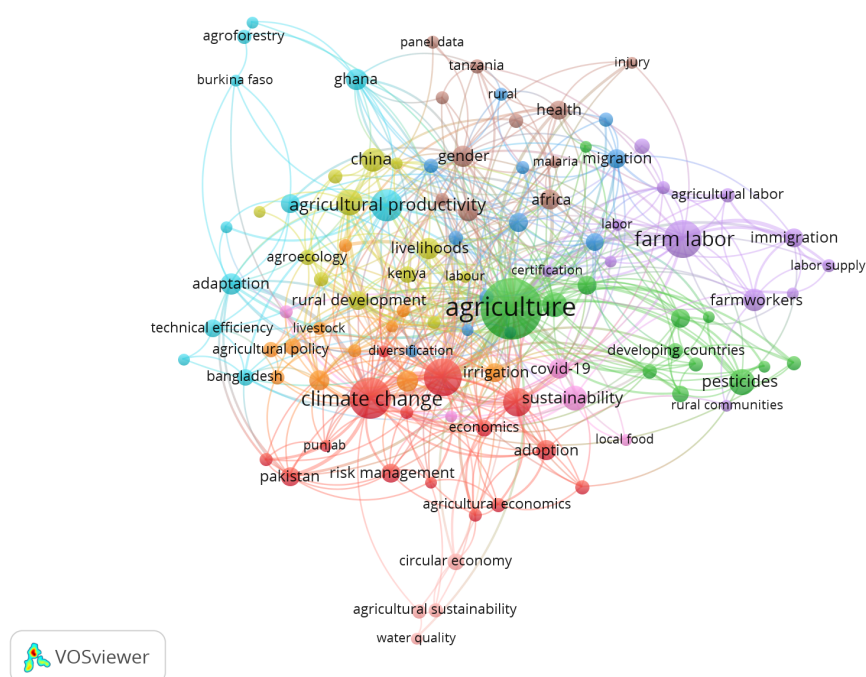


Figure 5. Co-occurrence network of author keywords in agricultural economics and occupational health research.

Several keywords show strong connectivity despite moderate occurrences, indicating their bridging role across topics. For example, policy has a total link strength of 15 with very high average citations of 159.28. Similarly, maize shows extremely high average citations of 208.5, water scarcity with 91 citations, and *horticulture* with 90.17 citations. These keywords indicate topics that have produced highly influential studies within the field.

The temporal distribution of keywords visualized in Figure 6 shows a clear thematic shift over time. Earlier studies, with lower average publication years, were associated with keywords such as *migration* with an average year of 2011.09, *land reform* with 2014.57, *agricultural labor* with 2002.43, and *certification* with 2010.2. These indicate early research attention to the labor movement, land issues, and market certification in agricultural systems.

More recent studies are characterized by keywords with higher average publication years. Keywords such as *circular economy* with an average year of 2024.78, *machine learning* with 2024.71, *agroecology* with 2023, *structural transformation* with 2023.2, *income* with 2022.14,

COVID-19 with 2022.15, sustainable agriculture with 2021.96, adaptation with 2021.14, and risk perception with 2020.83 demonstrate the emergence of sustainability, technological approaches, and resilience-oriented themes.

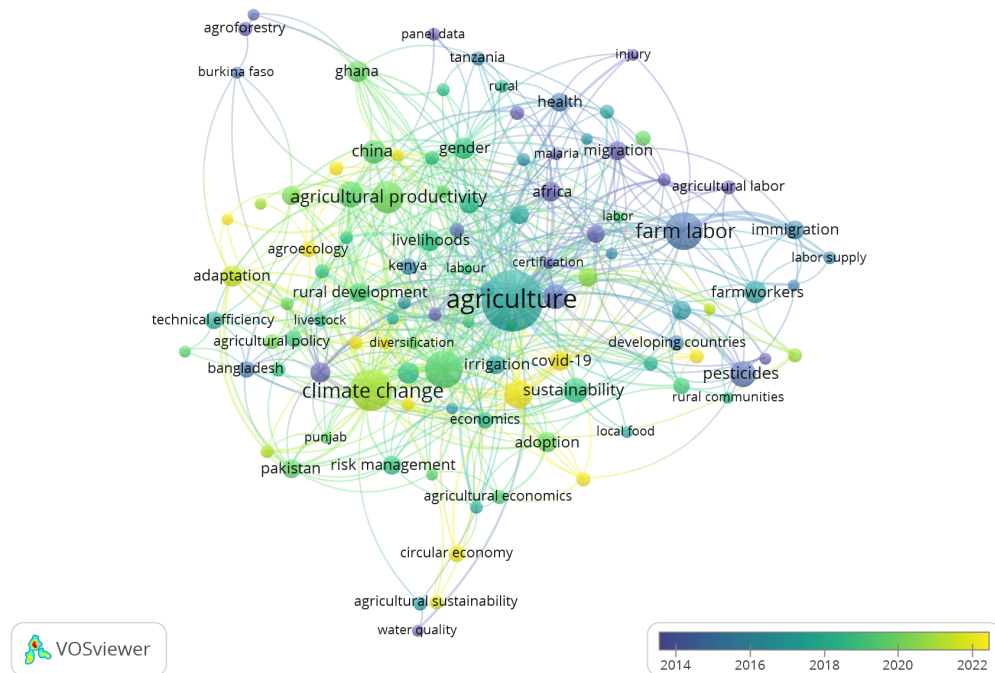


Figure 6. Temporal overlay visualization of author keywords based on average publication year.

Keywords directly related to occupational aspects, such as *occupational health* with an average year of 2020.57, *injury* with 2012.4, *health* with 2015.27, and *pesticides* with 2014.68, indicate that occupational safety and health topics are embedded within broader agricultural and environmental discussions rather than forming an isolated research stream.

Overall, the co-occurrence and temporal analysis indicate that the literature has evolved from early concerns about agricultural labor structure and rural development toward integrated themes combining sustainability, climate change adaptation, productivity, and occupational considerations within agricultural economic systems.

Thematic Map of Research Topics

The thematic map presented in Figure 7 illustrates the intellectual structure and development of research themes based on keyword co-occurrence centrality and density. The map classifies themes into four quadrants consisting of motor themes, basic themes, niche themes, and emerging or declining themes.

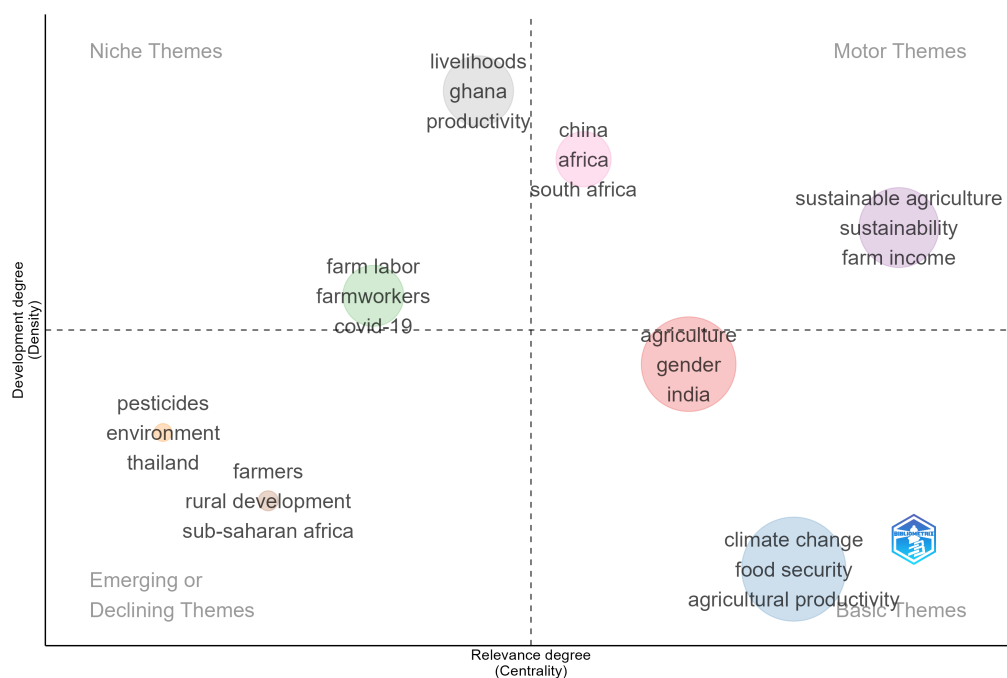


Figure 7. Thematic map of author keywords showing motor, basic, niche, and emerging themes in farm labor research.

As shown in Figure 7, agriculture emerges as the most dominant and central theme in the field, indicated by the highest betweenness centrality value of 7,759.962 and PageRank of 0.062. This cluster is closely associated with keywords such as gender, health, migration, poverty, and nutrition, demonstrating that agricultural research in this domain is strongly connected with social, labor, and welfare dimensions. The high centrality confirms that this theme acts as the main foundation linking various research topics. Furthermore, climate change forms another major motor theme. This is supported by high centrality values for food security at 2,118.093, agricultural productivity at 1,608.542, smallholder farmers at 1,054.848, and adaptation. These connections indicate that climate-related issues are deeply integrated into discussions of agricultural systems and farmer resilience, particularly in developing countries such as Pakistan and Bangladesh.

A distinct cluster labelled farm labor represents a specialized but well-developed theme. Keywords such as farmworkers, immigration, occupational health, COVID 19, and labor supply suggest strong attention to labor vulnerability, mobility, and health risks. Although its overall centrality is lower than the core themes, the density of connections within this cluster positions it as a niche theme with a focused research trajectory. The sustainable agriculture cluster bridges economic and environmental perspectives. It connects farm income, adoption, irrigation, circular economy, agricultural policy, and agroecology. Its moderate to high centrality indicates that sustainability has become an integrative theme linking economic, environmental, and policy discussions in agricultural research.

Several additional clusters, such as pesticides, farmers, China, and livelihoods, appear as emerging or context-specific themes. The livelihoods cluster is strongly linked with African contexts such as Ghana, Ethiopia, Tanzania, and Kenya, alongside methodological approaches like panel data and propensity score matching. This suggests a growing empirical focus on household-level agricultural welfare and productivity analysis. Overall, Figure 7 demonstrates that research in this field is anchored in core agricultural issues while increasingly expanding toward climate resilience, labor dynamics, sustainability, and rural livelihoods. The combination of high centrality values and diverse keyword linkages reflects a mature yet evolving research landscape that integrates environmental, economic, and social dimensions of agriculture.

Thematic Evolution of Research Topics (1973–2026)

The thematic evolution presented in Figure 8 illustrates how research topics in this field have shifted and developed across four time periods, namely 1973–2012, 2013–2020, 2021–2023, and 2024–2026. The evolution map reveals a gradual transition from geographically oriented and productivity-focused studies toward more complex themes integrating sustainability, labor issues, and technological adaptation. Furthermore, during the period 1973–2012, early research themes were dominated by geographically contextual topics such as Africa, Nigeria, South Africa, and Ghana, alongside themes related to food security, farmers, and agriculture. These themes were frequently associated with productivity, malaria, health, and technical efficiency, indicating that early studies emphasized agricultural performance, rural welfare, and efficiency analysis in developing regions.

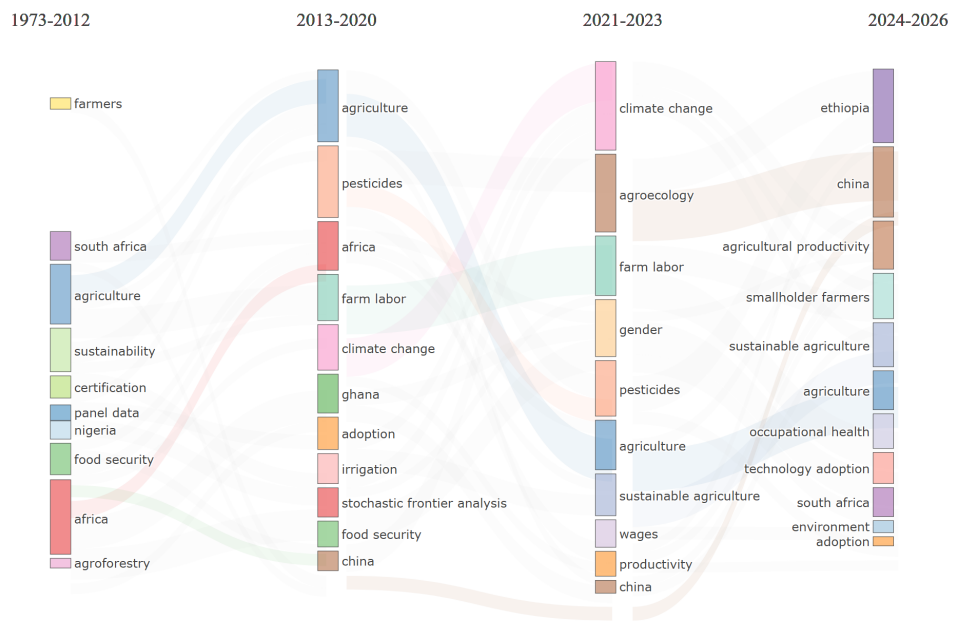


Figure 8. Thematic evolution of research topics from 1973 to 2026.

In the period 2013–2020, a shift toward more structured themes such as farm labor, pesticides, China, irrigation, sustainability, and climate change occurred. The transition from agriculture in the earlier period to farm labor and pesticides is supported by high inclusion links such as farm labor and immigration, pesticides, and developing countries. At the same time, food security evolved directly into climate change and agricultural productivity, showing that environmental concerns began to reshape the research direction. The period 2021–2023 marks a strong consolidation of climate change, farm labor, gender, productivity, and sustainable agriculture. Climate change is closely connected with food security, smallholder farmers, resilience, and adaptation. Farm labor becomes more closely associated with farmworkers, labor supply, and occupational issues. Gender also emerges as an important theme linked with agricultural productivity and the sub-Saharan African context. This indicates an increasing integration of social vulnerability, labor conditions, and environmental challenges in agricultural research.

Finally, in the most recent period, 2024–2026, research themes are moving toward technology adoption, precision agriculture, agroecology, occupational health, and circular economy. Farm labor evolves into occupational health and rural development themes. Sustainable agriculture relates to the circular economy and social reproduction. Climate change continues to influence agricultural productivity and smallholder farmers, while gender and technology adoption become increasingly linked. Overall, Figure 8 demonstrates that research in this field has evolved from basic agricultural productivity and regional studies toward a more integrated

perspective combining sustainability, labor safety, technological innovation, and rural livelihoods. The evolution pattern confirms that occupational health, sustainability, and economic productivity are no longer separate topics but are increasingly studied as interconnected dimensions of agricultural systems.

Discussion

This bibliometric study provides a structured understanding of how research on agricultural economics has progressively incorporated issues of occupational safety, labor dynamics, and sustainability. The results demonstrate that the field has evolved from a predominantly production-oriented and income-focused perspective toward a more integrated framework that links labor conditions, environmental risks, and policy interventions. This evolution reflects broader structural changes in global agricultural systems, where productivity gains increasingly depend on the quality, safety, and resilience of agricultural labor.

The dominance of keywords related to agriculture, climate change, food security, and productivity indicates that economic performance remains a central concern of the literature. However, the co-occurrence patterns reveal that these themes are no longer examined in isolation. Instead, they are increasingly connected to labor-related concepts such as farm labor, wages, migration, and occupational health. This integration suggests a growing recognition that economic outcomes in agriculture are closely tied to working conditions and human capital, particularly in labor-intensive farming systems. Previous studies have emphasized the role of labor productivity and farm income in agricultural growth, but often without explicitly addressing the safety and health risks faced by agricultural workers [3,43,44].

A key contribution of this study lies in highlighting the persistent fragmentation between economic analysis and occupational safety research. While the bibliometric network shows increasing linkages between productivity, sustainability, and labor, occupational health and injury-related keywords remain less central compared to production and climate-related themes. This indicates that, despite growing awareness, worker safety is still frequently treated as a peripheral or sector-specific issue rather than as an integral component of agricultural economic performance. This fragmentation may limit the development of comprehensive economic frameworks capable of capturing the true costs of unsafe working conditions, including productivity losses, income instability, and long-term health expenditures. Similar concerns have been raised in empirical studies showing that occupational injuries and poor health outcomes among farm workers can significantly reduce labor efficiency and household welfare [35,45,46].

The strong presence of climate change, adaptation, and sustainability-related keywords reflects the central role of environmental stressors in shaping contemporary agricultural economics. Climate variability affects not only yields and incomes but also labor demand, exposure to health risks, and the intensity of farm work [47–49]. The bibliometric evidence suggests that recent research increasingly addresses these interactions, particularly in the context of developing countries where agricultural labor remains a primary source of livelihood. Studies focusing on climate change adaptation and food security emphasize that economic resilience in agriculture depends on both technological innovation and the capacity of workers to operate safely under changing environmental conditions [50,51].

Another important insight concerns the growing attention to smallholder farmers, rural livelihoods, and poverty. The co-occurrence of keywords related to smallholders, livelihoods, gender, and rural development indicates that economic analyses are increasingly embedded within broader social contexts. This shift reflects an understanding that labor conditions, access to resources, and social vulnerability directly influence productivity and income outcomes. Research on smallholder systems has shown that improvements in labor safety and health can

enhance the adoption of sustainable practices and improve long-term economic performance [52].

The emergence of newer themes such as agroecology, circular economy, and machine learning highlights a forward-looking research agenda that combines economic efficiency with sustainability and technological innovation. These topics, characterized by more recent average publication years, suggest a transition toward systemic approaches that aim to optimize production while reducing environmental and labor-related risks. In particular, the application of digital technologies and data-driven methods has the potential to improve decision-making, monitor working conditions, and enhance productivity simultaneously. However, the bibliometric structure indicates that these technological themes are not yet fully integrated with occupational safety research, representing an important gap for future studies.

From a policy and business perspective, the findings underscore the need for integrated strategies that align economic incentives with labor protection and environmental sustainability [53]. Agricultural policies that focus solely on output growth may overlook the hidden economic costs associated with unsafe working conditions and labor exploitation. Conversely, policies that incorporate occupational safety standards, training, and social protection can contribute to more stable and productive agricultural labor markets. For agribusiness firms and supply chains, ensuring safe and decent working conditions is increasingly linked to market access, certification schemes, and consumer trust, reinforcing the economic relevance of occupational safety considerations.

Overall, this study contributes to the literature by demonstrating that research on agricultural economics and occupational safety is gradually converging but remains unevenly integrated. By mapping the intellectual structure and temporal evolution of the field, this bibliometric analysis provides evidence that economic performance, labor safety, and sustainability should be examined within a unified analytical framework. Future research would benefit from explicitly incorporating occupational health indicators into economic models of agricultural productivity and from exploring how technological and policy innovations can jointly enhance efficiency, safety, and resilience in agricultural systems.

Conclusions

This study provides a comprehensive bibliometric overview of research at the intersection of agricultural economics, labor, and occupational health by systematically mapping the structure, connections, and thematic development of the literature indexed in Scopus between 1973 and 2026. The findings demonstrate that issues related to productivity, labor, income, and safety are addressed through multiple, yet interconnected, research streams rather than as isolated topics. The analysis highlights how economic considerations and occupational health concerns coexist within the scholarly landscape, reflecting the complexity of agricultural systems where labor conditions, environmental pressures, and economic performance are closely intertwined. By consolidating fragmented bodies of knowledge into a unified analytical framework, this study identifies specific directions for future research and policy. The findings indicate the need to integrate occupational health indicators into economic models of agricultural productivity, to strengthen interdisciplinary collaboration between labor, health, and agricultural economists, and to support policies that link farm productivity programs with worker safety interventions. These results also provide a practical reference for researchers designing empirical studies, for policymakers developing labor protection strategies in agriculture, and for development agencies seeking to align productivity improvement with worker welfare.

This study has several limitations that should be acknowledged. First, the analysis relies on a single database, which may not capture all relevant publications indexed elsewhere. Second, the bibliometric approach focuses on publication patterns and keyword structures rather than

evaluating the substantive quality or empirical findings of individual studies. Third, the results depend on author keywords and database indexing, which may influence how themes appear connected in the network. Future research could address these limitations by combining multiple databases, integrating bibliometric mapping with systematic or meta-analytic approaches, and conducting empirical studies that explicitly model the interaction between occupational health conditions, labor productivity, and economic outcomes in agricultural systems.

Funding: This study does not receive external funding.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments: There are no acknowledgments to declare.

Conflicts of Interest: All the authors declare that there are no conflicts of interest.

References

- [1] Norton GW, Alwang J, Masters WA. Economics of Agricultural Development. 4th Edition. | New York : Routledge, 2021. | Series: Textbooks in Environmental and Agricultural Economics | Revised Edition of the Authors' Economics of Agricultural Development, 2015.: Routledge; 2021. <https://doi.org/10.4324/9780429316999>.
- [2] Loizou E, Karelakis C, Galanopoulos K, Mattas K. The Role of Agriculture as a Development Tool for a Regional Economy. *Agricultural Systems* 2019;173:482–90. <https://doi.org/10.1016/j.agsy.2019.04.002>.
- [3] Gollin D, Lagakos D, Waugh ME. The Agricultural Productivity Gap. *The Quarterly Journal of Economics* 2014;129:939–93. <https://doi.org/10.1093/qje/qjt056>.
- [4] Shiferaw B, Prasanna BM, Hellin J, Bänziger M. Crops That Feed the World 6. Past Successes and Future Challenges to the Role Played by Maize in Global Food Security. *Food Security* 2011;3:307–27. <https://doi.org/10.1007/s12571-011-0140-5>.
- [5] Barrett C, Reardon T, Swinnen J, Zilberman D. Structural Transformation and Economic Development: Insights from the Agri-Food Value Chain Revolution. *Cornell University* 2019:1–56.
- [6] Yadin Y, Ibrahim MBH, Irawan A, Akbar MA, Yendra Y. Labor Mobility and Wage Dynamics: Understanding the Interplay of Factors in Modern Labor Economics. *Advances in Human Resource Management Research* 2024;2. <https://doi.org/10.60079/ahrmr.v2i2.186>.
- [7] Bilenko Y. Labor Productivity in the Agriculture, Structural Shifts and Economic Growth in the Central and Eastern European Countries. *Agricultural and Resource Economics: International Scientific E-Journal* 2022;8:5–32.
- [8] Moyo S. Family Farming in Sub-Saharan Africa: Its Contribution to Agriculture, Food Security and Rural Development. Working paper; 2016.
- [9] Miyata S, Minot N, Hu D. Impact of Contract Farming on Income: Linking Small Farmers, Packers, and Supermarkets in China. *World Development* 2009;37:1781–90. <https://doi.org/10.1016/j.worlddev.2008.08.025>.
- [10] Frelat R, Lopez-Ridaura S, Giller KE, Herrero M, Douchamps S, Djurfeldt AA, et al. Drivers of Household Food Availability in Sub-Saharan Africa Based on Big Data from Small Farms. *Proceedings of the National Academy of Sciences* 2016;113:458–63. <https://doi.org/10.1073/pnas.1518384112>.
- [11] Noviandy TR, Idroes GM, Hardi I, Afjal M, Ray S. A Model-Agnostic Interpretability Approach to Predicting Customer Churn in the Telecommunications Industry. *Infolitika Journal of Data Science* 2024;2:34–44. <https://doi.org/10.60084/ijds.v2i1.199>.
- [12] Ibitayo OO. Egyptian Farmers' Attitudes and Behaviors Regarding Agricultural Pesticides: Implications for Pesticide Risk Communication. *Risk Analysis* 2006;26:989–95. <https://doi.org/10.1111/j.1539-6924.2006.00794.x>.
- [13] Holmes SM. Structural Vulnerability and Hierarchies of Ethnicity and Citizenship on the Farm. *Medical Anthropology* 2011;30:425–49. <https://doi.org/10.1080/01459740.2011.576728>.
- [14] Nguyen T-H-Y, Bertin M, Bodin J, Fouquet N, Bonvallot N, Roquelaure Y. Multiple Exposures and Coexposures to Occupational Hazards Among Agricultural Workers: A Systematic Review of Observational Studies. *Safety and Health at Work* 2018;9:239–48. <https://doi.org/10.1016/j.shaw.2018.04.002>.

- [15] Molina-Guzmán LP, Ríos-Osorio LA. Occupational Health and Safety in Agriculture. A Systematic Review. *Revista de La Facultad de Medicina* 2020;68:625–38.
- [16] Sharma VP, Singh S, Dhanjal DS, Singh J, Yadav AN. Potential Strategies for Control of Agricultural Occupational Health Hazards, 2021, p. 387–402. https://doi.org/10.1007/978-981-15-6949-4_16.
- [17] Azharuddin A, Sasmita NR, Idroes GM, Andid R, Raihan R, Fadlilah T, et al. Patient Satisfaction and its Socio-Demographic Correlates in Zainoel Abidin Hospital, Indonesia: A Cross-Sectional Study. *Unnes Journal of Public Health* 2023;12:57–67. <https://doi.org/doi.org/10.15294/ujph.v12i2.69233>.
- [18] Fazli QS, Pramayudi N, Sayuth M. Effectiveness of Gegarang (Mentha sp.) Leaf Extract Againsts *Plutella xylostella* L. in Laboratory 2023;8.
- [19] Naughton SX, Terry A V. Neurotoxicity in Acute and Repeated Organophosphate Exposure. *Toxicology* 2018;408:101–12. <https://doi.org/10.1016/j.tox.2018.08.011>.
- [20] Perry J, Cotton J, Rahman MA, Brumby SA. Organophosphate Exposure and the Chronic Effects on Farmers: A Narrative Review. *Rural and Remote Health* 2020;20:206–22.
- [21] Muñoz-Quezada MT, Lucero BA, Iglesias VP, Muñoz MP, Cornejo CA, Achu E, et al. Chronic Exposure to Organophosphate (OP) Pesticides and Neuropsychological Functioning in Farm Workers: A Review. *International Journal of Occupational and Environmental Health* 2016;22:68–79. <https://doi.org/10.1080/10773525.2015.1123848>.
- [22] Kori RK, Singh MK, Jain AK, Yadav RS. Neurochemical and Behavioral Dysfunctions in Pesticide Exposed Farm Workers: A Clinical Outcome. *Indian Journal of Clinical Biochemistry* 2018;33:372–81. <https://doi.org/10.1007/s12291-018-0791-5>.
- [23] Colémont A, Broucke S Van den. Psychological Determinants of Behaviors Leading to Occupational Injuries and Diseases in Agriculture: A Literature Overview. *Journal of Agricultural Safety and Health* 2006;12:227–38. <https://doi.org/10.13031/2013.21230>.
- [24] Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R. Review and Meta-analysis of Emerging Risk Factors for Agricultural Injury. *Journal of Agromedicine* 2016;21:284–97. <https://doi.org/10.1080/1059924X.2016.1179611>.
- [25] Barrett CB, Ortiz-Bobea A, Pham T. Structural Transformation, Agriculture, Climate, and the Environment. *Review of Environmental Economics and Policy* 2023;17:195–216. <https://doi.org/10.1086/725319>.
- [26] Horlings LG, Marsden TK. Towards the Real Green Revolution? Exploring the Conceptual Dimensions of a New Ecological Modernisation of Agriculture That Could “Feed the World.” *Global Environmental Change* 2011;21:441–52. <https://doi.org/10.1016/j.gloenvcha.2011.01.004>.
- [27] Waha K, Krummenauer L, Adams S, Aich V, Baarsch F, Coumou D, et al. Climate Change Impacts in the Middle East and Northern Africa (MENA) Region and Their Implications for Vulnerable Population Groups. *Regional Environmental Change* 2017;17:1623–38. <https://doi.org/10.1007/s10113-017-1144-2>.
- [28] Liu X, Pei F, Wen Y, Li X, Wang S, Wu C, et al. Global Urban Expansion Offsets Climate-Driven Increases in Terrestrial Net Primary Productivity. *Nature Communications* 2019;10:5558. <https://doi.org/10.1038/s41467-019-13462-1>.
- [29] Surna MI, Fazli QS, Chamzurni T, Susanna S, Idroes GM. Influence of Elevational and Environmental Factors on Parasitic Nematode Distribution in Arabica Coffee in the Gayo Highlands, Indonesia. *Leuser Journal of Environmental Studies* 2025;3:56–66. <https://doi.org/10.60084/ljes.v3i2.293>.
- [30] Idroes GM, Hafizah I, Hartono D, Dharma DB, Hardi I, Noviandy TR, et al. Investigating Hydropower Energy Consumption’s Effect on Southeast Asia’s Path to Achieving Environmental Sustainability and Carbon Neutrality. *Carbon Research* 2025;4:57. <https://doi.org/10.1007/s44246-025-00218-4>.
- [31] Arkadinata T, Fazli QS, Alfizar A, Hakim L, Idroes GM. Environmental Influence of Altitude on Coffee Leaf Rust Severity in Arabica Coffee of Aceh Tengah, Indonesia. *Leuser Journal of Environmental Studies* 2025;3:79–86. <https://doi.org/10.60084/ljes.v3i2.344>.
- [32] Hardi I, Kurniawan R, Ray S, Idroes GM, Noviandy TR, Majid MSA. Reducing the Poverty Gap and Severity in Indonesia: The Role of Renewable Energy Access and Consumption. *Human Settlements and Sustainability* 2025. <https://doi.org/10.1016/j.hssust.2025.06.001>.
- [33] Fabregas R, Kremer M, Schilbach F. Realizing the Potential of Digital Development: The Case of Agricultural Advice. *Science* 2019;366. <https://doi.org/10.1126/science.aay3038>.
- [34] Rotz S, Gravely E, Mosby I, Duncan E, Finnis E, Horgan M, et al. Automated Pastures and the Digital Divide: How Agricultural Technologies Are Shaping Labour and Rural Communities. *Journal of Rural Studies* 2019;68:112–22. <https://doi.org/10.1016/j.jrurstud.2019.01.023>.

- [35] Curl CL, Spivak M, Phinney R, Montrose L. Synthetic Pesticides and Health in Vulnerable Populations: Agricultural Workers. *Current Environmental Health Reports* 2020;7:13–29. <https://doi.org/10.1007/s40572-020-00266-5>.
- [36] Barnay T. Health, Work and Working Conditions: A Review of the European Economic Literature. *The European Journal of Health Economics* 2016;17:693–709. <https://doi.org/10.1007/s10198-015-0715-8>.
- [37] Salim Fazli Q, Isaack Delya M, Hironimus Kihwili E, Qashmal M, Shabrina Hilal I, Idroes GM. How Is Research Connecting Artificial Intelligence, Sustainability Governance, and Agri-Food Supply Chains Evolving? A Bibliometric Analysis. *Indatu Journal of Management and Accounting* 2025;3:88–100. <https://doi.org/10.60084/ijma.v3i2.368>.
- [38] Fazli QS, Lorente DB, Hilal SI, Maulidar P, Idroes GM. Mapping Global Research on Agrochemicals and Sustainability: A Bibliometric Analysis of Environmental and Economic Perspectives. *Innovations in Environmental Economics* 2025;1:109–24.
- [39] Fazli QS, Idroes GM, Hilal IS, Hafizah I, Hardi I, Noviandy TR. Agrochemicals, GHG Emissions, and GDP in Southeast Asia: A Machine Learning Approach with Hierarchical Clustering. *Grimsa Journal of Business and Economics Studies* 2025;2:140–51. <https://doi.org/10.61975/gjbes.v2i2.93>.
- [40] Fazli QS, Noviandy TR, Idroes GM, Idroes GM. Research Landscape on Occupational Hazards and Pesticide Exposure among Agricultural Workers: A Bibliometric Analysis. *Narra Review* 2025;1:e13–e13.
- [41] Lee M, Sharma P. Leveraging the Louvain Algorithm for Enhanced Group Formation and Collaboration in Online Learning Environments. *International Journal of Educational Technology in Higher Education* 2024;21:65. <https://doi.org/10.1186/s41239-024-00495-w>.
- [42] Idroes GM, Syahnur S, Majid SA, Sasmita NR, Idroes R. Provincial Economic Level Analysis in Indonesia Based on the Geothermal Energy Potential and Growth Regional Domestic Products Using Cluster Analysis. *IOP Conference Series: Materials Science and Engineering* 2021;1087:012079. <https://doi.org/10.1088/1757-899X/1087/1/012079>.
- [43] Macchiavello R, Reardon T, Richards TJ. Empirical Industrial Organization Economics to Analyze Developing Country Food Value Chains. *Annual Review of Resource Economics* 2022;14:193–220. <https://doi.org/10.1146/annurev-resource-101721-023554>.
- [44] Dorward A. Agricultural Labour Productivity, Food Prices and Sustainable Development Impacts and Indicators. *Food Policy* 2013;39:40–50. <https://doi.org/10.1016/j.foodpol.2012.12.003>.
- [45] Coye MJ. The Health Effects of Agricultural Production: I. The Health of Agricultural Workers. *Journal of Public Health Policy* 1985;6:349. <https://doi.org/10.2307/3342402>.
- [46] Jadhav R, Achutan C, Haynatzki G, Rajaram S, Rautiainen R. Risk Factors for Agricultural Injury: A Systematic Review and Meta-analysis. *Journal of Agromedicine* 2015;20:434–49. <https://doi.org/10.1080/1059924X.2015.1075450>.
- [47] de Lima CZ, Buzan JR, Moore FC, Baldos ULC, Huber M, Hertel TW. Heat Stress on Agricultural Workers Exacerbates Crop Impacts of Climate Change. *Environmental Research Letters* 2021;16:044020. <https://doi.org/10.1088/1748-9326/abeb9f>.
- [48] Molua EL. Climate Variability, Vulnerability and Effectiveness of Farm-Level Adaptation Options: The Challenges and Implications for Food Security in Southwestern Cameroon. *Environment and Development Economics* 2002;7:529–45. <https://doi.org/10.1017/S1355770X02000311>.
- [49] El Khayat M, Halwani DA, Hneiny L, Alameddine I, Haidar MA, Habib RR. Impacts of Climate Change and Heat Stress on Farmworkers' Health: A Scoping Review. *Frontiers in Public Health* 2022;10. <https://doi.org/10.3389/fpubh.2022.782811>.
- [50] Lobell DB, Schlenker W, Costa-Roberts J. Climate Trends and Global Crop Production Since 1980. *Science* 2011;333:616–20. <https://doi.org/10.1126/science.1204531>.
- [51] Change IPOC. Climate Change 2007: Impacts, Adaptation and Vulnerability. *Genebra, Suíça* 2001.
- [52] Karimi-Shahanjarini A, Afshari M, Besharati F. Cultural Appropriateness in Randomized Controlled Trials (RCTs) Aimed at Reducing Pesticide Exposure among Farmers and Farmworkers: A Systematic Review. *International Archives of Occupational and Environmental Health* 2023;96:27–44. <https://doi.org/10.1007/s00420-022-01880-6>.
- [53] Hardi I, Ali N, Duwal N, Devi NC, Mardayanti U, Idroes GM. Business Confidence in Indonesia: Which Macroeconomic Factors Have Long-Term Impact? *Indatu Journal of Management and Accounting* 2024;2:40–54. <https://doi.org/10.60084/ijma.v2i1.203>.