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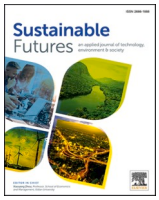

Impact of technology transfer on food security in developing territories: a bibliometric analysis and systematic literature review

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ABSTRACT

Technology Transfer (TT) refers to the movement of technical knowledge between organizations, including tools, expertise, and capacities that are useful in new productive contexts. Based on this premise, this study presents a systematic literature review (SLR) and a bibliometric analysis to explore the relationship between technology transfer and food security in emerging territories during 2014–2024. The Scopus and Web of Science databases were used, selecting only scientific and review articles in English. The methodology included the use of R's "Analyze Results" and "bibliometrix" tools for bibliometric analysis, following the PRISMA 2020 declaration for the SLR. 393 articles were identified across both databases, with 52 duplicates. Of the remaining 337 texts, 72 fullfilled the PICO criteria, and 55 were finally selected, focusing on the impact of technology transfer on food security. The bibliometric results indicate that 76.9 % of the documents analyzed are scientific articles and 20.4 % are reviews. The countries with the highest production in this topic were the United States, China, India, Germany and Brazil, while the most represented areas were Agriculture, Biological Sciences, Development of Sciences and Social Sciences. Although these issues are fundamental, the analysis highlights limited development in emerging territories, evidencing technological and socioeconomic barriers. This work highlights the importance of strengthening technology transfer strategies to address food insecurity, promoting agricultural sustainability and resilience in the face of climate change. The findings offer a robust foundation for future research and the formulation of effective public policies.

1. Introduction

In the last decade, technology transfer has become a key element for sustainable development, especially with regard to food security. The ability to transfer innovative agricultural technology from developed countries to emerging territories has proven to be a decisive factor in improving agricultural productivity and ensuring food availability in vulnerable regions. In Latin America and the Caribbean—a region that accounts for approximately 22 % of global agri-food exports, generates 5 % of the regional GDP, and employs 15 % of the population—technology transfer emerges as a strategic pillar for addressing the challenges of climate change and rising food insecurity, which currently affects 43.2 million people, or 6.5 % of the regional population. Although the adoption of digital technologies in rural areas still faces limitations, significant transformations are already being observed in agricultural practices, particularly in countries that have advanced in digital infrastructure and in strengthening productive capacities [1]. According to recent studies, the adoption of advanced technologies in agriculture not only improves production efficiency, but also contributes to the resilience of food systems in the face of climate and economic challenges [2]. For instance, in Latin America, technologies such as precision agriculture—which integrates sensors, drones, and big data analytics [3, 4]—have begun to transform production systems by reducing input use and improving the operational efficiency of crops. This has resulted in a significant increase in productivity and a reduction in environmental pressure [5].

In Brazil, approximately 42.4 % of farms in the southern region are already connected to the Internet, facilitating access to advanced digital technologies, such as automated crop monitoring and smart irrigation systems. However, in other regions, such as the Brazilian Northeast and

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several Central American countries, the lack of connectivity and digital literacy continues to be a significant barrier to technological adoption, highlighting the need for public policies that reduce these gaps. These innovations also have the potential to minimize environmental impacts, such as reducing the use of agrochemicals, contributing to sustainable development and climate resilience [5]. However, despite its potential, the effectiveness of technology transfer in the field of food security remains the subject of debate, especially in contexts where socioeconomic and political barriers make the implementation of these technologies difficult [6].

This review is crucial for understanding how food insecurity dynamics affect the global landscape, particularly in emerging territories. According to the FAO et al. [7] report, in 2023, it is estimated that between 713 and 757 million people suffered from hunger worldwide, representing approximately 9.1 % of the global population and an increase of 152 million compared to 2019. Additionally, 2.33 billion people (28.9 % of the world's population) faced moderate or severe food insecurity—a figure that has remained virtually unchanged since 2020. In this context, strengthening technology transfer to these territories can play a fundamental role, not only in mitigating these challenges but also in advancing toward the Sustainable Development Goals, such as Zero Hunger and Innovation Promotion (SDG 2 and SDG 9). This approach is particularly relevant given that an estimated 582 million people will still suffer from chronic undernourishment by 2030—around 130 million more than before the COVID-19 pandemic. This projection highlights the urgent need to transform agri-food systems in order to move toward the Zero Hunger goal set out in the SDGs [7].

This document is structured as follows: the introduction with the conceptualization of technology transfer, its applications and types, in addition to the concept of food security and its current state in the world and Latin America. Next, the methodology is presented, which addresses the stages of 1- inclusion/exclusion criteria, 2- sources of information and search strategy and 3- Systematic Literature Review (SLR). The results are based on the analysis of data obtained through the tools "Analyze Results" of Scopus and "Bibliometrix" of R. Finally, the conclusions and discussions of the work are presented.

1.1. Concepts related to technology transfer and food security

Technology transfer refers to the process by which knowledge, skills, technologies, manufacturing methods, samples, and manufacturing facilities are transmitted from one organization to another or from one country to another for application in new products, services, or production processes. This process is fundamental for economic development and innovation, facilitating the adoption of advanced technologies in different contexts and contributing to sustainable development [8].

Technology transfer can be applied in various sectors, including agriculture, medicine, manufacturing, energy, and information technology. For example, in the agricultural sector, technology transfer enables the adoption of genetically modified seeds and advanced cultivation practices to improve productivity and sustainability [9]. In the field of medicine, technology transfer facilitates the implementation of new diagnostic and treatment technologies, such as gene therapies and advanced medical devices [10]. A clear example is the South African case, where companies managed to adapt ultrasound probes originally designed abroad, demonstrating how absorptive capacity enables the integration and innovation of highly complex medical solutions [11]. Additionally, in the manufacturing industry, technology transfer is reflected in the incorporation of automated production techniques and the use of innovative materials, which enhance the sector's efficiency and competitiveness [8]. A representative example of this dynamic can be found in the Iranian automotive industry, where technologies such as polymer tanks—which reduce vehicle weight and fuel consumption—and automatic navigation systems based on advanced sensors have been implemented [12].

There are several types of technology transfer, among which the following stand out:

Horizontal transfer: refers to the transfer of technology between industries or sectors that operate at the same level of technological development. This includes, for example, the adoption of production technologies between different companies within the same sector [10].

Vertical transfer: involves the transfer of technology from research and development ($R + D$) to commercial production. This type of transfer is common in the transition of technological innovations from research laboratories to mass manufacturing [10].

International transfer: refers to the process of technology transfer between countries, especially from developed nations to developing nations, which is crucial for the technological advancement and economic development of the latter [8].

Related to research, food security is defined as physical, social and economic access to sufficient, safe and nutritious food to meet people's dietary needs and food preferences at all times, in order to lead an active and healthy life. healthy. This concept encompasses four key dimensions: food availability, food access, food utilization, and stability of these dimensions over time [13].

Moreover, the relationship between technology transfer and food security in emerging territories can also be considered in relation to trust management in organic agriculture, particularly regarding sustainable consumption behavior, environmentally conscious purchase intention, and healthy food choices [14], organic food consumption [15], and the sustainable management of food product brands [16].

In this regard, by 2022, it was estimated that around 828 million people worldwide were suffering from hunger—an increase of 46 million since 2020 and 150 million since the beginning of the COVID-19 pandemic. This rise in food insecurity is linked to conflict, climate change, and the economic effects of the pandemic [17]. In 2023, moderate or severe food insecurity affected 28.2 % of the population in Latin America and the Caribbean, equivalent to 187.6 million people. This figure represents a significant improvement compared to 2021, a year in which the prevalence was 6.1 percentage points higher—meaning 40.2 million more people were affected. Although this progress marks a second consecutive year of recovery, food insecurity in the region remains slightly above pre-pandemic levels, highlighting the persistence of structural barriers that limit regular access to sufficient and nutritious food [18].

Regarding child nutrition, the prevalence of stunting among children under five years old in the region was 11.5 % in 2022, reflecting a decrease compared to previous years, although major challenges remain [7]. In 2022, 440 million children under the age of five worldwide experienced child food poverty, of whom 181 million faced severe forms of nutritional deprivation. In Latin America and the Caribbean, 18 million children were affected, and 5 million suffered its most severe form—reflecting a structural issue that compromises their overall development [19].

In this study, a broad view of agricultural technology transfer is adopted, understood as the set of processes through which knowledge, tools, and productive capacities are shared, adapted, or implemented in diverse agricultural contexts. This perspective includes both nationally and internationally originated forms of technology transfer, without being limited to a single type or geographic scale. The diversity of analyzed experiences—from rural extension programs in Ghana and Colombia to public-private cooperation strategies in China, Rwanda, and India—provides insight into the multiple configurations that technology transfer assumes in emerging territories. This theoretical choice responds to the need to capture the complexity of the phenomenon in contexts where structural, institutional, and socio-cultural conditions may significantly influence technology adoption. Therefore, this study does not focus on a specific type of technology transfer (such as international transfer), but rather aims to comprehensively analyze how various forms of agricultural transfer impact the improvement of food security in vulnerable regions, identifying common patterns, barriers, and opportunities through a systematic analysis of recent scientific

literature.

Accordingly, this study is guided by the following research question: How does the implementation of agricultural technology transfer programs, compared to traditional methods, impact the improvement of food security in communities within emerging territories, considering food availability, nutritional quality, and supply stability? This question guides both the systematic literature review and the bibliometric analysis conducted, enabling the identification of patterns, gaps, and opportunities to strengthen the role of technology transfer in achieving the Sustainable Development Goals—particularly SDG 2 (Zero Hunger) and SDG 9 (Industry, Innovation and Infrastructure).

Finally, the objective of this work is to analyze the relationship between technology transfer and food security, evaluating how the adoption and diffusion of innovative technologies in agriculture can improve the availability of and access to food in vulnerable regions, especially in emerging territories. The scope of the review includes a comprehensive analysis of studies published in the last ten years, focusing on the effectiveness of different technology transfer strategies to strengthen food security. However, the limitations of the article include the possible exclusion of relevant literature published in languages other than English and the dependence on studies available in specific databases (Scopus and Web of Science), which could restrict the diversity of approaches considered in the review. In this context, the proposed work integrates a bibliometric analysis and a systematic literature review to identify trends, challenges and opportunities in technology transfer applied to food security, especially in emerging territories. This approach will not only map the current state of knowledge, but also provide tools to guide future research and strategies in the field, thus contributing to the achievement of the Sustainable Development Goals.

2. Methodology

This paper seeks to fill a gap in the literature by integrating quantitative (bibliometrics) and qualitative (systematic review) analysis to understand the impact of technology transfer on food security in emerging contexts.

The methodology proposed for this work is described in Fig. 1, which allows to evidence the roadmap of the Systematic Review of Literature and the bibliometrics carried out. In this sense, it begins with the criteria for inclusion or exclusion of the studies to be carried out, followed by the choice of the databases of scientific journals, selected keywords and search equations, continuing with the Systematic Literature Review -SLR- based on the PRISMA 2020 statement, and finally, the analysis of the results (Bibliometrics) obtained using the software tools: Analyze Results by Scopus and Bibliometrix by R.

2.1. Inclusion/exclusion criteria

This section details the criteria used to include or exclude (search filters) studies in the review. On this occasion, studies from original scientific articles and reviews in English and with a time period from 2014 to 2024 were taken into account.

2.2. Sources of information and search strategy

In this stage, the Scopus (Elsevier) and Web of Science (Clarivate) databases were used. The search equation was constructed through an iterative process, based on an exploratory review of recent literature and consultation of the UNESCO Thesaurus. The main terms identified were "technology transfer" and "food security," which were expanded with synonyms and related concepts to ensure more accurate thematic coverage. The search was structured with the term "technology transfer" in the title, abstract, and keyword fields (TITLE-ABS-KEY), combined using the AND operator with "food security" and its variants applied across all fields (ALL). This approach allowed for maximizing the relevance of results, reducing bias, and ensuring methodological traceability in accordance with PRISMA 2020 guidelines.

The resulting equation applied with all the inclusion/exclusion criteria mentioned for the Scopus database was:

(TITLE-ABS-KEY ("technology transfer") AND ALL ("food security" OR "food safety" OR "food protection" OR "food availability" OR "nutritional security" OR "food supply security" OR "food access" OR "food assurance" OR "food security" OR "food safety" OR "food protection" OR "food availability" OR "nutritional security" OR "food supply security" OR "food access" OR "food guarantee")) AND PUBYEAR > 2013 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English"))

The resulting equation applied with all the inclusion/exclusion criteria mentioned for the Web of Science database was:

(TS=("technology transfer")) AND ALL=("food security" OR "food safety" OR "food protection" OR "food availability" OR "nutritional security" OR "food supply security" OR "food access" OR "food assurance" OR "food security" OR "food safety" OR "food protection" OR "food availability" OR "nutritional security" OR "food supply security" OR "food access" OR "food guarantee") and 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 (Publication Years) and Article or Review Article (Document Types) and English (Languages)

From the searches carried out, 324 texts from Scopus and 69 from Web of Science were obtained for a total of 393 works.

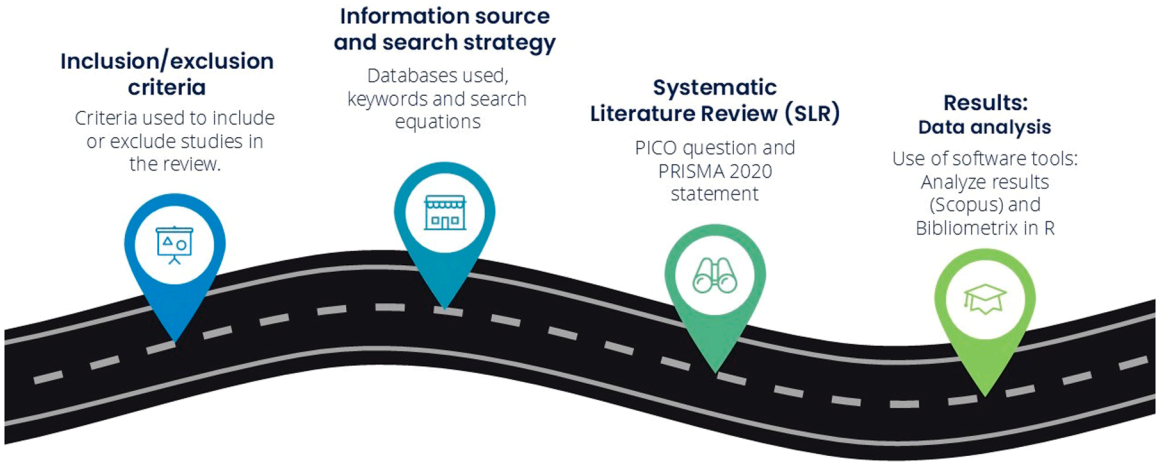

Fig. 1. Methodological route for the development of SLR and bibliometrics. **Source**: own elaboration.

2.3. Systematic literature review (SLR)

This stage allowed the selection of the works through the flow diagram of the PRISMA 2020 declaration [20], which shows the number of studies identified, eliminated for duplicates, reviewed for eligibility and finally included in the revision. To achieve a rigorous RSL and obtain quality literature results, the PICO question [21] was posed with the following criteria:

P (Population/Problem): communities in emerging territories (synonyms).

I (Intervention/Exposure): implementation of agricultural technology transfer.

C (Comparison): traditional methods of agriculture without technological intervention.

O (Outcome): improvement in food security, measured through food availability, nutritional quality, and stability of supply.

From the above, the following PICO question was raised:

"In communities of emerging territories (P), how does the implementation of agricultural technology transfer programs (I) compared to traditional agricultural methods (C) impact the improvement of food security, considering the availability of food, quality nutritional and supply stability (O)?"

The SLR proposes a database of 389 documents, and in the attempt to guarantee a scientific standard with transparency of the existing data relevant to the study, the PRISMA 2020 statement was used. Fig. 2 presents the PRISMA flow chart developed.

For the identification of new studies via databases and registries, previous studies, individual registries and other study searches (gray literature) were not taken into account, since they did not exist. The proposed stages are the following:

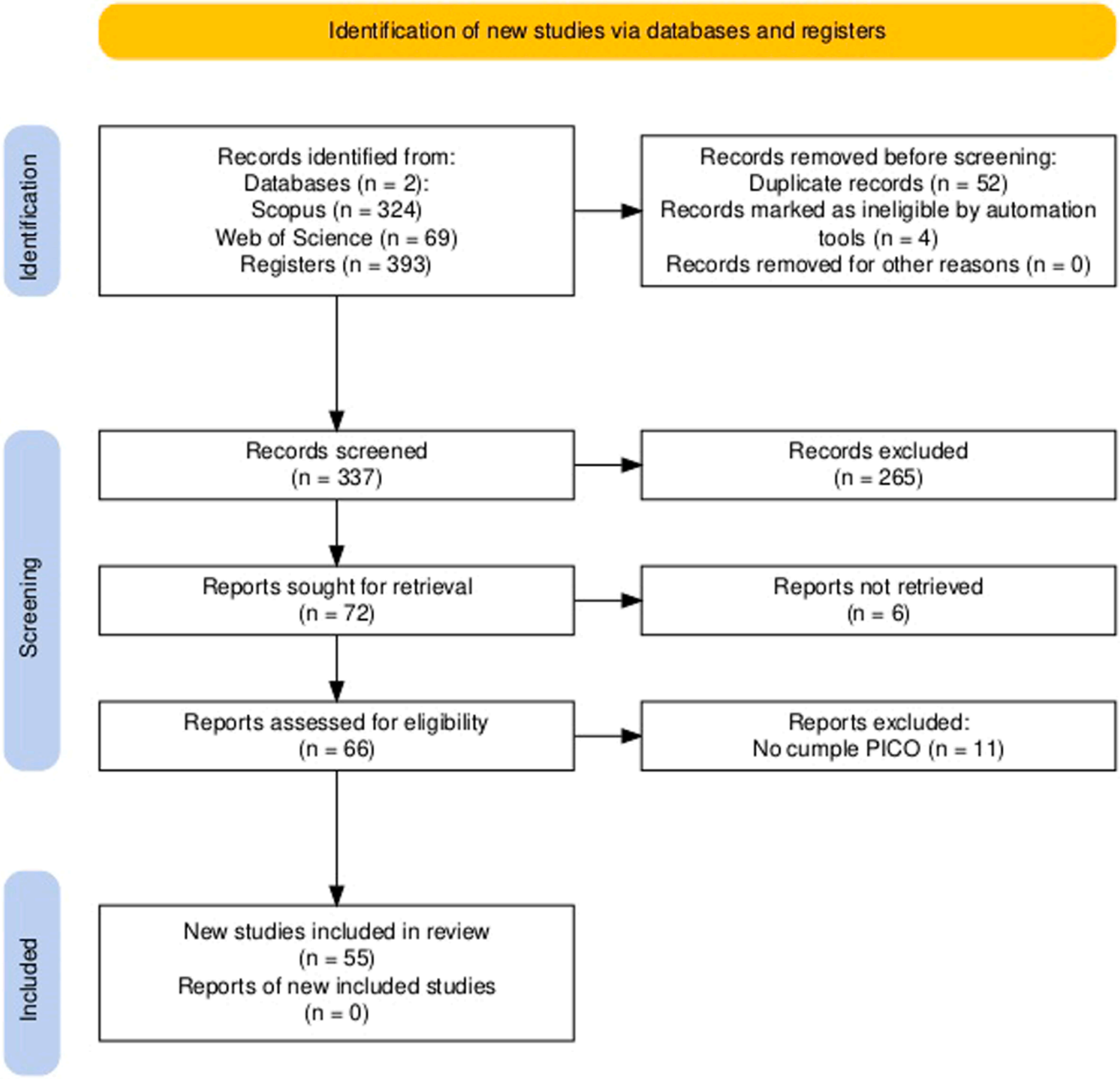

Fig. 2. PRISMA 2020 flowchart for the SLR.
Source: own elaboration.

- *Identification*: two databases were identified: Scopus and Web of Science, of which 393 records were totaled. 52 duplicate documents and 4 automatically deleted were found, resulting in 337 papers for initial review.
- *Screening or sifting:* the titles and abstracts of the 337 documents were analyzed in such a way that they were focused on the PICO question posed. This relationship allowed 72 papers to be admitted and 265 papers to be excluded. Next, of the 72 articles, 66 works could be accessed, of which a detailed reading of each one was carried out in such a way that it could be determined which articles will be taken into account for the construction of the state of the art. The exclusion of these is related to non-compliance with the PICO question, where due to: P (Population/Problem), I (Intervention/Exposure), C (Comparison) and O (Outcome/Results) 11 were excluded. Likewise, it is important to mention that 36 works partially fulfilled the PICO question and could be included in the state of the art, but require complementary studies to delve into more detailed aspects.
- *Include:* at the end of the SLR, 19 documents that fully complied with the criteria of the PICO question and 36 that partially did so are admitted, for a total of 55 works that will be used for the construction of the state of the art. Based on the selected articles, an inductive thematic analysis was carried out through an analytical reading of their objectives, results, and conclusions. Through this process, findings were grouped into different emerging categories, which served as the foundation for the qualitative discussion. This was done without the use of specialized software, but by following criteria of thematic coherence and alignment with the study's objectives.

3. Results

3.1. Data analysis using scopus' "Analyze results" and R's "Bibliometrix"

Taking into account that the total number of works analyzed (393) from the two databases with repetitions (337) is not significant with respect to that of the Scopus database (324), only this one was taken into account for the analysis, of which according to the "Analyze Results" tool, 258 correspond to scientific articles and 66 to reviews. The areas where the topics are being worked on the most are: Agriculture and Biological Sciences, Science Development, Social Sciences and Engineering.

To quantitatively analyze the information, and take into account the research trends that relate the study variables, a series of figures are presented below with the respective discussion of results.

Fig. 3 shows the annual scientific production, where a general upward trend is evident from 2014 to a peak around 2021, followed by a slight decrease towards 2023. The maximum peak occurs in 2021 with 51 published documents., but then there is a decrease in scientific output in 2022 and 2023. This could be due to changes in research priorities, adjustments in funding, or delays in projects caused due to the pandemic.

Table 1 presents the most relevant sources in terms of the number of documents published. It highlights that Sustainability (Switzerland) is the main source of publication on the subject analyzed with 15 publications, followed by other influential journals in the fields of sustainability and policies related to clean production and food security. The diversity of sources suggests a multidisciplinary approach to research, with a strong presence in journals covering key areas of scientific knowledge.

Fig. 4 presents the production of scientific articles over time, broken down by country for the years 2014 to 2023. The countries analyzed include Brazil, China, Germany, India and the United States. As can be demonstrated, all countries show an increase in the production of

Table 1
Most relevant sources in terms of published documents.

Sources	Articles
Sustainability (Switzerland)	15
Frontiers in Sustainable Food Systems	7
Journal of Cleaner Production	6
Science of the Total Environment	6
Food Policy	5
Agricultural Systems	4
Agricultural Water Management	4
Agronomy for Sustainable Development	4
Agronomy Journal	4
Technology in Society	4

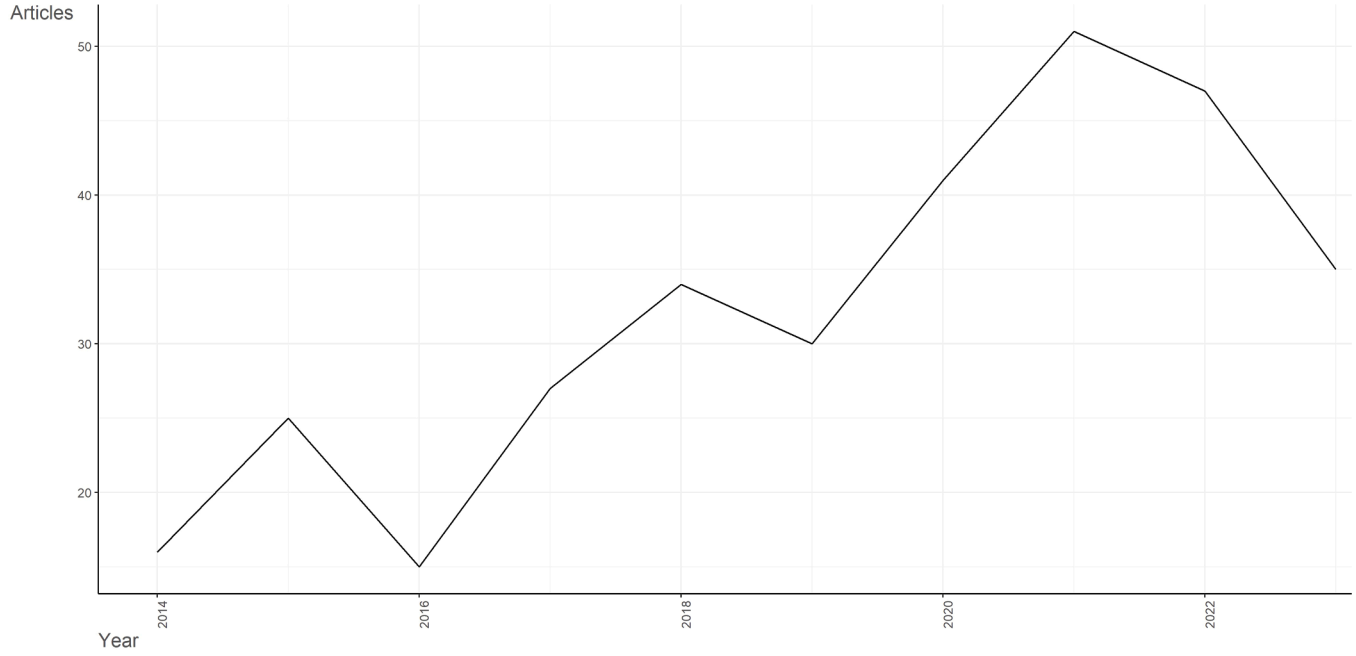

Fig. 3. Annual scientific production.
Source: own elaboration using the Bibliometrix tool by R.

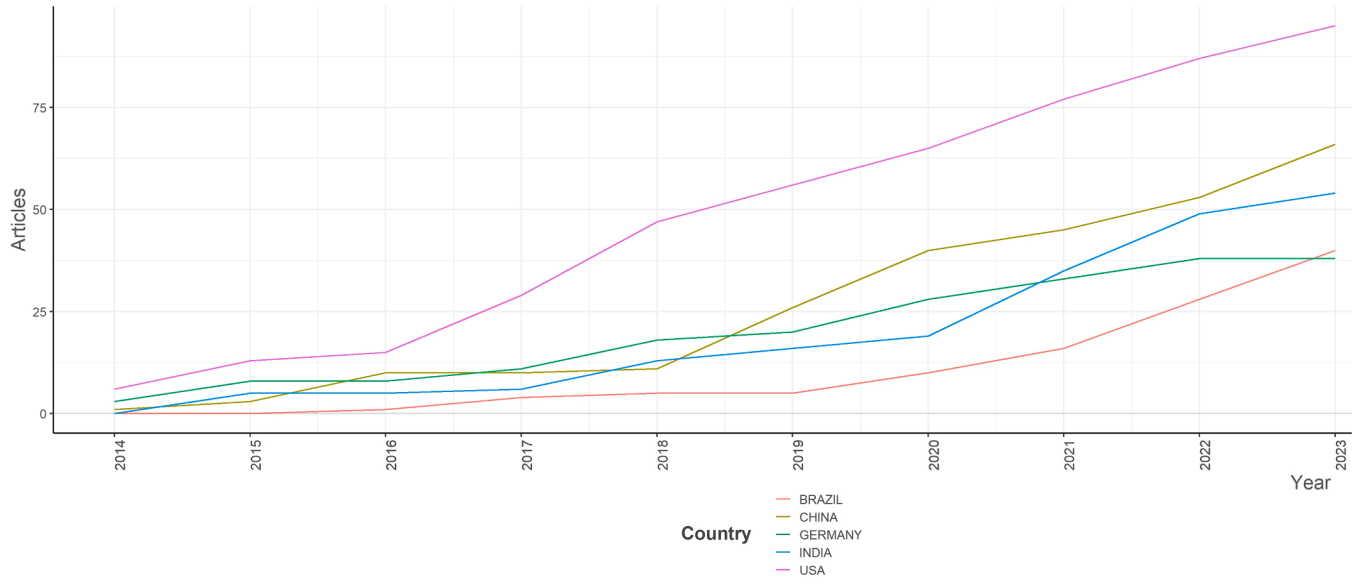

Fig. 4. Production of scientific articles by country over time.
Source: own elaboration using R's Bibliometrix.

scientific articles over time, however, the pace of growth varies between them. Likewise, the continued leadership of the United States in scientific production is evident, followed by strong growth in China and India. Germany maintains stable growth, while Brazil, although with the lowest production, shows an increasing trend. These patterns reflect global research dynamics, where emerging economies such as China and India are significantly increasing their scientific production, contributing significantly to global knowledge.

Fig. 5 represents a network of concurrency of terms or keywords. The term "technology transfer" is the most prominent central node in the network, indicating that it is the key concept around which the other terms are organized and connected. Its size in the graph suggests that it has the greatest number of connections with other concepts, reflecting its central relevance in the studies analyzed. Two thematic groups (red and blue) are also presented. The Azul group is related to agriculture and sustainable development. It includes terms such as "crops," "agricultural production," "climate change," "innovation," and "sustainability." These terms are strongly interconnected, suggesting that technology transfer in this context is significantly linked to improved agricultural productivity and adaptation to climate change, especially in developing countries. The Red group is more associated with issues of environmental impact, food security and biodiversity. It includes terms such as "food safety," "environmental impact," "biodiversity," and "ecosystem." The connections in this group indicate that technology transfer also has a significant impact on natural resource management and environmental protection, as well as on human and animal health. It is also important to mention

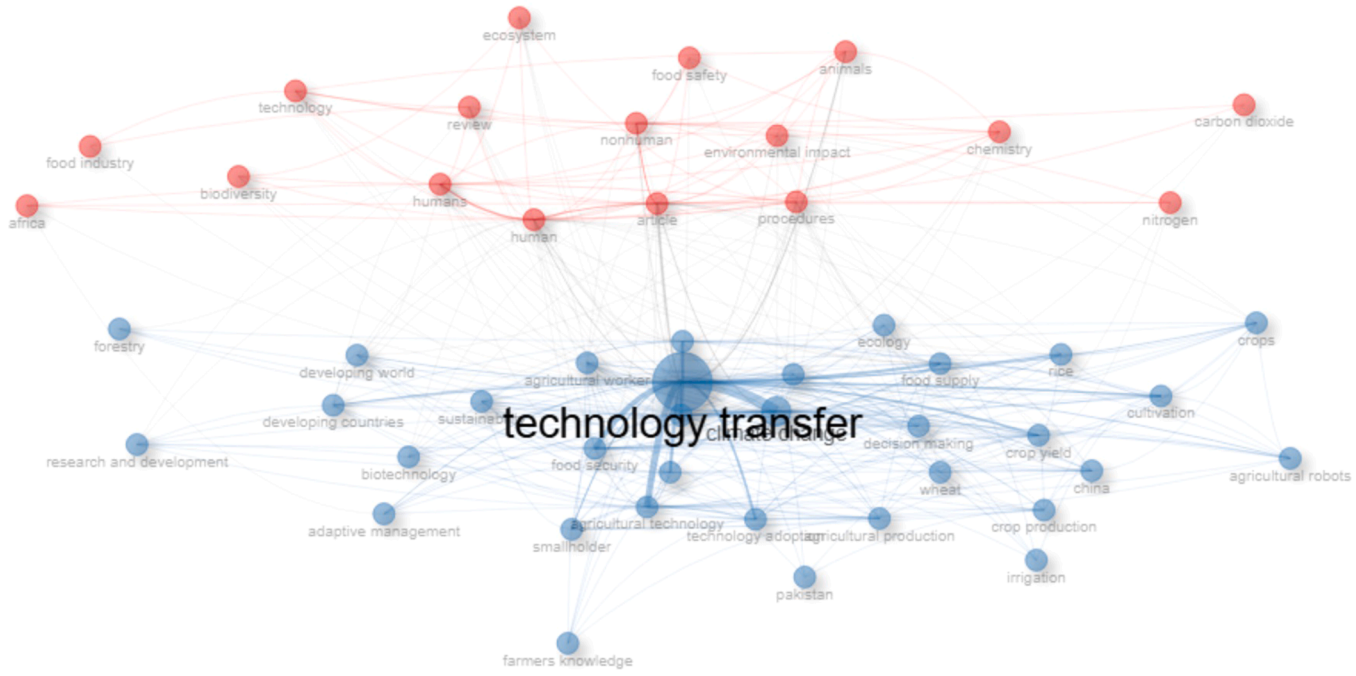

Fig. 5. A network of concurrency of terms or keywords.
Source: own elaboration using R's Bibliometrix.

that the network shows a remarkable interconnection between the terms of the blue and red groups. This suggests that the issues of technology transfer, agriculture, sustainable development, and the environment are intrinsically linked. For example, the term "climate change" connects directly to "food safety" issues, showing how technologies that are transferred to improve agricultural production must also address environmental challenges.

Fig. 6 presents the analysis of the thematic map with the distribution of the themes according to their degree of development (density) and their relevance (centrality), distributed as follows:

The lower right quadrant represents the basic or transversal themes (Low Density, High Centrality), grouping the terms: “technology transfer”, “climate change” and “agricultural technology”. These themes have high centrality, which means that they are fundamental to the field, but they present a low density, which indicates that their development is still limited or incipient. This interpretation suggests that technology transfer is crucial for advancing innovations, but its low development implies that it requires more attention in terms of research and practical application. Likewise, climate change is a central topic on the global agenda, especially in the agricultural context, but it also highlights the need for greater focus to develop effective strategies. Also, topics related to agricultural technologies are essential for the modernization of agriculture, but their low development suggests that research is still in its early stages or requires greater integration into current practices. These topics are crucial for developing strategies that improve food security through technology transfer, but it is evident that they require greater investment in research and development to reach their full potential.

In the same order of ideas, the upper left quadrant represents the Niche themes (High Density, Low Centrality), grouping the terms: “nitrogen”, “fertilizer application”, “carbon dioxide”, “animals” and “chemistry”. The themes in this quadrant are well developed, indicating that there is a strong internal structure around them, but they have low centrality, suggesting that they are relatively isolated from the core of the research. These topics are important within specific niches and can be highly relevant in specialized contexts. However, their low centrality suggests that they are not as interconnected with other broader or strategic themes in the field of food security or technology transfer.

3.2. Analysis of supported documents for the state of the art

For the descriptive analysis of the admitted documentation, the criteria of the PICO question were taken into account in such a way that only 36 texts partially complied and 11 in full.

Table 2 groups those works that partially met the criteria of the PICO question, but that were admitted for their relevance and contribution to the state of the art, as well as for their relevance to the topics treated. The topics included were defined through an inductive analysis of the selected articles, grouping those with similar approaches, objectives, or types of intervention. Assignment was based on reviewing the title, abstract, and main content of each article, which allowed for the identification of common patterns related to technology transfer and its impact on food security. This procedure enabled the organization of the corpus into coherent thematic categories suitable for comparative analysis.

Likewise, in Table 3 the works that fulfilled all the criteria of the PICO question, and admitted to the state of art for their relevance and impact are grouped.

To assess the robustness of the synthesis results, sensitivity analyses were performed considering different scenarios. First, we excluded studies with high risk of bias and low methodological quality, finding

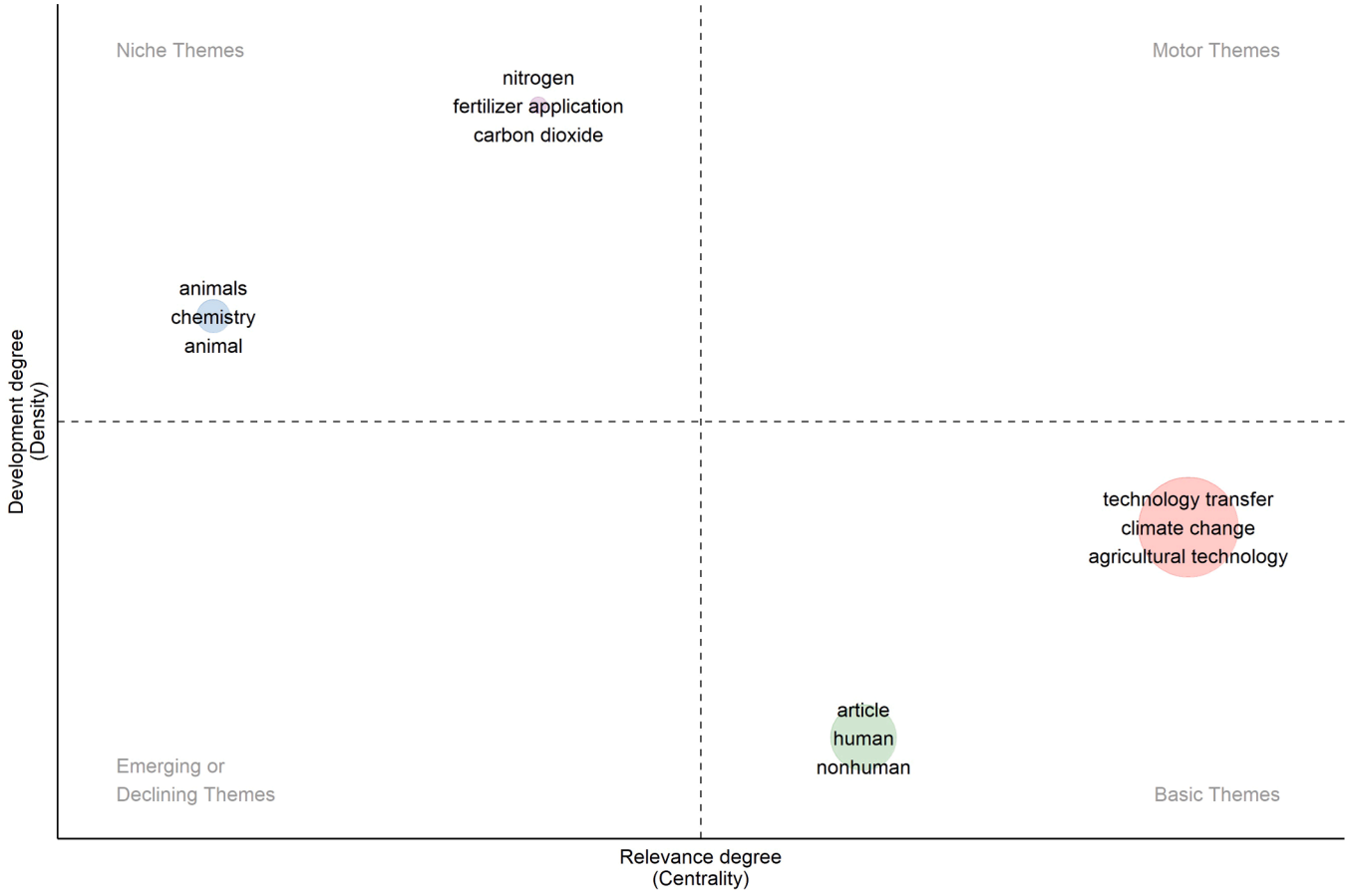

Fig. 6. Thematic map that relates the degree of development (density) and its relevance (centrality).
Source: own elaboration using R’s Bibliometrix.

Table 2
Accepted documents in the state of the art that partially meet the PICO question criteria.

Topic - Technological adoption in agricultural communities in emerging territories: This group shares a common approach in the implementation of agricultural technologies in rural communities, highlighting technological adoption challenges. The intervention consists of the technological transfer to improve the productivity and sustainability of agricultural practices.	
Title	**Description**
Addressing the paradox – the divergence between smallholders' preference and actual adoption of agricultural innovations	The article focuses on smallholder farmers in Sub-Saharan Africa and the challenges they face in adopting new agricultural technologies versus traditional methods. It is relevant for its focus on adoption and resistance factors [22].
Agricultural extension approach: evidence from an Integrated Soil Fertility Management Project in Ethiopia	Similar in its approach, this article analyzes the adoption of new technologies for the improvement of soil fertility in Ethiopia [23].
Dissemination paradox: how contextual realities influence smallholder farmers' modifications of agroforestry technologies in Uganda's Mt. Elgon region	It explores how smallholder farmers modify recommended technologies to suit their needs, which also reflects technology adoption challenges [24].
Incentives and the Diffusion of Agricultural Knowledge: Experimental Evidence from Northern Uganda	This article focuses on incentives to foster the adoption of agricultural technologies in Uganda, with a focus on the dissemination of technological knowledge [25].
Investigating Technology Transfer Gaps Through Farmers Field School	The article focuses on the methodology of field schools for farmers (FFS), a strategy used to transfer agricultural technologies in various rural communities with the philosophy of "learning by doing" [26].
Model sites: A new direction towards cooperation among extension agents, field experts, researchers, and farmers	The study given in agricultural communities in the province of Khuzestan, Iran, examines a technological transfer approach through "Model Sites", which are agricultural units that serve as training and demonstration centers for the implementation of new agricultural technologies [27].
Reviewing the current state of extension in Gauteng province: Case of food security sub-directorates	The article discusses the adoption of the technology transfer approach by the Gauteng Department of Agriculture and Rural Development (GDARD) to improve agricultural production in community gardens [28].
To what extent is the diversity of Farmer Field Schools aligned with the needs of farmers?	The article discusses the implementation of field schools for farmers (FFS) as a tool for technological transfer in agriculture. Through these schools, farmers are trained in techniques such as integrated pest management, efficient use of supplies and sustainable production [29].
Transfer Of Technology Skills, Human Resource Development Skills And Extension Agents' Work Performance: The Perceptions Of Cocoa Growers In Malaysia	The article discusses technology transfer in the agricultural sector, specifically in cocoa production. It analyzes how extension agents facilitate the adoption of new technologies through training programs [30].
Topic - Technology Transfer in Value Chains: This group examines how technology and value chain modernization influence agricultural productivity in emerging territories	
Title	**Description**
Agri-food Value Chain Revolutions in Low- and Middle-Income Countries	It focuses on how the modernization of value chains has transformed agriculture into low -income countries, highlighting the role of technologies in this transformation [31]
Value Chain Innovations for Technology Transfer in Developing and Emerging Economies	Similar to the previous one, it addresses how innovations in agricultural value chains facilitate the transfer of technology in emerging economies [32].
Value Chains and Technology Transfer to Agriculture in Developing and Emerging Economies	Another article that analyzes the modernization of agricultural value chains through the adoption of technologies in emerging territories [33].
Prospects and challenges of date fruit value-addition in Oman	The article examines how adding value to datil products through mechanization and modernization of processes can enhance agricultural productivity in Oman [34].
Technology Adoption, Vertical Coordination in Value Chains, and FDI in Punjab's Dairy Sector	The article focuses on the dairy sector in Punjab, India and addresses the adoption of modern agricultural technologies through vertical coordination in value chains, facilitated by foreign direct investment (FDI) [35].
Topic - Specific challenges of technological transfer in agricultural sectors: This group includes articles that highlight specific case studies in different agricultural sectors and emerging territories	
Title	**Description**
Development of Guidelines and Procedures for Value Addition to Improve Productivity and Sustainability: Case of Dates in Oman	It focuses on the implementation of value-added technologies in date production in Oman, improving productivity [36].
Challenges and opportunities for a sustainable agriculture in Brazil	This article analyzes the challenges and opportunities for sustainable agriculture in Brazil, highlighting technology transfer [37].
The Ironies of New Innovation and the Sunset Industry in Malaysia's Paddy Farming Sector	It explores the adoption of innovative technologies in rice agriculture in Malaysia [38].
Impact of the Agricultural Technology Transfer to the Production of Independent Palm Oil Smallholders: A Review	It focuses on smallholder independent palm oil farmers in Malaysia. Agricultural extension and technology transfer programs, such as TUNAS, designed to improve the productivity and technical knowledge of these farmers are discussed [39].
Implementation Mechanism Research of Scientific Institutions Involved in Crop Breeding Cooperation: Evidence from Western China	The article discusses technology transfer in the context of seed breeding, where scientific institutions collaborate with companies to develop and commercialize new varieties [40].
The Impact of Technology Transfer on Agribusiness Performance in Kenya	The article addresses technology transfer in Kenya's agricultural sector, focusing on the adoption of advanced technologies within the dairy sector [41].
Topic - International cooperation in agricultural innovation: this group examines how international cooperation drives technology transfer in agriculture	
Title	**Description**
Beyond technology transfer: Innovation cooperation to advance sustainable development in developing countries	It focuses on innovation cooperation for sustainable development in emerging territories, proposing a broader approach than pure technology transfer [42].
Triple Helix approach to innovation in Rwanda's agriculture resulted in a partnership between educational institutions and a private firm producing clean seed potatoes	It highlights the cooperation model between educational institutions, the private sector, and the government to promote the adoption of agricultural technologies in Rwanda [43].
When food meets BRI: China's emerging Food Silk Road	The article describes how China, through the Belt and Road Initiative (BRI), implements agricultural cooperation programs that include the

(*continued on next page*)

Table 2 (*continued*)

Topic - Technological adoption in agricultural communities in emerging territories: This group shares a common approach in the implementation of agricultural technologies in rural communities, highlighting technological adoption challenges. The intervention consists of the technological transfer to improve the productivity and sustainability of agricultural practices.	
Title	**Description**
	transfer of advanced technologies. It mentions how investment in agricultural technology, along with infrastructure and policy improvements, is part of the effort to improve agricultural production in partner countries [44].
Topic – No direct similarities: articles provide valuable perspectives on technology transfer in sectors or through mechanisms not addressed in other works.	
Title	**Description**
Benefits of Agricultural R&D International Spillovers: The case of aquaculture	This article is unique in its focus on the effects of research and development in aquaculture, highlighting international technology spillovers [45].
Leveraging informal lending mechanisms to facilitate technology transfer and microenterprise in developing countries	It highlights the use of informal lending mechanisms to facilitate the adoption of agricultural technology, without addressing a specific sector [46].
An extended Canvas business model: A tool for sustainable technology transfer and adoption	It presents the transfer and adoption of agricultural technologies in emerging territories and offers a useful approach on how to structure a business model to ensure the sustainable adoption of these technologies [47].
Building a global platform for organic farming research, innovation, and technology transfer	It focuses on the promotion and development of organic farming at a global level, with particular emphasis on the challenges and opportunities in Africa, Asia, and Latin America. It describes the role of the IFOAM Technology Innovation Platform (TIPI) in advancing organic farming through research, innovation, and technology transfer [48].
Chinese Technology Transfer to Local Farmers in the Russian Far East	It addresses the transfer of agricultural technology from Chinese farmers to local farmers in the Russian Far East. It focuses on the transfer of agricultural technology from Chinese farmers to their Russian counterparts through direct interaction and cooperation [49].
Identifying Potential for Decision Support Tools through Farm Systems Typology Analysis Coupled with Participatory Research: A Case for Smallholder Farmers in Myanmar	It focuses on smallholder farmers in Myanmar, aiming to understand their characteristics and how decision support tools (DSTs) can be designed to improve decision-making in their farming systems [50].
Management of successful technology transfer in agriculture: The case of Kazakhstan	The study examines how agricultural technology transfer has been managed in Kazakhstan, using a SWOT analysis to identify strengths, weaknesses, opportunities, and threats in the technology transfer process [51].
Managing Agricultural Research for Prosperity and Food Security in 2050	The article analyzes how six emerging economies in Asia and Africa (the Philippines, India, Sri Lanka, Egypt, Uganda, and Kenya) are implementing agricultural innovations and technology transfer, including modern biotechnology, intellectual property management, and public-private partnerships to enhance agricultural productivity [52].
Private Sector Incentives and the Diffusion of Agricultural Technology: Evidence from Developing Countries	The study examines the impact of private sector incentives and intellectual property rights (IPR) on the transfer and adoption of agricultural technologies in developing countries [53].

Table 2 (*continued*)

Topic - Technological adoption in agricultural communities in emerging territories: This group shares a common approach in the implementation of agricultural technologies in rural communities, highlighting technological adoption challenges. The intervention consists of the technological transfer to improve the productivity and sustainability of agricultural practices.	
Title	**Description**
Protected cultivation of vegetable crops in sub-Saharan Africa: limits and prospects for smallholders. A review	The article focuses on horticultural crop production in SubSaharan Africa and discusses the transfer and adoption of low-tech protected cultivation techniques as an intervention to improve agricultural production [54].
Shortcomings Technology Transfer in Indonesia: A Critical Appraisal	The article addresses technology transfer in a broader context, including agricultural technology. It critiques the effectiveness of technology transfer in Indonesia, highlighting failures in program implementation due to issues with the patent system and a lack of effective policies [55].
Transforming Agriculture Research into Commercialisation: Experience of Universiti Putra Malaysia	The article describes how agricultural research is transformed into technological innovations that are transferred to the field. It mentions technologies such as animal vaccines and other innovations [56]
Why do smallholder farmers dis-adopt conservation agriculture? Insights from Malawi	The article examines conservation agriculture as a technological intervention to improve agricultural sustainability. This technology includes practices such as soil cover, no-till farming, and crop rotation, which are part of agricultural technology transfer programs [57].

that the main results on technology transfer and food security remained consistent. We also compared the results of studies from Scopus and Web of Science and found no significant differences in the overall trends identified. In addition, an analysis by publication period was conducted. This revealed that more recent studies tended to focus on the adoption of digital and sustainable technologies, while older studies favoured traditional agricultural extension approaches. Finally, the analysis by geographical region revealed that the barriers to technology transfer vary depending on the socio-economic context, but that international cooperation strategies remain a crucial factor in all regions. These analyses confirm the robustness of the results obtained in the systematic review.

4. Discussion

Technology transfer is emerging as a key tool to address global challenges related to food security, particularly in emerging territories. This study allowed us to identify significant patterns in scientific production and to analyze how technology transfer strategies have been implemented in different contexts. Through bibliometric analysis and the Systematic Review of Literature, it was possible to map an interdisciplinary field that connects technological innovation with the agricultural, social and economic dynamics of vulnerable regions.

The results of the bibliometric analysis indicate that there is a growing interest in this issue, with a peak of publications achieved in 2021. This behavior may be related to the prioritization of international agendas that seek to strengthen resilience against global events such as the Covid Pandemia 19 and climate change. However, the decrease in scientific production in recent years suggests that it is necessary to revitalize the research approach in this field, especially in areas where emerging technologies can have a significant impact. The terms concurrence network showed that concepts such as "Climate Change," "Sustainability," and "Agricultural Production" are closely linked to technological transfer, which underlines the importance of integrating

Table 3
Documents admitted to the state of the art that fully comply with the criteria of the PICO question.

Title	Description
Topic - Technology transfer and increased agricultural productivity: these works focus on how the implementation of technology transfer programs has impacted agricultural productivity in emerging territories, which improves food security	
Closing yield gaps in China by empowering smallholder farmers	The article describes how the "Science and Technology Backyards" program in China has increased yields of key crops through the transfer of agricultural technologies [58].
Increasing wheat yield for smallholder farmers with technology transfer	In Hebei Province, China, the positive impact of technology transfer on increasing wheat productivity is documented by comparing traditional methods with those introduced through technology transfer programmes [59]
Science and Technology Backyard: A novel approach to empower smallholder farmers for sustainable intensification of agriculture in China	The text highlights the model of direct interaction between scientists and farmers, showing an increase in production without increasing the use of chemical fertilizers [60]
Marginal returns on Chinese agricultural technology transfer in Nigeria	This study shows how the transfer of agricultural technology from China to Nigeria significantly increased agricultural yields in farmers who participated in the program [61].
Topic - Innovative approaches in technology transfer: these papers highlight innovative approaches in technology transfer, including innovation in rural development	
Title	**Description**
From technology transfer to innovation-based rural development: A necessary turn at the Indio Hatuey experimental station	The article analyzes the transition from a traditional approach to an innovation-based approach for rural development in Cuba [62].
Shifting the Crops Towards Artificial Intelligence: Challenges and Opportunities for Technology Transfer to Farmers	The article explores the use of advanced technologies such as artificial intelligence and the Internet of Things to enhance agricultural productivity in India [63].
Socio-technical transitions and sustainable agriculture in Latin America and the Caribbean	This article reviews how the transition to sustainable agriculture in Latin America and the Caribbean is driven by technology transfer [64].
Topic - adoption of agricultural technologies through extension programs: these articles analyze the impacts of agricultural extension programs on the adoption of new technologies in emerging territories	
Title	**Description**
Effects of technology dissemination approaches on agricultural technology uptake and utilization in Northern Ghana	The study describes various approaches for the diffusion of agricultural technologies as part of the Agricultural Technology Transfer (ATT) project funded by USAID in Ghana [65].
Impact of improved agricultural extension approaches on technology adoption: Evidence from a randomised controlled trial in rural Tunisia	It examines the adoption of a new barley variety in Tunisia using different agricultural extension approaches [66]
Learning and Technology Adoption Impacts on Farmer's Productivity	It studies how field schools have improved technology adoption and agricultural productivity in Indonesia [67].
Topic - Technological transfer and adaptation to climate change: This group focuses on technological transfer with the objective of improving resilience against climate change	
Title	**Description**
Technology Transfer and Adoption for Smallholder Climate Change Adaptation: Opportunities and Challenges	It focuses on the adoption of advanced agricultural technologies in Honduras to improve climate resilience [68].
Technology Transfer Model for Small-Scale Farms	It proposes a technology transfer model (model H) specific to smallholder farms, validated in Colombia [69].
Topic - Scalability of Agricultural Innovations: These articles discuss how agricultural innovations can be scaled to benefit broader communities	
Title	**Description**
Scaling up innovations in smallholder agriculture: Lessons from the Canadian international food security research fund	The article addresses agricultural technology transfer as part of its analysis of the scaling up of innovations, highlighting programs that have managed to implement agricultural technologies in various rural communities [70].
Systemic perspectives on scaling agricultural innovations. A review	This work focuses on the scalability of technological innovations and their large-scale adoption in different agricultural contexts [71].
Topic - Economic Impact and Improvement on Food Safety: These works focus on the economic impact of technological transfer in the improvement of agricultural production and food security	
Title	**Description**
The Assessment of Capital Flow and Technology Transfer in Asparagus Production	Explores how technology transfer has improved asparagus production in Bali, Indonesia [72].
The Feeding of the Nine Billion: A Case for Technology Transfer in Agriculture	Analyzes how technology transfer can increase global agricultural productivity and improve food security [73]
Topic - without direct similarities: articles with unique approaches	
Tittle	**Description**
The role of technology transfer to improve fertiliser use efficiency	This work examines how the transfer of advanced technologies, such as remote sensors, has improved efficiency in the use of fertilizers in developing countries [74]
Strategies for White and Yellow Maize Cultivar Improvement Research and Technology Transfer in Mexico	The article describes the implementation of programs such as the Masagro Project, which focuses on the transfer of agricultural technology to improve corn production in Mexico [75]
Technology Transfer in Agriculture: The Mexican Experience, 2021	The article describes how technological transfer has played a key role in the modernization of agriculture in Mexico, highlighting several programs and policies that have been implemented over the years [76].

these approaches to achieve sustainable solutions.

On the other hand, the qualitative analysis of the selected articles showed that, although advanced agricultural technologies are essential to improve food security, their adoption faces multiple barriers. These include lack of adequate infrastructure, limitations in technical training, and socioeconomic obstacles such as unequal access to financial resources. Likewise, the role of public policies and government incentives appears as a crucial factor to guarantee the sustainability of technology transfer programs. Without these conditions, the efforts made may be limited to isolated cases, without generating a transformative impact on the target communities.

In emerging territories, technology adoption faces multiple challenges that are deeply rooted in socioeconomic and political factors. Among the main obstacles is the lack of equitable access to financial resources, such as agricultural credit or subsidies, which limits the ability of smallholder farmers to invest in advanced technologies. In addition, gaps in infrastructure, such as internet connectivity and access to basic services, restrict the implementation of digital technologies and modern farming tools.

From the political point of view, the absence of consistent and sustainable public policies hinders technological transfer. On many occasions, technological adoption programs lack continuity due to changes in government administrations or lack of long -term financing. Likewise, corruption dynamics and power concentration can divert resources for agricultural innovation, exacerbating existing inequalities.

An additional factor is the level of literacy and technical training of

rural communities. Without adequate training programs, the adoption of advanced technologies is usually limited, since farmers do not have the necessary skills to use them effectively. This is aggravated by cultural barriers, where deeply rooted traditional agricultural practices can generate resistance to change.

In this context, emerging territories require a comprehensive approach that combines inclusive policies, sustainable investments and training strategies to overcome these barriers. Only through the creation of an enabling environment can guarantee the effective adoption of technologies and its contribution to food security and sustainable development.

In terms of geographical areas, the countries with the greatest scientific contribution – such as the United States, China, India, Germany and Brazil – stand out for their ability to generate applied research and develop technological innovations in the agricultural field. However, this also highlights a structural inequality in the distribution of knowledge, since developing nations, which represent a significant part of emerging territories, have a lower participation in scientific production. This implies that the dynamics of technology transfer are not always led by the benefited regions themselves, which could limit the contextualization and effectiveness of the solutions implemented.

In terms of the strategies analyzed, intervention models that involve collaboration between multiple actors—such as governments, academic institutions, and private companies—show a greater potential for success. Examples of innovative approaches include direct agricultural training programs, technologies adapted to climate change, and the development of inclusive value chains that enable the integration of smallholders into broader markets. These findings reinforce the importance of promoting international cooperation frameworks that combine technology transfer with the strengthening of local capacities.

Despite the advances identified, significant gaps were detected in the literature. Issues such as the evaluation of the long-term impact of transferred technologies, the economic sustainability of implemented programs, and the effect of cultural dynamics on technology adoption require further attention. In addition, the results suggest that the integration of new technologies, such as artificial intelligence and the Internet of Things, represents a key opportunity to transform agriculture in emerging territories. These technologies can boost productivity and resilience, but their implementation requires overcoming challenges related to accessibility and digital literacy in rural communities.

5. Conclusions

The bibliometric analysis and the Systematic Literature Review (SLR) carried out in this study have identified key trends and significant gaps in the relationship between technology transfer and food security in emerging territories. The results highlight a growing interest in the topic, with a peak in scientific production reached in 2021. However, the subsequent decline suggests the need to reinvigorate research, particularly in contexts where emerging technologies could have a transformative impact.

The identification of socio-economic and political barriers, such as lack of access to financial resources, limited infrastructure, and the absence of sustainable public policies, highlights the urgency of adopting a comprehensive approach. This should include strategies that combine public and private investment, technical training, and the strengthening of regulatory frameworks to ensure the long-term sustainability of technology transfer programs.

One of the most significant contributions of this work is the interdisciplinary mapping that connects technological innovations with agricultural, social, and economic dynamics in vulnerable regions. This underscores the importance of integrating advanced technologies, such as artificial intelligence and the Internet of Things, to boost productivity and resilience in the face of global challenges such as climate change.

The findings of this study have direct practical implications for policymakers, researchers, and international organizations. First, it highlights the need to formulate inclusive public policies that facilitate access to advanced technologies, especially in rural communities. In addition, it is proposed that technology transfer strategies include closer cooperation between the public and private sectors, with the goal of reducing structural inequalities and promoting sustainability.

At the global level, this work reinforces the importance of aligning technology transfer initiatives with the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 9 (Industry, Innovation and Infrastructure). This means prioritizing programs that not only increase agricultural productivity, but also minimize environmental impact and foster social equity.

The results offer a solid basis for future research, suggesting areas of exploration such as assessing the long-term impacts of transferred technologies, analyzing effective international cooperation models, and developing solutions tailored to the cultural and economic specificities of each region. Based on the bibliometric findings and the thematic analysis conducted, several specific lines for future research have been identified. First, there is a notable underrepresentation of studies addressing the environmental impact of technology transfer in agricultural contexts, which presents an opportunity to expand the focus toward sustainability. Additionally, the thematic map reveals low density in areas such as digital inclusion and access to technologies in regions with limited connectivity, suggesting the need for studies that analyze structural barriers to technology adoption. Finally, it is recommended to explore more deeply models for scaling up and replicating successful technology transfer experiences—particularly those documented in isolated case studies but not yet systematically evaluated across diverse contexts. These research lines are directly derived from the gaps identified in the term co-occurrence network (Fig. 5), the thematic map (Fig. 6), and the state-of-the-art categories (Table 3), which strengthens their academic and applied relevance.

Finally, this study reaffirms technology transfer as an essential tool to address food insecurity in emerging territories. However, it also highlights that its effectiveness depends on overcoming structural barriers and implementing comprehensive solutions that combine innovation, sustainability and equity.

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Edward Jhohan Marín-García: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Carlos Ocampo-López:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **José Bestier Padilla Bejarano:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2025.100770.

Data availability

Data will be made available on request.

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