Research Article

Global Trends in Agricultural Extension Research: A Bibliometric Analysis Using Scopus Database

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Abstract |Although agricultural extension and advisory services research has been growing rapidly, a bibliometric study elucidating the field's global developing trend and intellectual structure is still unavailable. The current study fills this gap by drawing from the data to identify trends in publications and influential stakeholders and developing themes that can help inform future research and policy direction. A total of 1,948 articles indexed in Scopus (2010–2023) were analysed using VOSviewer and Biblioshiny in bibliometric analysis. Data retrieval and extraction were based on titles, abstracts, keywords, and then the descriptive, co-authorship, network, and thematic analyses. The USA ranked first in articles (834), citations (3,839), and international cooperation. The primary source was the Journal of Agricultural Education and Extension (88 articles). The author, Hu R, was the most productive (15 articles). Key research topics were "agricultural worker," "climate change adaptation," "smallholder decision-making," and "ICT-enabled extension services." Research within agricultural extension is trending towards sustainability, digital tools, and climate resilience. Policymakers and development professionals should focus on AI-based extension models, local e-services, and farmer-centric risk interventions. These gaps need to be tackled in future studies to enhance global agricultural resilience.

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Introduction

Agricultural Extension (AE) plays a vital role in agricultural and rural development by providing information, policies, and technology to farmers and other rural actors (Gebremariam *et al.*, 2021). The field of agricultural extension research has evolved to address new challenges facing the agricultural industry, such as food and nutrient security, product marketing, climate change and adaptation, agricultural mechanization, and other issues related to rural development (Wijerathna-Yapa and Pathirana, 2022). Therefore, AE is an essential tool for promoting sustainable agriculture and helping to address the complex issues that the agricultural sector is currently facing in the twenty-first century. According to

scholars, agricultural extension is a crucial component of the political economy of agrarian reform. This has been deemed necessary in the efforts to reduce poverty and promote rural development. The primary focus of agricultural extension is to highlight the untapped economic potential of making technology more accessible to smallholder farmers. This can lead to an improvement in on farm productivity, benefiting the farmers significantly. AE services have the potential to promote the adoption of innovative farming techniques that can enhance the quality of crops, reduce costs, and increase production. However, these services face various challenges such as climate instability, soil erosion and degradation, salinity, pest and disease vectors, global population trends, changing consumption patterns, mechanization, and rapidly restructuring labor markets (Weis, 2010). The significance of information and communication technologies (ICTs) in agriculture has increased in recent years, leading to substantial changes in AE (Heeks, 2017). Innovative extension forms, such as mobile phone-based advisory services and farmer-to-farmer knowledge-sharing networks, have made it possible to reach and engage farmers and other rural people (Emeana *et al.*, 2020). The use of ICTs has made agricultural extension services less expensive, especially in areas with low population density. For instance, GPS enabled hardware has made it easier to customize information, such as alerting farmers to local insect outbreaks or enabling two-way communication so that farmers may ask questions about their own needs and surroundings. This hardware transmits information through video and links farmers with professionals. It is ten times more effective per dollar invested in India than formal training and visit based extension techniques in promoting the adoption of certain beneficial behaviors (Clarke *et al.*, 2020). Information transmission through mobile devices has also been shown to increase yields in sub-Saharan Africa and India by 4%, and raised the possibility of increasing the use of suggested agrochemical inputs by up to 22% (Sheahan and Barrett, 2017).

For years now, there has been substantial growth in newly established journals and publishing avenues in farming development. While some publications have gained Science Citation Index and Emerging Citation Index accreditation and received an impact factor, such as the Journal of Agricultural Education and Extension, Journal of Agricultural Extension, Rural Extension, and Innovation Systems Journal, no bibliometric analysis has provided a current overview of agricultural extension publications. This kind of research is imperative to pinpoint existing gaps in current trend and understanding, and guide forthcoming research and policy roadmaps. The study will focus on the most notable authors, institutions, and countries, as well as patterns and tendencies in investigational themes and methodology, using the quantitative process of bibliometric examination. Overall, this analysis assists us in detecting present gaps within current research. Thus, the queries that led to our data gathering and assessment are as follows.

RQ1: How has the main line of inquiry in the AE literature evolved?
RQ2: How are several actors (authors, institutions, and nations) related to this extensive study field?
RQ3: What are the top articles in this field based on citations and their findings?
RQ4: What are the significant keywords, and how are themes distributed in their centrality and density?
RQ5: What knowledge gaps in AE may identify the need for future research?

Materials and Methods

Bibliometric analysis is a robust quantitative approach for identifying the directions and dynamics of a knowledge domain used in literature review methods (Gan et al., 2022). As Scopus is one of the most dependable and trustworthy databases, with the most significant abstract and citation database of peer-reviewed research used by many academics, Scopus was chosen as the basis of this review (Pranckute, 2021). The research method is shown in Figure 1 below. We searched titles, abstracts, and keywords on March 21, 2023. Primarily, we got 1,985 articles. After sorting and deleting the duplicates, we found 1,948 articles. The time frame was established from 2010 to 2023, and only research articles were analyzed. The search history and analytical methodologies are shown in Appendix A. Descriptive Analysis (Most cited documents, most productive authors, most productive source), Co-Authorship Analysis (most relevant authors, Journals, organizations, countries), Network Analysis (Keyword analysis, Trend topics) were conducted (Mahedi *et al.*, 2025; Kabir *et al.*, 2025).
We also carried out an unsupervised machine learning-based visualization of the author's keywords to provide a clearer understanding of the connections between various themes (Figure 15). This visualization

shows how the top 50 author keywords are clustered based on various author keywords using the Multiple Correspondence Analysis (MCA) approach. With this method, we developed the conceptual structure map. Finally, we also summarized the top ten articles in this area based on the citations.

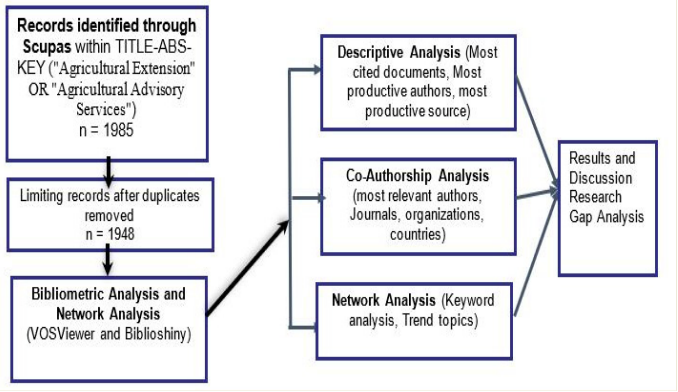

Figure 1: *The research methodologies*

Results and Discussion

Description of the data

Table 1 presents information about a collection of 1,948 articles from 2010 to 2023 that were sourced from 669 journals. On average, these articles are 5.32 years old and have 13.62 citations per article. The dataset includes 4,124 Keywords Plus and 5,115 author-provided keywords. Among the 5,694 authors in the dataset, 209 have written papers independently, without co-authors. On average, there are 3.64 co-authors per article, with 32.65% of them being international collaborations. All of the articles in this dataset are categorized as "articles". Table 1 provides a summary of the descriptive statistics of the dataset.

Influential Publications

Figure 2 provides citation metrics for the top fifteen academic publications in AE. The data shows that, with 440 total citations, the citation rate is 36.67 per year, and the normalized total citation score was 13.14, 'Below TB, 2012, Global Environ Change' has the most significant total number of citations. With 197 total medals, a citation rate of 17.91 per year, and a normalized total citation score of 7.78, 'Abebaw D, 2013, Food Policy' has the second highest number of citations.

Table 1: *Descriptive statistics for the dataset*

Description	Results
Timespan	2010:2023
Sources (Journals, Books, etc.)	669
Documents	1948
Annual growth rate %	2.63
Document average age	5.32
Average citations per doc	13.62
References	86279
Document contents	
Keywords plus (ID)	4124
Author's keywords (DE)	5115
Authors	
Authors	5694
Authors of single-authored docs	209
Authors collaboration	
Single-authored docs	223
Co-authors per doc	3.64
International co-authorships %	32.65
Document types	
Article	1948

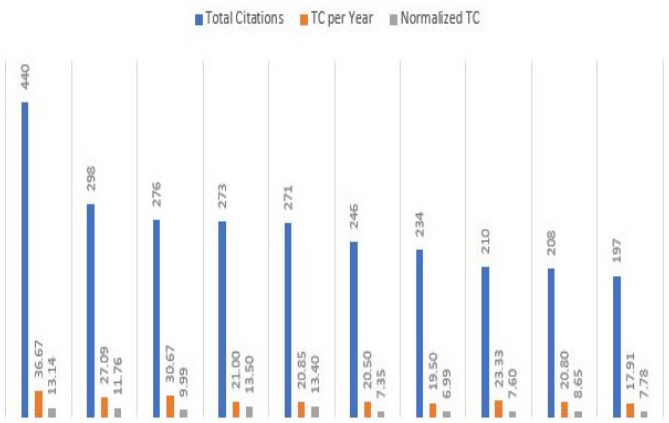

Figure 2: *Top 10 Articles in terms of citations*

Influential journals

The top fifteen journals in agricultural extension research are shown in Figure 3. With 88 articles, the Journal of Agricultural Education and Extension tops the list. Sustainability (Switzerland) is second with 64 pieces, while the Journal of Agricultural Extension is third with 55 pieces. With 38 and 33 articles, respectively, Land Use Policy and the International Journal of Agricultural Sustainability are in 3rd and 4th place.

Author's Outputs

The top fifteen authors in agricultural extension and the number of articles they have published are shown in Figure 5. The authors are ranked by the total number of articles they have contributed to. Hu R has published 15 papers with a fractionalized count

of 3.96. Similarly, Baig MB has published 12 pieces with a fractionalized count of 2.90, and Zhang C has also published 12 articles but with a slightly higher fractionalized count of 3.18. Other vital authors are Bijani M, Jermsittiparsert K, Kassem HS, Oladele OI, Abbasi E, Klerkx L, and Leeuwis C.

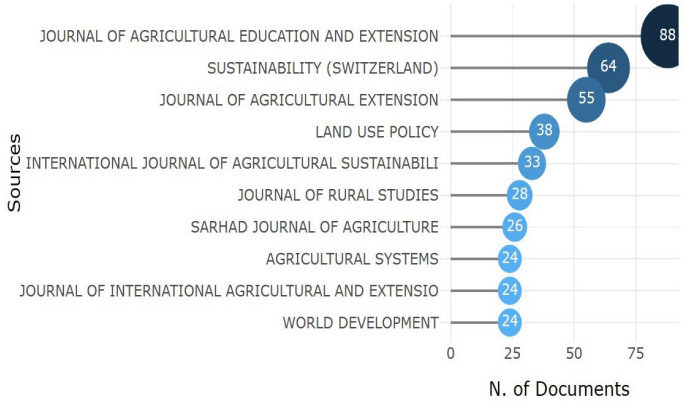

Figure 3: *Top ten journals in terms of production of agricultural extension issues*

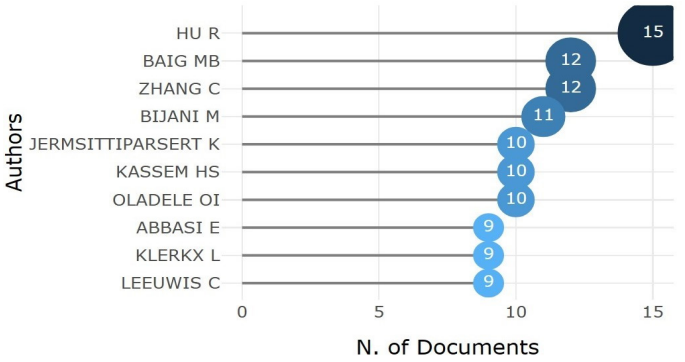

Figure 4: *Top ten authors in agricultural extension*

Author productivity through Lotka's Law

Alfred J. Lotka investigated the frequency distribution of scientific output based on chemical abstracts from 1907 to 1916 in 1926. According to Lotka, around 1/n2 as many writers contribute as writing alone, which 60% of all authors do. Lotka developed the Inverse Power Law as follows:

$$y = C \times x^{\wedge} - n$$

where y is the anticipated proportion of authors with frequency x of publications; x is the number of publications of interest (1, 2, etc.); n is an exponent constant for a particular data set; and C is a constant. This law depicts the pattern of authors' scientific activity in a specific field during a given time, In Figure 6, we can see the number of authors in a specific research field according to the number of papers they have written. The table also displays the total number of writers for each document count and the percentage of authors in each category. The purpose of the table is to determine the productivity of the writers in the research field.

The majority of writers (85.5%) have only written one paper, while only 9.3% have written two documents. As the number of papers produced increases, so does the number of writers and their share. For instance, 3.0% of writers have three documents, while 1.1% have four, 0.5% have five, 0.2% have six, and 0.1% have seven, eight, nine, or ten documents, respectively.

This figure provides a clear picture of author productivity within the field of study. It reveals that while most authors have only produced a few papers, a select few have created more work overall. This information can help us to understand the research environment and the general author contribution trends in the subject.

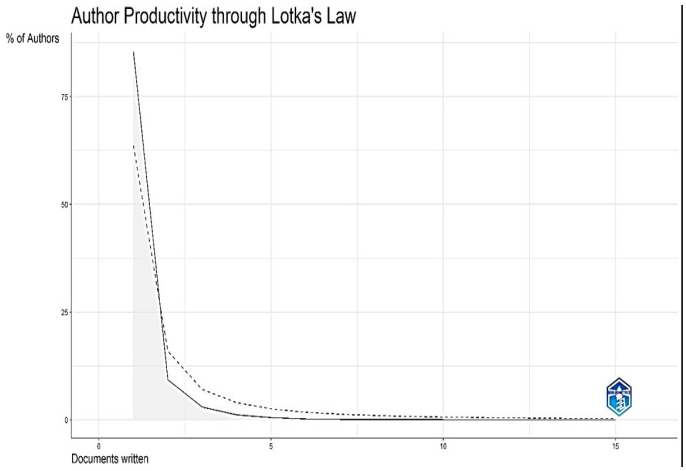

Figure 5: *Productivity of authors in AE based on Lotka's Law*

Corresponding authors' countries

How many papers are published on a specific study topic by a nation, along with the frequency (Freq), Multiple Country Publications (MCP), and Single Country Publishing (SCP), is shown in Figure 7. With 198 articles, 138 SCPs, 60 MCPs, a frequency of 0.102, and an MCP ratio of 0.303, the USA comes first as a contributor to AE. Other nations with varying degrees of articles, SCPs, MCPs, frequency, and MCP ratios include China, Nigeria, Iran, Germany, Ethiopia, South Africa, the United Kingdom, and Australia.

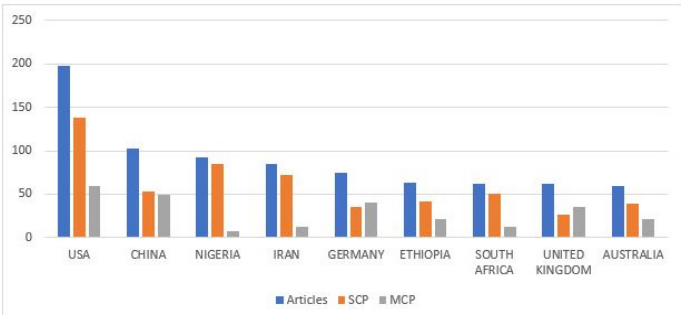

Figure 6: *Scientific production by corresponding authors' countries in AE research*

Scientific production by countries

Figure 8 displays the frequency of publications for each country and the distribution of articles in AE research. For example, researchers from the United States published 834 papers, followed by China (439). The table also includes publications from Nigeria, India, Germany, Indonesia, Iran, Kenya, the UK, and Australia, with frequencies ranging from 331 for Nigeria to 248 for Australia.

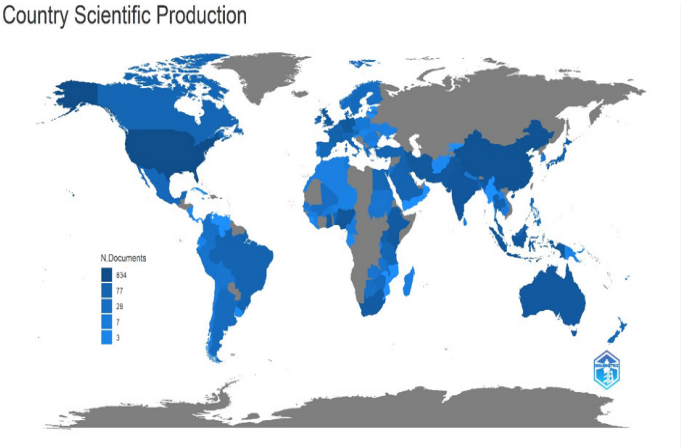

Figure 7: *Country-specific scientific production in AE*

Most cited countries

The following statistics show the average number of citations received by academic works published in different countries (Figure 9). According to the data, researchers from the USA (3839) and Germany (2252) have received the highest number of citations, followed by China (1761), the United Kingdom (1675), Australia (1172), Ethiopia (870), the Netherlands (802), Iran (751), France (647), and South Africa (518). Researchers from Germany have the most significant average rate of article citations (30.03), followed by the UK (27.02), France (23.96), Netherlands (22.28), USA (19.39), Australia (19.53), China (17.26), Ethiopia (13.81), Iran (8.84), and South Africa (8.35).

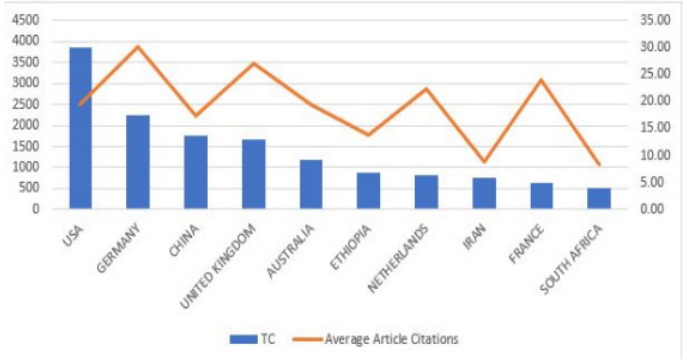

Figure 8: *Country-specific scientific production In AE*

Country collaboration

Figure 10 presents data on the frequency of research collaborations among authors from different countries. For instance, researchers from the United States and China collaborated on 25 research projects. The authors from the United States and the United Kingdom worked together on 18 research projects, indicating a strong research collaboration. Furthermore, authors from China, Pakistan, Kenya, and the United Kingdom collaborated 17 times each. Further, the data shows that several countries, including the USA, Germany, and Kenya, have multiple collaborations with different countries. For example, the USA collaborated with India, Uganda, Ethiopia, and Tanzania, while Germany collaborated with the United Kingdom and China.

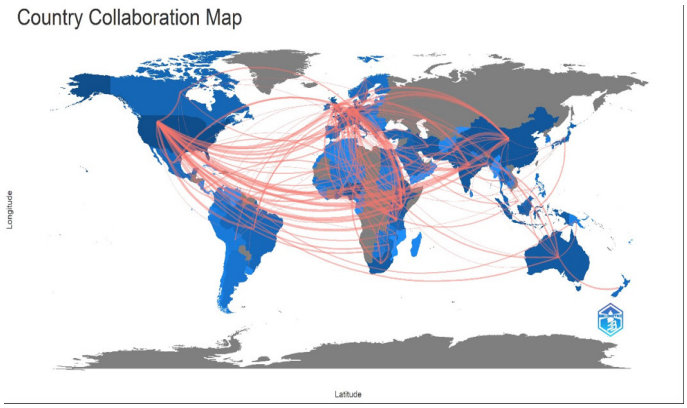

Figure 9: *Inter-country collaboration in research*

Network analysis and trend word analysis

Co-occurrence network

Figure 11 displays the author's "Keyword" in an academic publication in AE. Meanwhile, Figure 12 depicts the relationship between the different words. The term "agricultural extension" appears 547 times throughout the titles, keywords, and abstracts, making it the most frequently used word and emphasizing

its importance to the study project. The table also highlights the significance of the terms "agricultural" and "climate change," which occur 268 and 154 times, respectively. Other notable terms in the text include "farm laborer," which appears 148 times, "human," which appears 124 times, and "crop production," which appears 120 times. These words suggest that the primary focus of the study is the interaction between agriculture and human factors, particularly agricultural workers. Additionally, with 116 and 107 instances of "article" and "smallholder," respectively, it can be inferred that the research project is an article that explores the role of smallholders in agriculture and agricultural extension.

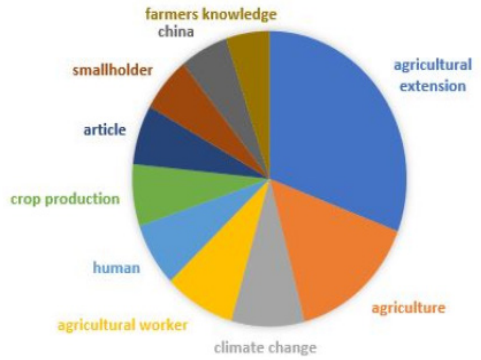

Figure 10: *Most frequent words in agricultural extension research*

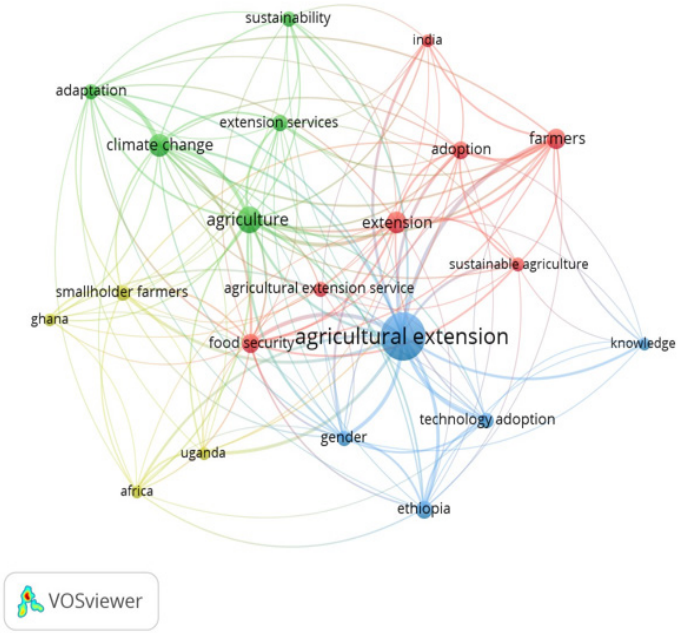

Figure 11: *Most frequently-used keywords and their relationship*

Changes in keywords' frequency of use over time

Figure 13 displays the frequency of ten different keywords over 14 years, from 2010 to 2023. These keywords include crop production, article, smallholder, China, agricultural extension, agriculture, climate change, human, and agricultural worker. As per the data presented in Figure 13, the frequency of these keywords has been increasing over time, highlighting their growing importance. Agricultural extension is the most commonly used term, with 547 occurrences, followed by agriculture with 268 occurrences, reaching its peak frequency in 2023. The majority of the keywords focus on agriculture, smallholder farming, and crop production. Additionally, the frequent use of these keywords demonstrates the rising concerns about climate change and its potential impact on agriculture and human livelihoods. Figure 13 provides a snapshot of current agricultural research trends.

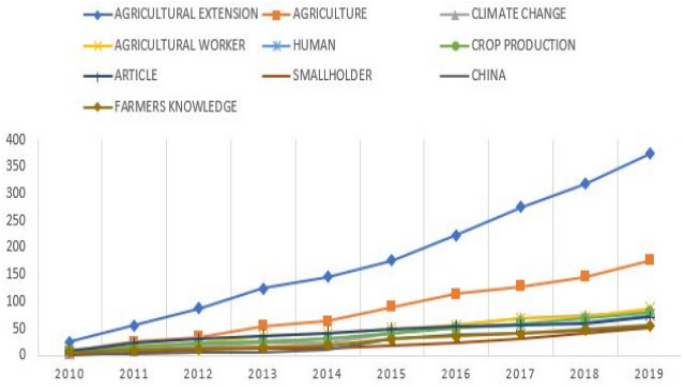

Figure 12: *Keyword frequency of use over time*

Trending Topics

The data presented in Figure 14 shows where the recent research in agricultural extension has been focused. Agriculture is the most commonly discussed trend, followed by climate change and agricultural extension. The topics that have been studied include "agricultural worker," "human," "crop production," "article,""smallholder,""decision making,""agricultural production," "agricultural research," "crop yield," "land use change," "land use," "Zea mays," etc. These topics reflect the current interests and areas of concentration in research and may indicate future research goals and directions.

Conceptual framework map (Multiple Correspondence Analysis (MCA))

A visual representation of the keywords related to agricultural extension research. This two-dimensional graph shows the similarity between the keywords but compresses a large amount of data with many variables into a smaller space. As a result, the keywords located near the center point have likely received the most attention.

To interpret the results, we can look at the relative positions of the dots and their distribution along the dimensions.

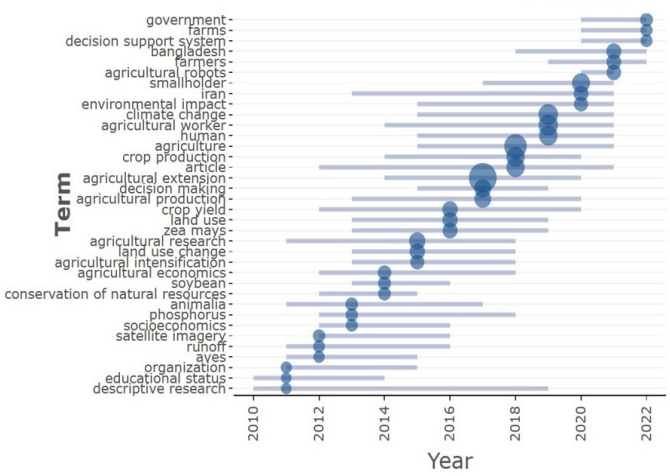

Figure 13: *Trending topics in AE research*

The closer two keywords are to each other on the map, the more similar their distributions are (Aria and Cuccurullo, 2017). For instance, Cluster 1 (marked in red) includes papers on agricultural technology, education, perception, adoption, crop yield, agricultural land, and so on. Meanwhile, Cluster 2 (marked in blue) has only seven keywords that are mainly related to publications on agrarian workers, human, male, female, agriculture, etc.

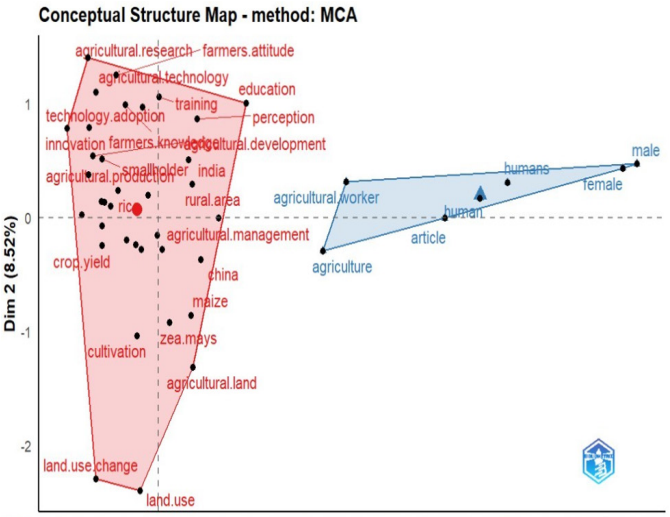

Figure 14: *Conceptual framework map*

Discussion

This research sought to analyze the prevailing focuses and tendencies of Agricultural Extension (AE) investigation globally. We applied bibliometric and network analysis methods to discern the theoretical and practical subjects of AE inquiry. Furthermore, the ten most widely-cited works internationally within this domain have been extensively investigated, with their substance examined and organized. This has enabled us to identify modern investigatory issues facing AE. The complex examination surveyed the variant emphases within AE research, recognizing both the persistent and developing matters explored. Periodically, specific longer works delivered comprehensive reviews synthesizing key theories or datasets, whereas briefer papers put forth novel viewpoints or applications warranting further consideration.

The article with the most significant total number of citations in the journal "Global Environ Change" was published by TB in 2012 and got extensive recognition and impact. Abebaw D, 2013, on the other hand, takes second place with excellent citation metrics and academic implications. The key journal is the "Journal of Agricultural Education and Extension," closely followed by "Sustainability (Switzerland)" and the "Journal of Agricultural Extension."

The most productive Author in AE research according to the total number of publications is Hu, R, who stands out as the top contributor with 15 articles published (fractionalized count = 3.96%). With 12 publications each but different fractionalized counts of 2.90% and 3.18%, respectively, Baig MB and Zhang C are closely behind. We also used an in-depth examination of author productivity using a classification system based on the total number of articles written. In addition to giving a clear picture of how authors are distributed across various document counts, we also determined the overall number of writers in each category and the associated percentage. The results show that a significant portion of authors (85.5%) have only contributed one publication, which is consistent with the widespread practice of single authorship in the study area.

On the other hand, 9.3% of writers have produced two documents, demonstrating a greater degree of activity. There is an increasing trend, meaning that the number of authors in each category rises proportionately to the number of publications per author. The distribution makes this clear: 3.0 percent of writers have written three papers, and the percentages for those who have written four, five, six, and so on decrease.

With 198 articles, 138 Single Country Publications

(SCP), and 60 Multiple Country Publications (MCP), the United States emerges as the top contributor in the area of AE. The United States of America has a significant presence in AE, as shown by its computed frequency of publications of 0.102. Furthermore, the United States' estimated MCP ratio of 0.303 suggests notable participation in cooperative international research endeavors. Other countries, including China, Nigeria, Iran, Germany, Ethiopia, South Africa, the United Kingdom, and Australia, demonstrate varied contributions with diverse SCPs, MCPs, frequencies, and MCP ratios. We observed that with 834 publications, American researchers ranked first and highlighted their influence in the academic debate in AE. China follows closely behind, showing its significant presence in the sector with 439 articles, making it a noteworthy contributor.

On the other hand, researchers from the United States and Germany are the best achievers in terms of citations, and their respective numbers of citations are 3839 and 2252. China, the United Kingdom, Australia, Ethiopia, the Netherlands, Iran, France, and South Africa display remarkable citation numbers. Surprisingly, German researchers had the highest average rate of per-article citations (30.03), closely followed by those from the UK (27.02), France (23.96), the Netherlands (22.28), and the USA (19.39).

The data reveals important collaboration initiatives, such as 25 research projects involving authors from the United States and China, underlining the worldwide aspect of research partnerships. Strong academic cooperation is shown by the eighteen collaborative research projects involving writers from the United States and the United Kingdom. Moreover, the information indicates that writers from China, Pakistan, Kenya, and the United Kingdom collaborated on projects 17 times each. Significantly, the study emphasizes that nations such as the United States, Germany, and Kenya participate in numerous partnerships with different countries. These partnerships include the United States' associations with Tanzania, India, Uganda, Ethiopia, and Kenya, and Germany's partnerships with the United Kingdom and China.

Based on the keyword analysis in AE-related academic papers, including essential details about the study's topic emphasis. Across titles, keywords, and abstracts, the phrase "agricultural expansion" appears 547 times, making it the most often occurring keyword and highlighting its vital relevance to the study endeavor (Figure 11). The relevance of phrases such as "agricultural" (268 times) and "climate change" (154 times) highlights the study's attention on the delicate interaction between agriculture and environmental issues. Furthermore, repeated phrases like "farm laborer" (148 times), "human" (124 times), and "crop production" (120 times) reveal a core topic centered around the interplay between agriculture and human issues, with a special focus on agricultural laborers. From the in-depth analysis of the frequency patterns of ten important keywords in AE research from 2010 to 2023, a period of 14 years. The other emerging keywords are related to agriculture, agricultural production, and smallholder farming, indicating an ongoing emphasis on these critical areas. The keyword "climate change" is becoming increasingly common, highlighting that agricultural extension scientists are becoming aware of the possible effects of climate change and that attention on the topic is growing.

Table 2: *Top ten articles in the field*

Paper title	Journal name	Key findings	Total Citations	TC per Year	Normalized TC	References
Farmers' knowledge and perception of climatic risks and options for climate change adaptation: a case study from two Tanzanian villages	Regional Environmental Change	Different levels of adaptability and sensitivity in their farming systems and their perceptions of and adaptation to climate and yield dynamics were described in the paper. The key findings were also how farmers interpret climate patterns and the numerous advantages of regional agricultural systems.	440	36.67	13.14	(Below et al., 2015)

The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia	Food Policy	The influence of cooperatives on the adoption of agricultural technologies was examined in this article. The research found that households headed by men are most likely to belong to cooperatives. Additionally, cooperative participation is substantially correlated with geography and the age of the head of the household. Cooperative membership is significantly correlated with the use of fertilizer.	298	27.09	11.76	(Abebaw et al., n.d.)
Farmers' Perceptions of and adaptation strategies to climate change and their determinants; the case of Punjab province, Pakistan	Earth System Dynamics	How farmers adjust their farming methods to respond to climate change was described. The results demonstrate that there is still a concern about climate change in the area and that farm households modify their agricultural practices in response to climatic change.	276	30.67	9.99	(Abid et al., 2015)
The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty	The Journal of Peasant Studies	Agroecology expanded quickly and successfully, and agricultural techniques altered, in large part due to social process methodology and social movement dynamics. They considerably enhanced the peasant sector's relative and absolute productivity, and those methods brought about other advantages, including more resilience in the face of climate change.	273	21.00	13.50	(Michael Rosset et al., 2011)
Assessing farming eco-efficiency: A Data Envelopment Analysis approach	Journal of Environmental Management	This study measures the eco-efficiency of farming using Data Envelopment Analysis (DEA) techniques. Eco-efficiency scores are computed for a sample of Spanish farmers operating in the Campos County rain-fed agricultural system. mental situation. Government funding for agricultural extension and farmer training may support better integration of farming with the environment.	271	20.85	13.40	(Picazo-Tadeo et al., n.d.)
Mapping abandoned agriculture with multi-temporal MODIS satellite data	Remote Sensing of Environment	The article aimed to assess methods for mapping abandoned agricultural areas on a wide scale, utilizing phenology data and low-resolution satellite images. With an overall categorization accuracy of 65%, the results showed that mapping abandoned agriculture over large regions using MODIS data is possible.	246	20.50	7.35	(Alcantara et al., 2012)
Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique	Field Crops Research	Farmers preferred the in-row intercropping of maize and legumes because both crops provided good yields. Intercropping increased the amount of weeding labor by 36% compared to monoculture. In addition, maize-pigeon pea intercropping may boost productivity while requiring less area for cultivation in Ruaca owing to labor constraints brought on by extensification.	234	19.50	6.99	(Rusinamhodzi et al., 2012)

Drivers for global agricultural land use change: The nexus of diet, population, yield and bioenergy	Global Environmental Change	The results show that animal product production accounts for 65% of land use change and has dominated agricultural land use and land use change during the last 50 years. The research suggests that changing dietary habits may ultimately take the lead in influencing land use change, requiring the implementation of demand-side regulations to regulate the spread of agriculture.	210	23.33	7.60	(Alexander et al., 2015)
Information Transmission in Irrigation Technology Adoption and Diffusion: Social Learning, Extension Services, and Spatial Effects	American Journal of Agricultural Economics	The study examines how extension services and social learning may promote the adoption and spread of agricultural technology. Social learning and extension services significantly impact new technology adoption and dissemination rates, and the presence of one of these two variables enhances the effectiveness of the other as an educational medium.	208	20.80	8.65	(Genius et al., 2014)
Impact of land fragmentation, farm size, land ownership and crop diversity on Profit and Efficiency of irrigated farms in India	Land Use Policy	Land fragmentation may also have a very negative effect on agricultural revenues. Smaller farms often have fewer inefficiencies than larger farms since the latter group utilizes resources inefficiently. Additionally, unfragmented, large, owner-operated farms all have higher average profits than fragmented farms.	197	17.91	7.78	(Manjunatha et al., n.d.)

Conclusions and Recommendations

This bibliographic analysis provides three significant insights regarding worldwide agricultural extension research from 2010 to 2023. Initially, the subject demonstrates robust thematic evolution towards sustainability challenges, with climate change adaptation, smallholder decision-making, and ICT-enabled services emerging as dominant study priorities. Secondly, notable geographic imbalances exist in scholarly production, with the United States (834 publications) and China (439 publications) guiding productivity and international collaborations, while regions of the Global South remain underrepresented. Finally, despite rapid technological advancements, transformative methods like AI-assisted extension remain critically underexplored in the literature despite their disruptive potential.

These results carry substantial policy implications. Governments and development agencies should prioritize: (1) Investment in AI-driven extension models (e.g., predictive analytics for precision farming) and locally adapted e-extension platforms to decentralize knowledge access; (2) Integration of climate-risk interventions into national extension frameworks, specifically targeting smallholder vulnerability; and (3) Establishment of North-South research consortia to leverage the expertise of leading research nations while strengthening capacity in developing regions. Agricultural ministries must recognize digital extension not merely as a communication tool but as a strategic infrastructure for food system resilience. Acknowledging constraints, this analysis exclusively drew from Scopus-indexed publications, potentially overlooking significant contributions in non-indexed journals, conference proceedings, or regional databases. Future bibliographic studies would benefit from multi-database validation.

Critical research priorities emerge from this study:

- Developing economically practical AI-assisted extension models.
- Assessing private sector extension schemes for sustainability.
- Designing hyper-localized digital services for marginalized farming communities.
- Creating ICT infrastructure for real-time decision support systems.
- Investigating blockchain applications for transparent knowledge sharing.

As agricultural systems face escalating climate pressures, the convergence of extension services with digital technologies represents not merely an operational upgrade but a fundamental reorientation

toward data-driven, farmer-centric knowledge ecosystems. Prioritizing this digital transformation while bridging geographical research disparities will be essential for achieving global food security goals.

Novelty Statement

The study provides the first bibliometric overview (2010–2023) on agricultural extension research, indicating the USA as the leading country for author's affiliation, Journal of Agricultural Extension and Education as the most important publication outlet, and burgeoning themes such as digital tools and sustainability. It identifies trends, collaboration networks, and research gaps, providing a roadmap for future interdisciplinary research.

Authors' Contribution

A.K.M. Kanak Pervez: Conceptualization, methodology, supervision, project administration, writing original draft, writing review and editing.
Ataharul Chowdhury: Methodology, validation, formal analysis, writing review and editing, critical revision.
Md Shahriar Kabir: Data curation, formal analysis, visualization, writing original draft.
Md Mahedi: Data extraction, software application, investigation, writing original draft.

Generative AI or AI assisted technology statement
The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors should declare that there is no conflict of interest among the authors of the manuscript.

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