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# TECHNOLOGICAL IMPACT ON POTATO FARMERS' INCOME: INSIGHTS FROM A BIBLIOMETRIC ANALYSIS

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**ABSTRACT: This research encompassed a bibliometric analysis aimed at assessing the advancement of studies concerning the technological impact on potato farmers' income. The analysis employed Dimensions.ai data and involved querying keywords such as "Impact" and "Technology" and "Income" and "Potato" "Farmer" from 1974 to 2023, yielding 1329 pertinent documents in CSV format. To comprehend the intellectual framework, VOS viewer software (version 1.6.19) was utilized to visualize and analyze the collected data. The results unveiled the pre-eminence of human society in publications concerning the effects of technology on farmers' income, with 578 papers. Among these articles, a majority (613) were aligned with Sustainable Development Goal 2, focused on zero hunger. Investigation into co-authorship among countries highlighted the United States as a prominent and active contributor to present research, with other nations forming clusters around it. In terms of organizational citations, Wageningen University and Research, International Maize and Wheat Improvement Center and International Food Policy Research Institute as the leading entities, underscoring their substantial influence in the field. Notably, the "Agricultural Systems" and "Agricultural Economics" journals emerged as a prominent source for present research. The study advocates for collaborative research efforts to effectively investigate the technological impact of farmers' income, emphasizing the importance of cooperation over isolated endeavours.**

**KEYWORDS:** Agriculture, potato farmers' income, sustainable development goal, technology

## INTRODUCTION

In today's rapidly evolving agricultural landscape, modern technologies are becoming indispensable for farmers, including those cultivating staple crops like rice, wheat, and even specialized crops such as potatoes. Technologies like precision farming, digital platforms, and data-driven tools are reshaping how farmers approach agriculture, helping them address key challenges, optimize resource use, and unlock new growth opportunities. These innovations not only enhance productivity and reduce costs but also provide valuable market insights, allowing farmers to create more value from their efforts.

Numerous studies highlight the transformative impact of these technologies. For instance, research by the National Council of Applied Economic Research (NCAER) in India found that farmers, including potato growers, who adopted precision agriculture techniques experienced a rise in net income by as much as 35% (NCAER, 2020). Similarly, the World Economic Forum suggests that embracing modern agricultural technologies could boost incomes by 70% and potentially lift 150 million people out of poverty by 2030 (World Economic Forum, 2020).

Precision agriculture tools, such as soil sensors, drones, and advanced data analytics, have proven especially beneficial in improving farming practices. Studies show that these technologies can increase crop yields by up to 20% while reducing the use of water

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and fertilizers by 30% and 20%, respectively (UNCTAD, 2020). For potato farmers, in particular, this translates into more efficient water use, improved soil health, and higher yields per hectare.

Beyond boosting production, modern technologies also help farmers, including potato growers, reduce operational costs. Automation, robotics, and IoT systems streamline farm operations, reducing the reliance on manual labour and making farming more efficient. The Food and Agriculture Organization (FAO) found that using drones for pest control, for example, can cut pesticide usage by 30%, resulting in significant cost savings (FAO, 2019). These efficiencies directly translate into higher profitability.

Moreover, access to real-time market data through digital platforms is revolutionizing how farmers make decisions. Mobile phones and the internet allow farmers to monitor live market prices, weather conditions, and demand trends, enabling them to make informed choices on what to grow, when to harvest, and how to price their crops. The World Bank reports that such platforms have contributed to a 10% increase in income for farmers in some developing nations (World Bank, 2021).

The positive impact of technology on farmers' incomes is strongly linked to the United Nations Sustainable Development Goals (SDGs), particularly those aimed at eradicating poverty (SDG 1), ensuring food security (SDG 2), and promoting sustainable economic growth (SDG 8) (United Nations, 2015; World Bank, 2020).

This study conducts a bibliometric analysis to explore how technological advancements influence farmers' incomes, particularly for crops like potatoes. By examining scientific literature, this analysis seeks to uncover trends, research gaps, and opportunities for collaboration in this evolving field. The study is divided into two main sections: the first focuses on the research methods, outlining data collection and processing, while the second presents a comprehensive analysis of the findings.

## MATERIALS AND METHODS

### The Data

This research employed bibliometric analysis to explore the implications of technology on farmers' income. The term "bibliometric analysis" was coined by Groos and Pritchard to refer to a set of quantitative tools used for tracking and assessing literature related to a specific subject (Pritchard, 1969; Roemer and Borchardt, 2015). Our approach followed the procedural steps outlined in Fig. 1 for this investigation, covering the time span from 1974 to 2023.

For data collection, we relied on Dimensions.ai, a research information system provided by Digital Science. While standardized research publications were traditionally confined to the Web of Science (WoS) (Bass *et al.*, 2020), alternatives like Scopus and Google Scholar gained prominence, especially in regions with limited resources. Google Scholar became a preferred choice for researchers in developing nations due to accessibility despite financial constraints. The platform enabled convenient data access and concept development for stakeholders.

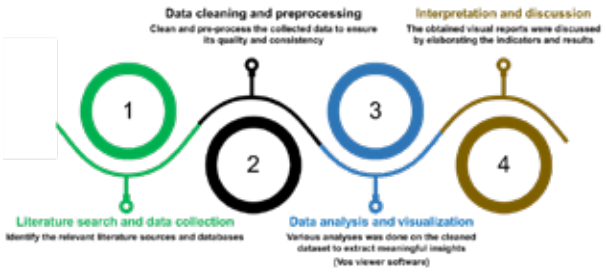


*Fig.1. Steps in bibliometric analysis*

The COVID-19 pandemic accelerated the pace of bibliometric studies, emphasizing the need for real-time trend analysis (Hook *et al.*, 2021, Das *et al.*, 2021). Dimensions, as a comprehensive platform, grants scholars access to a wide range of full-text data, including pre-prints, articles, conferences, and more, spanning different years. This expanded dataset offers new avenues for exploration. Machine learning techniques establish connections among scholarly items, while data enhancements like categorizations and disambiguation of entities provide additional context.

In this study, we relied on the Dimensions database to gather relevant information such as authors, article titles, affiliations, and other pertinent details. The Dimensions database, with its diverse analytical functions including citation and subject analysis, is well-suited for bibliometric research. Although no language restrictions were imposed during data extraction, we limited the collection to English language documents, as the search query specified English titles and abstracts. This approach enabled content evaluation of non-English documents through their titles and abstracts.

The efficacy of bibliometric analysis hinges on the precision of the search query. Hence, we crafted a meticulous query based on an extensive review of existing literature and the identification of research gaps. The aim was to create a comprehensive query that yields high-quality and reliable results

## Selection of Database and Search Query

A focused query, tailored to our study's theme, was employed to ensure data accuracy. Our search terms included "Impact" and "Technology" and "Income" and "Potato" and "Farmer". The search was confined to titles and abstracts within the timeframe of 1974 to 2023. We excluded unpublished sources, pre-prints, and book chapters to ensure data reliability. Utilizing Dimensions.ai, we retrieved pertinent articles and filtered out irrelevant ones, resulting in 1329 documents presented in CSV format.

Subsequently, the retrieved data was subjected to analysis using VOS viewer software (version 1.6.19), a commonly used tool for visualizing and dissecting the intellectual landscape of a field (van Eck and Waltman, 2017). Additionally, we conducted trend analysis to unveil patterns and developments within the literature. By adhering to these steps, we amassed and scrutinized an extensive collection of pertinent documents, facilitating visualization of the intellectual framework and identification of trends within the studied domain.

## Data Extraction and Analysis

For data analysis, we compiled the data in MS Excel CSV format to facilitate subsequent assessment. Tabular analysis was executed using Excel, while VOS Viewer software (version 1.6.19) was employed for constructing visual maps (van Eck and Waltman, 2017). Citation analysis gauged the scientific significance and impact of publications. To evaluate international research collaboration among participating countries, we introduced a metric called "connection strength," derived from visualized maps. This metric quantifies scientific collaboration between any two countries and is depicted by the thickness of connecting lines. A thicker line indicates greater collaboration and signifies higher connection strength.

# RESULTS AND DISCUSSION

After a thorough examination of pertinent data, a comprehensive total of 1329 documents underwent meticulous scrutiny within the scope of the study. Fig. 2 visually portrays the distribution of articles that adhered to the

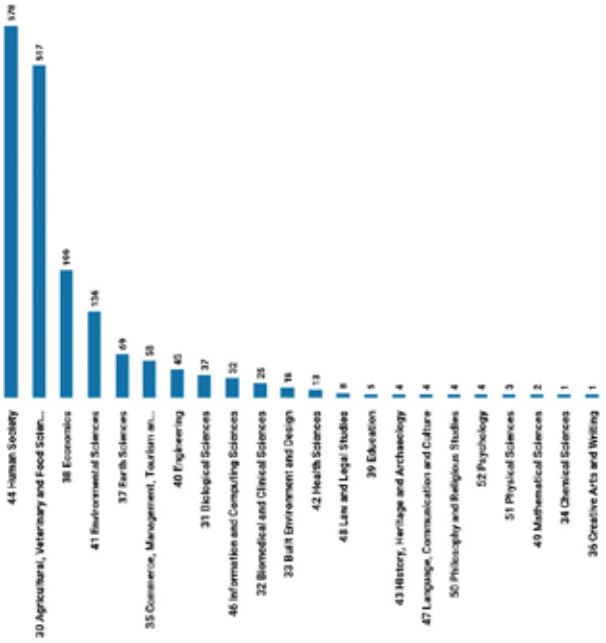


*Fig.2. Number of publications in each research category*

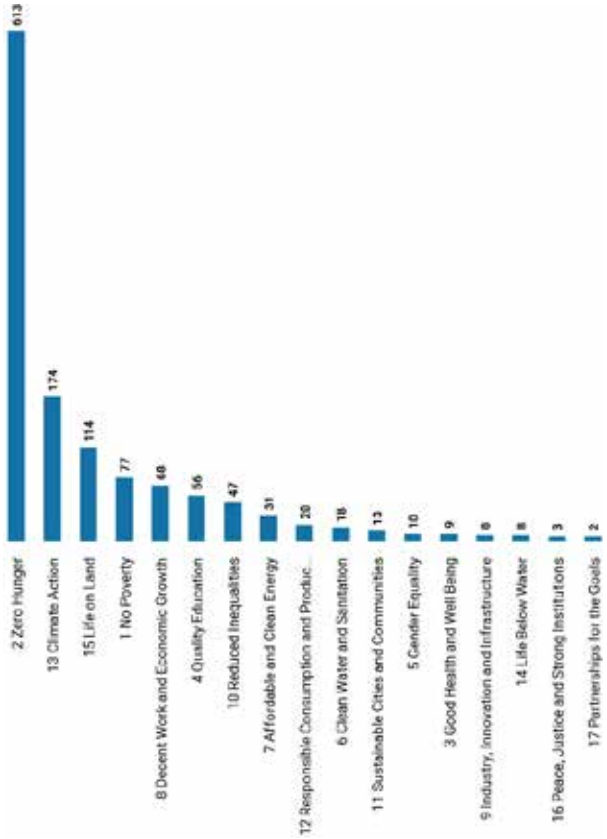


*Fig.3. Number of publications on the SDG themes*

criteria encompassing the broader subject area under investigation. The findings unveiled that the domain of human society exhibited the highest volume of publications pertaining to the influence of technology on farmers' income, totalling 578 articles, closely followed by agricultural, veterinary, and food sciences with 517 publications. In a bid to delve deeper into the correlation between technological impact on farmers' income and the Sustainable Development Goals (SDGs), an analysis of the publication count associated with each SDG criterion was undertaken. The outcomes of this analysis are effectively presented in Fig. 3. Notably, the preponderance of articles was aligned with SDG 2, namely Zero hunger, amounting to 613 publications, trailed by SDG 13, Climate Change, with 174 publications.

Fig. 4 provides an overview of the cumulative count of publications throughout the study duration. The graph unmistakably delineates a prevailing ascending trajectory in such publications from 2005-06 to 2022. The significant surge in publications after

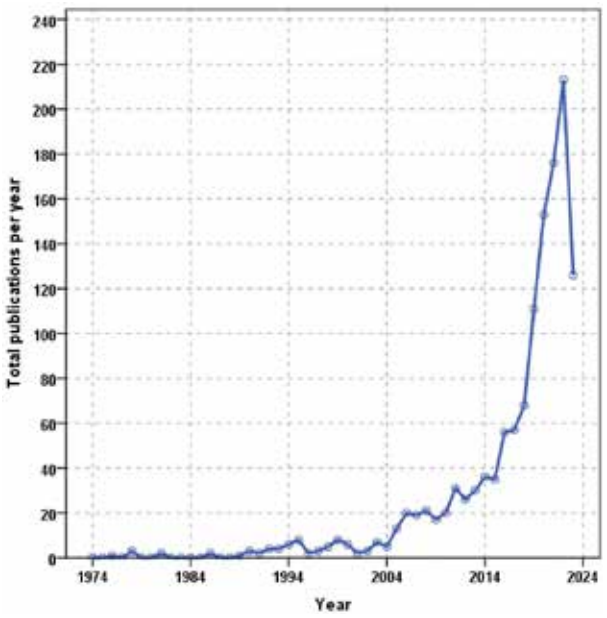


*Fig.4. Growth of publications during the study period*

2005 can be attributed to the confluence of several factors. Firstly, this period witnessed a notable advancement in technology, with the proliferation of digital tools, data analytics, and precision farming techniques. These innovations presented unprecedented opportunities for enhancing agricultural productivity and income, prompting researchers to delve into their implications. Moreover, the increasing availability and accessibility of data, coupled with the rise of open-access platforms and digital repositories, facilitated the dissemination of research findings, fuelling scholarly interest in the subject. Additionally, growing concerns about global food security, sustainability, and the need to uplift rural economies led to a heightened focus on leveraging technology to bolster farmers' incomes. Consequently, academia, policymakers, and agricultural practitioners recognized the urgent need to comprehensively study the multifaceted interactions between technology adoption and income generation, driving the exponential growth in publications on this vital nexus (Rosenzweig *et al.*, 2013; Wheeler and von Braun, 2013).

## Performance Analysis

### *Top Author Analysis*

Assessing an author's impact heavily relies on their contribution in terms of both the number of documents authored and citations received. Our study presents outcomes in both tabular and visual formats. Table 1 furnishes data about prolific authors, encompassing document count and average citations per document. Through scrutiny of co-authorship links, we quantify the extent of collaboration between individuals. The table analysis centres on the top 10 authors identified in our research. For a graphical depiction, refer to Fig. 5, illustrates the findings via visualization using VOS software.

**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 |

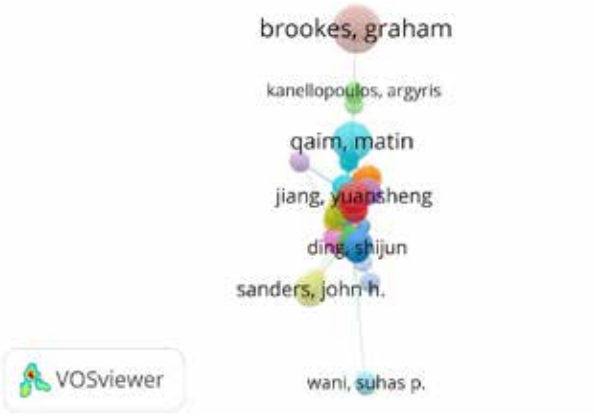


*Fig.5. Visualization map of co-authorship analysis of the authors*

This co-authorship scrutiny unveils authors' interconnectedness, spotlighting significant collaborative endeavours among them.

Employing the VOS viewer, we performed co-authorship analysis within specific parameters. We maintained a minimum of two documents per author and a maximum of twenty-five authors per document. Articles not meeting these criteria were automatically excluded. The outcomes of this analysis are depicted in Fig. 5, showcased in the VOS viewer's output interface.

Among the considered authors, 319 individuals met the stated requirements.

Yet, only 32 of them exhibited connections or associations with each other. The analysis unveiled 17 distinct clusters, each highlighting collaboration among authors within the respective cluster. Co-authorship stands as a highly quantifiable manifestation of scientific collaboration, well-documented and generating a "co-authorship network" through author interactions. Fig. 5 visually captures the robust networking within these nine clusters of authors. Noteworthy authors, such as Graham Brookes, Matin Qaim, and Yuansheng Jiang, among others, contributed significantly to collaborations within this context.

## Co-Authorship Analysis of Countries

The analysis of country co-authorship within the same dataset was conducted to explore collaborative relationships between nations. To establish a robust collaboration network, specific criteria were applied to filter and obtain pertinent data. The requirement was set at a minimum of five documents per country, resulting in 44 countries out of the initial 91 meeting the criteria. Fig. 6 visually illustrates this network, presenting a map featuring labelled circles denoting individual countries. The size of each circle corresponds to the quantity of documents produced by that specific country. Larger circles and labels indicate a more substantial impact and contribution to the particular study. Significantly, the United States emerges as a prominent and active participant, while other countries cluster around it. This observation indicates a strong network of collaboration among these nations.

## Citation Analysis

The collected data was employed for conducting a citation analysis, a widely adopted bibliometric method involving the scrutiny of citations within a paper to establish linkages with other researchers. Sandison emphasized that a citation transcends being a mere bibliographic reference appended to the end of a text, encompassing remarks, footnotes, or excerpts from a citation index (Sandison, 1989). Instead, it embodies an author's purposeful decision to forge a connection between their work and that of another researcher at a specific juncture. Likewise, Shaw asserted that citations create bonds among authors, signifying the degree of their indirect interaction through scholarly literature (Shaw, 1983). The citation analysis of organizations and sources is visually presented in Fig. 7 and 8, correspondingly.

To delve into inter-organizational citations, a minimum of five documents from each organization was set as a threshold.

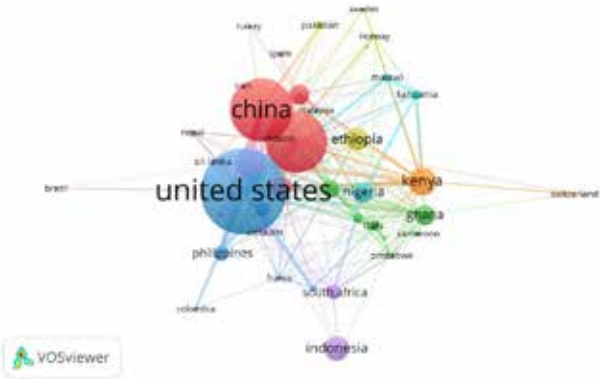


*Fig.6. Visualization map of co-authorship analysis of the countries*


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

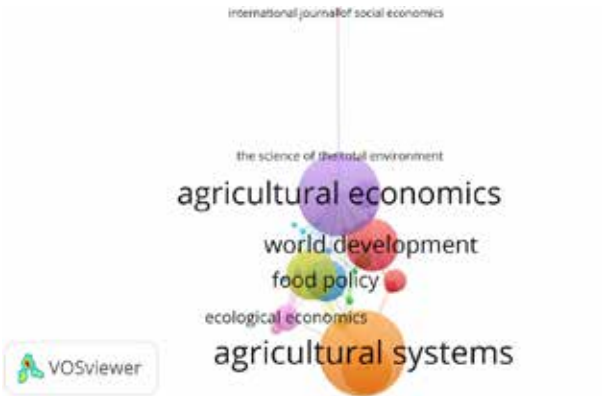


*Fig.8. Visualization map of the citation analysis by source*

The study identified a total of 54 relevant organizations and grouped them into 10 clusters based on predetermined criteria. Notably, Wageningen University and Research, International maize and wheat improvement center and International food policy research institute surfaced as the top three organizations, underscoring their substantial influence.

Citation analysis was also conducted for the sources engaged in this study, employing a criterion of at least four documents per source. Consequently, 38 sources fulfilled this criterion and were categorized into 9 clusters. Of the sources scrutinized, only 12 exhibited a robust interconnection. The size of the bubble associated with each source mirrors its impact, with larger bubbles denoting greater influence. Two journals namely "Agricultural systems" and "Agricultural economics" showing greater influence on research related to technological impact on farmers' income.

## Comprehensive research synthesis

Comprehensive research synthesis is essential for understanding how modern technology adoption affects the income of potato farmers. By reviewing various studies and findings, this review provides a broad perspective on how technological advancements influence potato farming practices and improve economic outcomes.

### a. Harnessing technology to address the agrarian crisis in India

India's agriculture sector, including its significant potato farming community, faces challenges such as low incomes, rising debts, and farmer distress. Technology has become a critical tool for transforming potato farming, helping farmers increase yields, reduce costs, and enhance market access, which are crucial steps toward alleviating the agrarian crisis.

#### *Remote sensing and satellite technology*

Remote sensing technology, using satellite imagery and aerial surveys, provides potato farmers with crucial data on crop health, soil moisture levels, and pest infestations. This information allows farmers to address specific problem areas proactively, improving productivity and securing their income. The Indian Space Research Organisation (ISRO) supports this through services like the "Farmers' Portal," offering real-time information to help potato farmers make informed decisions.

#### *Digital platforms and mobile applications*

Digital platforms and mobile applications have become powerful tools for potato farmers, enabling them to access critical information, connect with markets, and secure financial support. Platforms like e-NAM (Electronic National Agriculture Market) enable potato farmers to trade directly with buyers, bypassing intermediaries and securing better prices. According to the Ministry of Agriculture, over 1.7 million farmers, including many potato growers, have benefited from e-NAM, leading to better incomes.

## b. Importance of crop breeding in enhancing potato farmers' income

Crop breeding is crucial for potato farmers in developing varieties that yield more, resist diseases, and adapt to challenging environmental conditions (Nkonya *et al.,* 2004). This section explores how advances in crop breeding enhance the income potential of potato farmers.

### *High-Yielding Varieties (HYVs)*

The development of high-yielding potato varieties (HYVs) has significantly increased productivity per unit of land. These varieties are specifically bred for traits like disease resistance, high yield potential, and adaptability to different climates (Eberhart, 1989; Nkonya *et al.,* 2004). HYVs help potato farmers improve their output and income by ensuring stable and increased yields.

### *Resistance to pests and diseases*

Pest- and disease-resistant potato varieties are vital in reducing crop losses and boosting income. Research has shown that improving resistance in potato crops can significantly increase yields, helping farmers maintain consistent production even in the face of pest outbreaks (Sitch *et al.,* 1996).

### *Stress tolerance and market-preferred traits*

Breeding stress-tolerant potato varieties allows farmers to maintain production levels in difficult growing conditions, such as drought or poor soil quality. Additionally, breeding potatoes with traits preferred by the market, such as improved quality or nutritional value (Das and Das, 2023), increases the prices potato farmers can command, directly impacting their income.

## c. Agronomic practices and their role in improving potato farmers' income

Agronomic practices are critical for optimizing resource use, improving farm productivity, and minimizing risks for potato farmers. Techniques like crop rotation, soil management, water-efficient technologies, and integrated pest management (IPM) are key contributors to income growth (Mwania *et al.,* 1989).

### *Crop rotation*

Crop rotation, where potato farmers alternate crops in a planned sequence, helps break pest and disease cycles, improve soil fertility, and reduce weed issues (Bisanda and Mwangi, 1996). This practice improves soil health and contributes to yield increases, ultimately raising farm profits.

### *Soil management*

Effective soil management, such as balanced nutrient application and soil conservation, is crucial for maintaining high potato yields (Mwania *et al.,* 1989). A report by the International Plant Nutrition Institute (IPNI) found that proper nutrient management can improve incomes by up to 30%, as it ensures sustainable soil productivity and minimizes nutrient loss (Das *et al.,* 2024)

### *Water-efficient technologies*

Water-efficient technologies are essential for potato farmers, particularly in areas facing water scarcity. Techniques like drip irrigation reduce water wastage and improve efficiency. A study in the Journal of Agricultural Science showed that drip irrigation in potato farming can lead to a 47% increase in income (Yang *et al.,* 2023).

### *Integrated Pest Management (IPM)*

Integrated Pest Management (IPM) is an environment friendly approach that combines biological control, cultural practices, and careful pesticide use to manage pests effectively. The FAO estimates that IPM can increase potato farmers' incomes by up

to 50% by reducing crop losses and cutting chemical input costs.

### d. Factors influencing potato farmers' adoption of technology

The decision to adopt modern technologies in potato farming is influenced by several factors, including farmers' assets, vulnerability, institutional support, and other considerations.

#### *Assets*

Farmers' access to resources such as land, capital, and labour significantly impacts their ability to adopt new technologies (Meinzen-Dick *et al.,* 2004). Potato farmers with larger landholdings or better access to credit are more likely to adopt advanced technologies, as they can manage the associated costs and risks (Adesina and Baidu-Forson, 1995). For instance, access to credit has been a key factor in the adoption of improved potato varieties in India (Krishna and Qaim, 2007).

#### *Vulnerability*

Potato farmers' exposure to risks, such as climate variability and market price fluctuations, affects their willingness to invest in new technologies. Vulnerable farmers, especially those in drought-prone regions, may hesitate to adopt water-saving technologies due to uncertainty (Mazonde, 1993). A study in Uganda revealed that risk-averse farmers were less likely to adopt better agricultural practices (Kassie *et al.,* 2018).

#### *Institutions*

Institutional support, such as agricultural extension services and farmer cooperatives, plays a crucial role in encouraging technology adoption. Extension services offer potato farmers the technical training needed to implement new methods effectively (Meinzen-Dick *et al.,* 2004). Studies in Kenya and Nigeria show that access to extension services increases farmers' likelihood of adopting improved crop varieties (Adesina and Zinnah, 1993; Feder *et al.,* 1985).

#### *Other Factors*

Other factors influencing technology adoption include the perceived benefits, costs, and ease of use of the new technologies, as well as the influence of social networks and peers (Mwania *et al.,* 1989). Potato farmers are more likely to adopt new technologies if they see others in their community benefiting from them (Manda *et al.,* 2018).

### e. Traditional agriculture vs. Modern agriculture: Impact on potato farmers' income

The shift from traditional to modern agricultural practices has profound implications for potato farmers' incomes. While traditional farming methods are still in practice, modern techniques offer substantial advantages in terms of productivity and profitability.

#### *Merits of traditional agriculture*

Traditional agriculture, often practiced on a small scale, relies on local knowledge and is well-adapted to specific ecosystems (Altieri and Toledo, 2011). Potato farmers in traditional systems often save seeds from their harvests, reducing input costs and maintaining crop diversity, which can contribute to income stability (Pretty, 2007).

#### *Demerits of traditional agriculture*

However, traditional farming methods are generally less productive and more labour-intensive, limiting their income potential (Hazell and Wood, 2007). Potato farmers who rely on traditional methods may also struggle with limited market access, making it difficult to achieve higher incomes. Additionally, traditional systems are often

less resilient to climate change compared to modern farming techniques, which are better suited to withstand extreme weather events (Clarke, 1990).

## CONCLUSION

Based on the bibliometric analysis concerning the effects of technology on potato farmers' income, it was found that 44 nations displayed a robust collaborative network. Notably, the United States stood out due to its significant research contributions and impact in this field. Regarding the participating organizations, a total of 54 were identified and categorized into 10 distinct clusters. The top three influential organizations, as determined by their research impact, were the Wageningen University and Research, International maize and wheat improvement center and international food policy research institute. Among the various sources scrutinized, the agricultural systems and agricultural economics journals exhibited a noteworthy influence on technological impact of farmers' income research. In summary, technological impact of farmers' income studying the remains a crucial subject warranting continuous research and exploration. Further research in the realm of technological impact on farmers' income is imperative to unravel nuanced insights, optimize agricultural practices, and foster sustainable economic growth in farming communities worldwide. As technology continues to evolve, a deeper understanding of its implications holds the key to enhancing livelihoods and ensuring food security for generations to come. Robust investigation in this area will empower farmers with innovative tools and strategies, paving the way for resilient and prosperous agricultural systems.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## ETHICAL STATEMENT

This article does not contain any studies with human participants or animal performed by any of the authors.

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