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Research Paper

Bibliometric synthesis of technological interventions and their impact on chickpea cultivators' income

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ABSTRACT

In the present study, a bibliometric analysis exploring how technological advancements have influenced chickpea farmers' income over the past five decades. Using data sourced from Dimensions.ai, key words such as "Impact", "Technology", "Income", and "Chickpea" were employed to retrieve 1329 relevant documents published between 1974 and 2024. The findings indicate that human society has been a leading thematic area in publications focusing on technological effects on farmers' livelihoods. A significant portion of the studies aligned with Sustainable Development Goal 2 Zero Hunger, underscoring the role of chickpea as a nutrition-sensitive and climate-resilient crop. The United States emerged as a major contributor to this body of research, often forming collaborative clusters with other nations. Institutions such as Wageningen University and Research and the International Food Policy Research Institute were frequently cited, reflecting their thought leadership in the domain. Journals like Agricultural Systems and Agricultural Economics served as prominent publication sources. The analysis emphasizes the importance of interdisciplinary and international collaboration in understanding and enhancing the economic returns from technological adoption in chickpea farming.

Key words: Chickpea, Farmer income, Sustainable development, Technology adoption bibliometric analysis

INTRODUCTION

Chickpea (*Cicer arietinum* L.) plays a vital role in the food systems and farming livelihoods of many developing countries. As a protein-rich legume, it contributes not only to human nutrition but also to soil health through biological nitrogen fixation. In recent years, technological interventions in chickpea cultivation, ranging from improved seed varieties to digital advisory platforms, have shown promising effects on farm-level productivity and income, particularly among smallholders.

Advancements in agricultural technology have created new opportunities for chickpea farmers to improve yields, reduce production risks, and gain better access to markets. Tools such as remote sensing, weather-based advisories, soil testing kits, and precision input application are increasingly integrated into pulse farming systems. Studies show that such innovations can lead to significant improvements in net returns for farmers. For instance, the World Economic Forum estimates that technology-driven agriculture could increase farm income by up to 70% and help lift millions out of poverty.

Research conducted by the National Council of Applied Economic Research (NCAER) has demonstrated that farmers using precision tools and improved management practices reported substantial increases in income, especially in resource-constrained zones (NCAER 2018). In chickpea systems, specific gains have been observed through varietal replacement, mechanized sowing, and pest monitoring, which not only enhance efficiency but also reduce reliance on costly chemical inputs (Nkonya *et al.* 2004, FAO 2019).

Digital platforms are also reshaping chickpea value chains by connecting farmers directly with buyers and service providers. Platforms like e-NAM have enabled legume growers to access real-time market prices, negotiate fairer trade terms, and bypass intermediaries, thereby improving price realization (Press Information Bureau 2021). Similarly, mobile-based agricultural advisory services now allow farmers to make informed decisions on input use, sowing dates, and pest alerts.

The importance of technology in chickpea farming aligns closely with several United Nations Sustainable Development Goals, particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 13 (Climate Action) (United Nations 2015). As climate variability increasingly threatens yield stability, particularly in rainfed regions, technological solutions offer a pathway to resilience and long-term sustainability (Wheeler and von Braun 2013, Rosenzweig *et al.* 2013).

Against this backdrop, the present study undertakes a bibliometric analysis to assess how scientific research has addressed the intersection of technology and farmer income in chickpea cultivation. By analyzing global literature trends from 1974 to 2024, the study maps intellectual networks, identifies research hotspots, and highlights key contributors to the field. The objective is to provide a structured overview that can guide future studies and inform development policies aimed at scaling technology for chickpea farmers.

MATERIALS AND METHODS

The data

This study employs bibliometric analysis to examine how technological advancements have impacted chickpea farmers' income. Bibliometric analysis, as conceptualized by Pritchard (1969), provides a structured method to quantify and map the growth and direction of research in a particular field. It has proven valuable in identifying trends, research gaps, and networks of collaboration within academic literature (Roemer and Borchardt 2015).

The research process followed the standard bibliometric workflow as outlined in Figure 1, covering the time span from 1974 to 2024. Data for this investigation was sourced from Dimensions.ai, a well-established research information database developed by Digital Science. While databases such as Web of Science and Scopus are widely used, Dimensions has gained popularity in recent years due to its inclusion of pre-prints, reports, and open-access content, making it highly suitable for studies with a global and interdisciplinary scope (Baas *et al.* 2020).

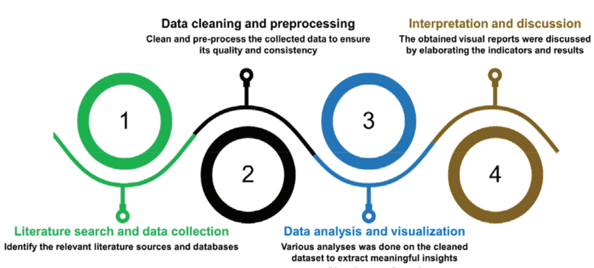

Fig. 1. Steps in a bibliometric analysis

Dimensions provided access to a large body of academic work, including journal articles, conference papers, and policy reports relevant to the technological impact on chickpea farming. The platform's ability to link scientific publications with funding data, institutional affiliations, and thematic areas made it ideal for tracking connections between technology adoption and farmer income.

In response to the growing interest in bibliometric research,especially during and after the COVID-19 pandemic (Hook *et al.* 2021), this study emphasizes real-time and broad-spectrum literature analysis. Titles and abstracts of publications in English were screened based on relevance, with no geographic limitations imposed.

Selection of database and search query

A precise search query was essential to obtain high-quality bibliometric data. The key words used for this study included: "Impact", "Technology", "Income", "Chickpea", and "Farmer". The search was applied to titles and abstracts of articles published between 1974 and 2024. To ensure consistency, only peer-reviewed articles were considered, while preprints, thesis, and book chapters were excluded.

The final data set, after screening and filtering, included 1329 documents exported in CSV format for further analysis.

Data extraction and analysis

The bibliographic data were compiled using Microsoft Excel for tabular analysis, while VOS viewer software (version 1.6.19) was used to generate visual maps of keyword co-occurrence, citation networks, and co-authorship links (van Eck and Waltman 2017). Citation analysis was employed to assess the influence and reach of specific publications, institutions, and journals.

International collaboration among countries was analyzed using a metric called link strength, as visualized through VOS viewer. This metric captures the extent of scientific cooperation between countries based on shared publications. Thicker lines between nodes indicate stronger collaboration networks.

By following these systematic steps, the study maps the intellectual landscape surrounding the technological impact on chickpea farmers' income and identifies key contributors, thematic trends, and gaps in the literature.

RESULTS AND DISCUSSION

Following a comprehensive bibliometric screening, a total of 1329 documents related to the technological impact on chickpea farmers' income were analyzed. The thematic classification of these documents revealed that the domain of human society accounted for the highest number of publications (578), followed by agricultural, veterinary, and food sciences (517). These findings suggest that the discourse around technology in chickpea farming extends beyond agronomic practices and enters the realm of rural development, social systems, and income equity.

Figure 2 illustrates the distribution of publications across major subject areas. The centrality of human society as a theme implies that chickpea is more than just a crop it is an instrument of social transformation, particularly in regions with large populations of marginal and smallholder farmers.

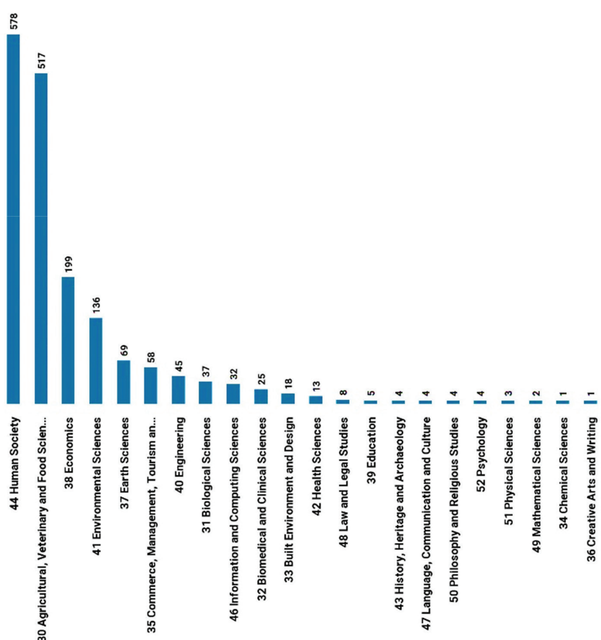

Fig. 2. Number of publications in each research category

To align the bibliometric output with broader global development narratives, the analysis also mapped publications against the Sustainable Development Goals (SDGs). Figure 3 presents the SDG-wise classification of literature. Notably, SDG 2 (Zero Hunger) was associated with the highest number of documents (613), followed by SDG 13 (Climate Action) with 174 publications. This alignment reflects the relevance of chickpea in advancing nutritional security, supporting low-carbon agriculture, and sustaining production under climate stress.

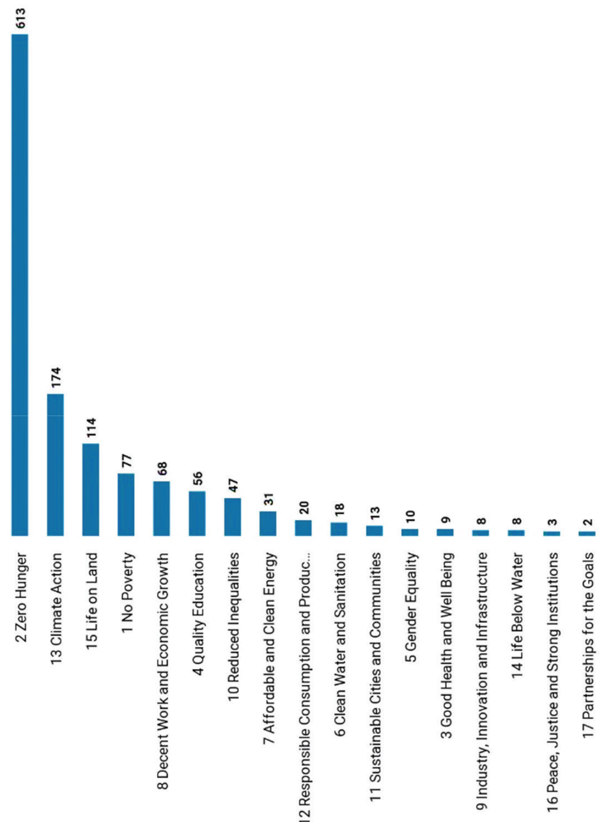

Fig. 3. Number of publications on the SDG themes

The cumulative publication trend over the decades is shown in Figure 4. A noticeable growth in research activity is observed post-2005, coinciding with rapid advancements in precision agriculture, mobile-based advisory tools, and genetic improvements in chickpea varieties. This upward trend is also supported by policy shifts promoting smart agriculture and the digitization of extension services (Rosenzweig *et al.* 2013, Wheeler and von Braun 2013).

The post-2005 surge can also be linked to increased funding for climate-resilient pulses and the integration of chickpea in national and international food security programs. This reflects a broader recognition of the chickpea's role in nitrogen fixation, nutritional supplementation, and climate mitigation.

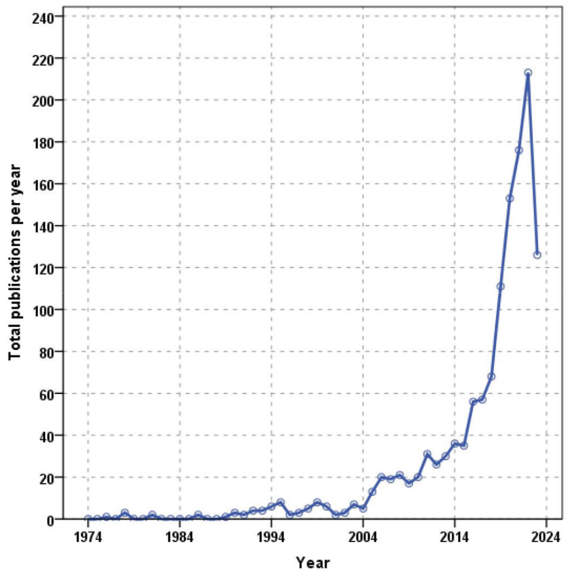

Fig. 4. Growth of publications during the study period.

Performance analysis

Top author analysis

The productivity and influence of authors in this domain were assessed based on two key indicators: the number of documents authored and the average citations received per document. Table 1 presents the top 10 most prolific authors working in the area of technology's impact on chickpea farming and related economic outcomes.

The VOS viewer software was used to map co-authorship relationships, providing insights into collaborative research dynamics. Figure 5 illustrates the interconnections among the most influential authors. These connections help identify research clusters and scholarly networks that have significantly contributed to the field.

For example, scholars such as Matin Qaim and Bekele Shiferaw are known for their work on the economic impacts of agricultural innovations in developing countries, including legumes like chickpea. Their inclusion here reinforces the relevance of their contributions to understanding technology adoption, yield improvement, and income diversification in pulse farming.

Figure 5 provides a visualization of these co-authorship clusters. A minimum threshold of two publications per author and a maximum of 25 co-authors per document were set to streamline the analysis. Out of 319 qualified authors, 32 showed interlinkages and formed 17 distinct collaboration clusters. This pattern reflects the interdisciplinary nature of chickpea research spanning economics, agronomy, extension science, and policy.

Table 1. Authors' analysis (Top 10).

Author's Name	Total number of documents	Citations	Citations (mean)
Bekele A Shiferaw	5	674	134.80
Matin Qaim	10	662	66.20
Graham Brookes	9	476	52.89
Peter Barfoot	7	442	63.14
Wanglin Ma	4	267	66.75
Victor M Manyong	5	121	24.20
Dil Bahadur Rahut	5	108	21.60
Yuansheng Jiang	5	70	14.00
Julius Manda	4	43	10.75
Camillus Abawiera Wongnaa	4	39	9.75

Fig. 5. Visualization map of co-authorship analysis of the authors

Co-authorship analysis of countries

To assess global collaboration in chickpea-related technology and income research, a co-authorship analysis of countries was conducted. Among the 91 countries represented in the dataset, 44 met the inclusion criteria of having at least five publications each.

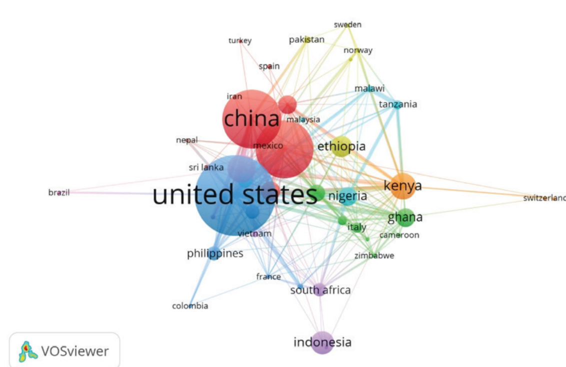

Fig. 6. Visualization map of co-authorship analysis of the countries

Figure 6 shows the collaborative landscape, with countries visualized as nodes and the strength of cooperation reflected by the thickness of connecting lines. The United States stood out as the most active collaborator, forming strong research alliances with countries like India, the Netherlands, Kenya, and Germany. This suggests that chickpea, while a regional staple crop, is embedded in global research discussions around food security and climate resilience.

Such international partnerships are critical in promoting knowledge exchange, testing innovations across agro-climatic zones, and influencing regional agricultural policies.

Citation analysis

Citation metrics were used to identify the most influential organizations and journals contributing to the domain of chickpea-focused technology research. Organizations with at least five published documents were considered for citation analysis.

Fig. 7. Visualization map of the citation analysis by organization

Figure 7 presents institutional citation mapping. Wageningen University & Research, the International Food Policy Research Institute (IFPRI), and the International Maize and Wheat Improvement Center (CIMMYT) ranked among the top institutions cited in the literature. Their cross-cutting work on pulses, sustainable intensification, and smallholder economics resonates deeply with the chickpea sector.

Figure 8 shows source-based citation patterns. Journals such as Agricultural Systems and Agricultural Economics emerged as key platforms for disseminating research on how technological interventions affect farmer income in legume-based systems. These journals consistently feature studies involving chickpea-growing regions in South Asia and Sub-Saharan Africa.

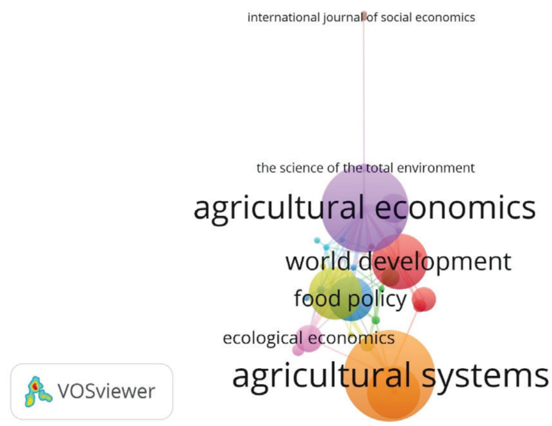

Fig. 8. Visualization map of the citation analysis by source

Comprehensive research synthesis

A broad synthesis of existing literature is essential to understand how modern technologies influence the income of chickpea farmers. As a widely grown pulse crop in South Asia, Sub-Saharan Africa, and parts of the Mediterranean, chickpea holds a strategic position in enhancing food security, soil fertility, and farmer incomes, particularly in resource-constrained regions. This section explores major thematic areas in the literature that link technological interventions to economic outcomes in chickpea cultivation.

Leveraging technology to strengthen chickpea-based farming system

Farmers cultivating chickpea often operate in marginal, rainfed, or semi-arid environments where traditional practices provide limited income stability. Over the past decade, technologies such as remote sensing, mobile advisory platforms, and on-farm diagnostic tools have increasingly been applied to chickpea farming to overcome production risks and market uncertainties.

Remote sensing and satellite technology

Satellite-based technologies are proving beneficial for chickpea growers by offering timely insights on soil moisture, pest infestations, and plant health. Many research organizations has supported chickpea-growing farmers through platforms like the Farmers' Portal, delivering satellite-driven advisories tailored to legume crops. Such tools empower farmers to make location-specific decisions, thereby improving yields and returns.

Digital platforms and mobile applications

Digital connectivity has transformed the way chickpea farmers access information and markets. Platforms like e-NAM enable direct market participation, allowing farmers to bypass intermediaries and secure better prices. As per the Ministry of Agriculture, over 1.7 million farmers, including pulse growers, have benefited from these platforms through increased transparency and reduced transaction costs (Press Information Bureau 2021).

Crop breeding: Unlocking chickpea's income potential

Genetic improvement has played a pivotal role in enhancing chickpea productivity. With increasing instances of droughts, pests like *Helicoverpa armigera* (pod borer), and soil nutrient depletion, breeding for resilience and market traits has become vital.

High-yielding and disease-resistant varieties

Breeding programs have produced several chickpea varieties with traits such as Fusarium wilt resistance, early maturity, and heat tolerance (CGIAR, 2015). These traits help stabilize yields in stress-prone environments. Varieties like 'JG 14' and 'Pusa 362' have shown promising yield gains under minimal input conditions.

Market-preferred and climate-smart traits

Efforts have also focused on developing chickpea lines with larger seed size, better cooking quality, and nutritional enrichment (e.g., higher protein or iron content). Such traits improve the marketability of the crop and offer farmers higher price realization per unit yield (Nkonya *et al.* 2004).

Agronomic practices supporting income enhancement in chickpea

Improved agronomic techniques can reduce costs and increase profitability in chickpea production. These include water-smart practices, soil fertility management, and integrated pest management (IPM).

Crop rotation and soil health

Inclusion of chickpea in cereal-based rotations improves nitrogen availability and soil structure. For instance, chickpea-wheat rotations have been shown to reduce fertilizer dependence and increase profitability (Pretty 2007). The legume's role in biological nitrogen fixation also reduces input costs in subsequent crops.

Water-efficient technologies

Though chickpea is generally grown under rainfed conditions, supplementary irrigation at critical stages using drip or sprinkler systems can improve water productivity. A study published in the Journal of Agricultural Science (Yang *et al.* 2023) highlighted that pulse crops using drip irrigation saw up to 40–45% income gains due to yield and input efficiency improvements.

Integrated pest management (IPM)

Chickpea is vulnerable to pod borer infestations, which can cause significant yield losses. IPM techniques combining neem-based biopesticides, trap crops, and natural predators have shown success in reducing pest loads and pesticide expenses. The FAO (2019) reports that IPM in pulses can increase net farm income by up to 50%.

Drivers of technology adoption among chickpea farmers

Technology adoption in chickpea cultivation is not uniform across geographies. It is shaped by a complex interplay of economic, institutional, and social factors.

Assets and risk capacity

Farmers with larger landholdings, access to credit, and higher education are more likely to adopt new technologies. Access to schemes like the Kisan Credit Card has been shown to accelerate the use of improved chickpea varieties in India (Krishna and Qaim, 2007).

Institutional support

Extension services play a critical role in training farmers and building awareness around improved seeds, IPM, and market platforms. Studies in West Africa and South Asia have shown that access to extension increases the likelihood of adopting advanced agronomic practices (Feder *et al.* 1985, Meinzen-Dick *et al.* 2004).

Social networks and peer learning

Farmer-to-farmer interaction and the visibility of success stories significantly influence adoption. Research indicates that chickpea growers are more likely to try new technologies when they observe tangible benefits among neighbors (Manda *et al.* 2018).

Traditional versus modern farming in chickpea cultivation

While traditional chickpea farming practices emphasize seed saving and indigenous knowledge, modern techniques promise scalability and resilience. Each system has its own implications for income.

Traditional practices

Many smallholders rely on traditional seed varieties passed down through generations. These systems help conserve local biodiversity and keep costs low. However, they often yield less and are susceptible to climate shocks and pests.

Modern approaches

In contrast, modern farming relies on improved cultivars, mechanization, and digital tools. Although the initial investment may be higher, the returns in terms of income, stability, and efficiency are often significantly better (Hazell and Wood 2007).

CONCLUSION

This bibliometric analysis highlights the expanding body of research on the economic implications of technology adoption in chickpea farming. With 1329 scholarly publications examined across several decades, the findings reveal a growing global interest in understanding how technological innovations can enhance the income and resilience of chickpea farmers. Notably, the United States emerged as a central player in collaborative research networks, forming strong links with countries such as India, which is among the world's leading producers and consumers of chickpea. Institutional analysis underscored the influential role of organizations like Wageningen University & Research, the International Food Policy Research Institute (IFPRI), and the International Maize and Wheat Improvement Center (CIMMYT), which have actively contributed to legume-based development studies. Prominent journals such as Agricultural Systems and Agricultural Economics were identified as key platforms for disseminating knowledge in this field. Many of the studies reviewed are closely aligned with the Sustainable Development Goals, particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action), reaffirming chickpea's role as a strategic crop in the fight against hunger and rural poverty. The synthesis of research themes points to several technological pathways that positively influence chickpea farmers' income. These include high-yielding and climate-resilient varieties, integrated pest management practices, mobile-based market information systems, and water-efficient irrigation technologies. However, the pace of adoption continues to be influenced by farmers' access to resources, institutional support, and perceived risk. Going forward, sustained investment in participatory breeding, digital extension, and cross-country research collaboration is essential. Chickpea's low input demand, soil-enhancing properties, and market versatility make it an ideal crop for sustainably scaling technological interventions. Continued exploration in this domain will empower smallholders with tools that improve livelihoods, stabilize income, and contribute to global food and nutrition security.

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