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Agricultural innovation: an analytical development from a bibliometric study

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Abstract

The objective of this article is to provide an overview of agricultural innovation that allows an evolutionary diagnosis over the last two decades, by means of a bibliometric analysis based on the concepts "agricultural innovation", "livestock innovation" or "agricultural technological change" in the period 2003-2022. A total of 462 documents obtained from the Scopus and Scielo databases were analyzed using descriptive statistics and bibliometric techniques through the VOSviewer software. The results show a clear dominance of the subject in Europe and North America, with little evidence of participation from Latin American countries, which represents an area of opportunity for researchers. Three lines of research were identified that confirm that agricultural innovation studies have had a growing development and will continue to be a topic of interest in the coming years.

Keywords: Bibliometrics; bibliometric indicators; Scopus; Scielo; VOSviewer

Introduction

Innovation is a highly significant issue for the development and sustainability of the agricultural sector. The application of new technologies, practices and approaches in production can improve crop efficiency, productivity and quality, while reducing environmental impact (Ojeda-Beltran, 2022).

Therefore, this sector faces important challenges worldwide, including climate phenomena, loss of biodiversity, as well as the presence of pests and diseases, increase in human population, reduction of arable land, scarce generational replacement, among others. These challenges must be met because it is necessary to satisfy the demand for products and services of current and future generations, guaranteeing profitability, environmental health and socioeconomic equity (HPLE, 2016).

Facing these new challenges, the role of innovation in this sector will be to maximize productivity in a more complex scenario from the point of view of production, rural development, environment and justice (Pretty et al., 2010). Therefore, innovation is essential because it helps reduce poverty, contributes to economic growth and the sustainability of countries with a strong presence of agriculture in their economic model (Sonnino and Ruane, 2013). Thus, innovations have become a decisive factor in agricultural development strategies.

Since innovation is the central theme of this study, the conceptual approach is relevant to situate the theoretical orientation. Schumpeter (1934) defined innovation as the first introduction of a new product, process or system. Spielman et al. (2009) define it as something new successfully introduced into an economic or social process, i.e., innovation is

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not only a phenomenon of creation, but also of adoption, which includes the effective incorporation of the new into processes or practices (Arocena y Sutz, 2023).

Authors such as Klerkx et al. (2012); Sira and Ryszard (2020) define agricultural innovation (AgIn) as a co-evolutionary process, i.e., a combination of technological, social, economic and institutional changes, which enables the production and exchange of knowledge. In addition to factors such as organizations, institutions, type of actors and their attributes, among others. These elements are the main drivers of technological change because they create and feed the agricultural innovations leading to a diversity of alternative technical options and make them available to farmers (Glover et al., 2019).

Therefore, knowledge transmission has become a fundamental task of the scientific process, especially in the development of innovation as a process of change and openness to new scenarios of applied knowledge. There, in the recreation of change and the development of new options for improvement, scientific publications become a channel for the dissemination of research results, to present the information developed in all disciplinary areas (Ruiz-Corbella et al., 2020), including the agricultural sector and related innovations. The analysis of these disciplines is a key link in the research process, so it has become a tool to qualify the quality and impact of this process. (Rueda-Clausen Gómez et al., 2005).

Because of the large number of publications, it has been necessary to analyze them by means of metric studies, which make it possible to explore, detect and show relevant or significant information (Solano López et al., 2009). This situation has contributed decisively to the research process and to the development of new lines of research, especially in higher education and research centers, by incorporating methodologies for the organization and representation of knowledge into the discussion of cutting-edge topics. Consequently, every analysis regarding a knowledge domain includes the potential of metric studies as an approach, method or tool that helps to characterize and identify relationships between individual documents (Hjørland, 2002).

A bibliometric study makes it possible to analyze and visualize the evolution, trends and current stage of scientific research; it provides valuable information for researchers, institutions and policy makers interested in promoting and supporting agricultural innovation (Rincon Soto et al., 2023).

In the agricultural sector, bibliometric studies are an essential tool in the research process, as they have become an evaluation method to qualify the process of knowledge generation and its impact on science, allowing to illustrate research trends by analyzing citations, journals, authorship, publication impact, institutional affiliation or association, keywords or descriptors, titles or abstracts, as well as the contribution of national and international experts. Bibliometrics is an exercise of mathematical and statistical quantification that can be applied to any written source and allows not only the analysis of scientific activities at a given time, but also their development and quality, so this type of analysis calls the attention of different scientists related to any productive activity (Ávila Suárez et al., 2012; Recio et al., 2017; Rueda-Clausen Gómez et al., 2005).

Garfield (1972) says that the main tool for evaluating the academic quality of scientific works, individuals or institutions are bibliometric indicators, based on the analysis of data from the scientific literature. Therefore, having current information on indicators that show the form and pace of progress in the transition of knowledge in societies allows us to know and make inferences about what is happening in different regions or countries (Moreno-Ceja et al., 2011).

In the area of agricultural innovation, different bibliometric studies such as those of Figueroa-Rodríguez et al. (2019); Romero-Riaño et al. (2021), have focused on the measurement of collaboration patterns (co-authorship networks), the power and effectiveness of interactions between authors, with the main objective of establishing an overview of the theoretical, practical and methodological scopes developed by researchers in this field.

Therefore, the objective of this article is to provide an overview of agricultural innovation that allows an evolutionary diagnosis over the last two decades by means of a bibliometric analysis based on the concepts "agricultural innovation", "livestock innovation" or "agricultural technological change" by highlighting the contributions of authors, journals and research institutions on this topic, using indicators to identify current lines of research.

Materials and Methods

The study is based on the development of a bibliometric analysis, which could be characterized as quantitative in relation to the focus of the problem and descriptive in relation to the purpose; for this purpose, a procedure was established consisting of two stages: 1) information gathering and search criteria and 2) indicators, visualization and interpretation of results.

Information collection and search criteria

Bibliometric analysis validity depends on the appropriate choice of the database, because it needs to adequately cover the area of study. It also requires that the sources of information be reliable and sufficient to efficiently carry out each stage of the analysis and achieve more accurate decision making (León et al., 2006).

As a result of the above, the literature search was conducted in two databases: 1) Elsevier's Scopus (http://www.scopus.com), which is a very comprehensive database, accessible and used by the scientific community due to its wide outreach and usefulness in diverse fields of science to be used in more detailed interdisciplinary comparisons, providing bibliographic records, abstracts and citations of the world literature in peer-reviewed journals, and 2) Scielo (https://scielo. org/en/) is a network of 12 national collections with a shared database containing more than 1 200 journals, 530 000 articles and approximately 12 million citations. For this reason, it is assumed that Scielo provides comprehensive information on Latin American science and is ideal for analyzing the scientific productivity of this region.

To delimit the knowledge area of interest, the documentary thematic indicator was used, which is based on the bibliographic references of published documents containing key words of the intellectual content topic and which are given by experts from thesauri of terms, which allows studying the frequency of the topic with the highest production (Sanz Casado and Martín Moreno, 1997).

Thus, the bibliographic search was carried out using the following key terms: 1) "agricultural innovation", 2) "livestock innovation" and 3) "agricultural technological change", in the title, abstract and keywords, as well as the record of these terms in Spanish. The search equation used was:

TS= (TITLE-ABS-KEY ("innovación agrícola") OR TITLE-ABS-KEY ("innovación ganadera") OR TITLE-ABS-KEY ("cambio tecnológico agropecuario") OR TITLE-ABS-KEY ("agricultural innovation") OR TITLE-ABS-KEY ("Livestock innovation") OR TITLE-ABS-KEY ("Agricultural technological change")).

Table 1 shows the inclusion and exclusion criteria of the papers analyzed. Figueroa Rodríguez et al. (2019) mention that innovation studies had an upward trend since 2001, so the period 2003-2022 was selected to analyze the most recent research, and to have a broad overview to evaluate its evolution. We considered those papers that were classified as scientific articles and reviews; in addition, only those papers related to the agricultural and biological sciences fields were selected, to reduce a measurement bias among the different areas (Koutsos, et al., 2019).

Indicators and display of results

The results were exported in CSV format and then imported into a Microsoft Excel database for cleaning and standardization, which was done manually. The variables considered in the exported database were: 1) author(s), 2) document title, 3) affiliations, 4) journal, 5) language, 6) abstract, 7) keywords and 8) type of access. This database was analyzed with the VOSviewer tool that allowed the creation of maps based on data collected from the network. These can be expressed by researchers, scientific journals, organizations, countries or keywords, and the data can be analyzed by co-authorship, co-occurrence, citation or co-citation links (Van Eck and Waltman, 2010). Indicators of quantity, quality and collaboration and identification of lines of research were also constructed and interpreted (Table 2).

The h-index considers both the number of articles and the number of citations they receive (Hirsch, 2005). This index is a parameter used to measure the productivity of a scientist. It is by its nature equally applicable to a journal, and even to an institution. It consists of ranking the author's works in descending order, based on the citations obtained in each work. When the rank (position in the list) exceeds or equals the citation value, the h-index is obtained. To calculate this indicator, only articles from the databases analyzed were considered.

The cluster analysis was performed with the VOSviewer software, using the bibliometric matching technique, based on the analysis of coincidences of terms, which allows describing the research in more detail, through a mapping of relationships that considers a set of terms and their association in thematic groups. This technique uses data mining to identify words in the text with the co-word tool, implying that its units of analysis can be any word taken from the title, abstract or keywords. The degree of association between two words in the network is proportional to the coincidence of those two words in the set of documents (Ortega-Priego and Aguillo, 2006).

Therefore, a network was generated using the country of each author involved as a variable. In this way, links were established between two or more countries, product of the collaboration of different institutions, for this, the indicators created by Belli and Balta (2019) were used, in which the bond force is defined as the number of times that this linkage occurs between two countries or authors thanks to the different publications. The total sum of the force of linkage that a country or author has with others is known as global linkage strength (GLS).

Results and Discussion

Quantity indicators

A total of 462 papers related to innovation or technological change in the agricultural field were found after overcoming the exclusion criteria. The papers published in Scielo represented 8.87 % and the rest came from the Scopus database. The distribution over time and type of document is shown in Figure 1, where it was identified that in the last decade there has been considerable development of works related to this topic, with the last 5 years

Table 1. Selection criteria of the papers considered for the bibliometric analysis on AgIn.

Selection criteria	Scopus (n)	Scielo (n)
Initial selection by search criteria	1 270	73
Exclusion criteria		
Publications not included in the period 2003-2022	179	1
Not being in the scientific article or review category	229	1
Not belonging to the agricultural and biological science field	356	30
No keywords	85	0
Inclusion criteria		
Papers that passed the exclusion criteria	421	41

Table 2. Indicators analyzed in the bibliometric study on AgIn.

Indicators	Description
Quantity indicators	
Number of documents	Number of articles published per year in the databases analyzed
Participating institutions	Number of institutions publishing on this specific topic
Countries publishing	Countries publishing on specific topic
Authors per publication	Number of participants per published research
Quality and collaboration indicators	
Top ranked journals	Number of publications per journal in the period under study, number of citations and h-index
Top ranked countries	Countries publishing on specific topic, number of collaborations with other countries, and total number of publications
Top ranked authors	Number of publications, total citations and h-index
Identification of lines of research	
Main topics	Growing, declining and emerging topics

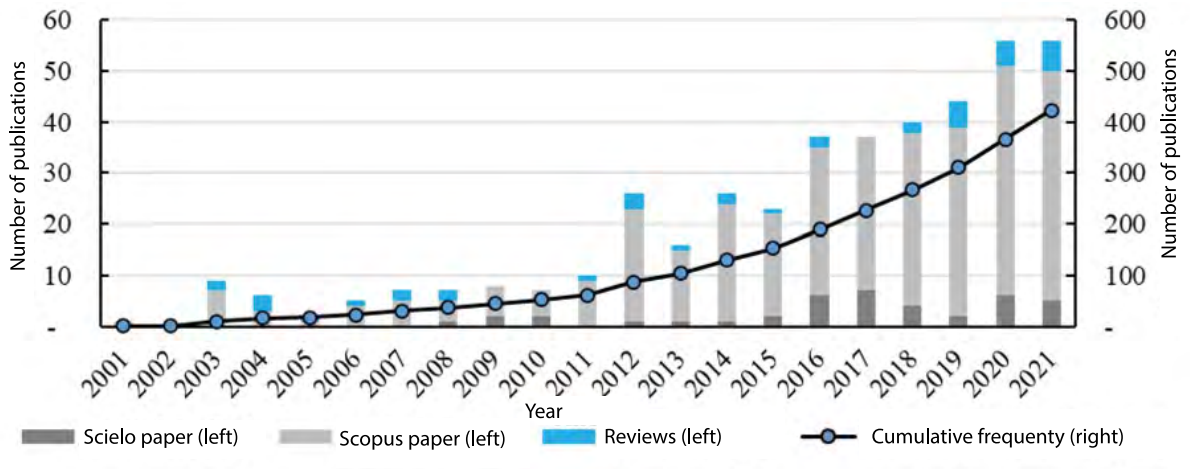

Figure 1. Evolution of documents published in the Scielo and Scopus databases on AgIn.

representing the period of highest productivity (235 documents ~ 50.87 %), with an average of 47 publications per year. Similar data were reported by Figueroa-Rodriguez et al. (2019), in their bibliometric mapping for the concepts of "*innovation and producers*".

The scientific article was the information resource most used by the authors, representing 89.83 % of the publications. Callon et al. (1995) mention that scientific articles are the most elaborate manifestation of writing and collective criticism, which is why they are the preferred medium for the publication of results. On the other hand, reviews, although to a lesser extent, contribute the remaining 10.17 %, with an average of 2.35 publications per year, which are published only in Scopus.

From the publications analyzed, 231 are under the payment or subscription modality and the same amount in open access. Koutsos et al. (2019) reported that 32.5 % of the articles in their research were available as free full text, in this research the percentage was higher, which could be explained by the fact that in the period 2019 to 2023 55 % of the open access articles were published, probably due to the availability of time that both authors and reviewers had during the pandemic (SARS-CoV-2).

Wagner (2010) says that articles available under open access are cited between 25 % and 250 % more than subscription articles. For the agronomy field and specifically for the AgIn search performed, this criterion is fully met, since open access articles are the ones that received the highest number of citations (Table 3). Thus, the number of citations could be explained by the Matthew effect enunciated by Merton (1968), which consists of greater recognition of scientific contributions made by researchers with a wide reputation, and the restriction of such recognition to scientists who have not yet made their mark. The article *Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment* (2010) has the highest number of citations and two of its authors (Klerkx and Leeuwis) are pioneers and references in agricultural innovation, thus fulfilling such effect.

The language most used in writing the articles was English, with 416 papers (90.04 %), thirty in Spanish, seven in French, three in Arabic, two in German, two in Portuguese, and two in Chinese. The predominance of the English language in the research coincides with that reported by Cadavid Higuita et al. (2012); Maldonado Carrillo and Montesi (2018). Therefore, some journals (Agronomía Colombiana, Cuadernos de Desarrollo Rural, Cultivos Tropicales and Revista Mexicana de Ciencias Agrícolas) have decided to publish their articles in a bilingual form (English/Spanish) to increase their visibility at the international level.

In the research process, institutional and organizational interventions play a crucial role in the execution and dissemination of knowledge (Hernández Montoya et al., 2020). The main institutions in scientific production by ascription of the first author were: Wageningen University (Netherlands), with 45 publications, followed by the National Institute of Agricultural Sciences (Cuba) with fourteen publications and, in third place, the University of Reading (United Kingdom), with eight publications. This means that more than 14 % of AgIn publications are concentrated in a few mainly European institutions.

Hernández Montoya et al. (2020), mention that determining the country of origin or its collaborations determines the direction of the research and its possible potential. In this regard, a total of 69 participating countries were counted. Figure 2 shows the countries that have written the most about AgIn. Almost a quarter of the publications correspond to United States, Netherlands and Germany,

Table 3. Main papers referring to AgIn according to the number of citations.

DOI	Authors	Number of citations	Access
10.1016/j.agsy.2010.03.012	Klerkx L., Aarts N. and Leeuwis C.	441	Open access
10.1080/14735903.2014.912493	Meijer S., Catacutan D., Ajayi O., Sileshi G. and Nieuwenhuis M.	340	Open access
10.1016/j.landusepol.2004.10.001	Niroula G. and Thapa G.	247	Payment or subscription
10.1016/j.foodpol.2007.10.001	Klerkx L. and Leeuwis C.	235	Payment or subscription
10.1016/j.agsy.2013.03.003	Kilelu C., Klerkx L. and Leeuwis C.	202	Payment or subscription

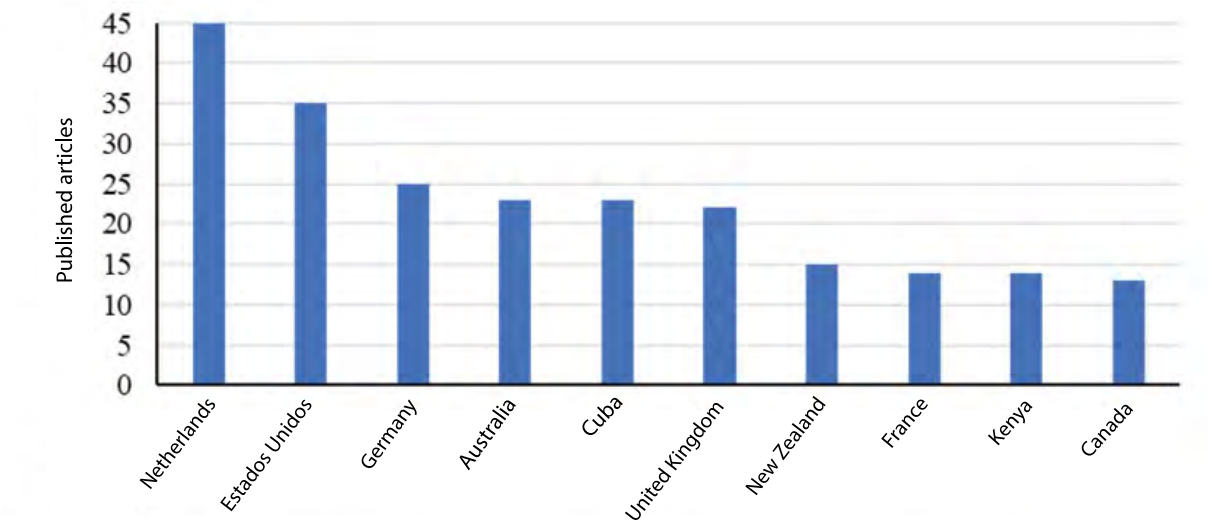

Figure 2. Country of correspondence of the first author with the most publications on AgIn in the period 2003-2022.

which is directly associated with the fact that these countries have the best agronomy schools in the world.

Soete (2008) considers that research is congregated in some countries due to a higher degree of concentration and centralization of capital. On the other hand, Lederma et al. (2014) confirm that innovation is low in underdeveloped regions, where most countries are less likely to diffuse and introduce new products in the market compared to developed countries. This is reflected in the low productivity of publications (only 23) in Latin American countries. Colombia and Mexico are ranked 15th and 17th respectively, accounting for almost half of these (47.8 %).

Collaboration and quality indicators

Pandiella-Dominique et al. (2019) mention that international collaboration in published papers is a relevant aspect to consider in evaluation, as it indicates recognition and acceptance outside their country of publication. Regarding this case, research on AgIn has been published in 152 journals, of which 136 belong to the Scopus database. The ranking of journals was done by organizing the number of publications in descending order and considering the h-index. Scientific journals from Latin America were not considered, since not all of them have the data to calculate this indicator, reducing their worldwide visibility.

Table 4 shows the leading journals, which cover topics on agricultural education and extension, land use, policy formulation, implementation and evaluation for the agrifood sector, to mention a few. The journal *Agricultural Systems* is the leading journal with 55 publications on the AgIn topic, with 2 762 citations and an h-index of 27. In second place is the *Journal of Agricultural Education and Extension* with 7.8 % of the papers. It is important to mention that

Table 4. Ranking of top journals with AgIn publications according to number of citations and h-index.

Journals	Publications	%	Citations	%	H index
Agricultural Systems	55	11.9	2,762	28.93	27
Journal of Agricultural Education and Extension	36	7.79	606	6.35	15
Outlook on Agriculture	24	5.19	464	4.86	14
Land Use Policy	21	4.55	762	7.98	12
International Journal of Agricultural Sustainability	20	4.33	774	8.11	12

the *International Journal of Agricultural Sustainability* is in second place according to the number of citations (774), which implies that each paper has an average of 38 citations. Figueroa-Rodríguez et al. (2019) reported similar results, confirming the importance of these journals for the publication of results on AgIn, thanks to the fact that these can be classified within agricultural, multidisciplinary journals.

Latin American journals focused on research dissemination have less visibility because they represent a little-known universe, due to factors such as: low investment in R&D, limited private investment for scientific-technological activities and a scarce presence in information services, which leads to insufficient recognition by the international scientific community, in spite of the relevance of the scientific articles they disseminate. For the Scielo database, the journals with the highest number of publications were *Cultivos Tropicales* with 15 publications, followed by *Pastos y Forrajes* with an average number of citations of less than one, both journals are published in Cuba, and in third place was the *Chilean journal of agricultural research* with five articles and an average of 1.25 citations per article.

The development of science is closely related to collaboration and co-authorship, which represents higher quality standards of scientific publications (López López et al., 2011). In terms of the collaboration index, the rate of papers signed by more than one author was 88.9 %, exceeding the 80 % reported by Prpic (1996). The remaining 11.1 % are signed by a single author. Figure 3 shows the papers distribution according to the number of authors.

For the analysis of the coauthorship network, a cut-off point of ≥5 was established; that is, only those authors with at least five published articles cited more than once were selected, resulting in a total of fourteen researchers (Figure 4). At first glance, it is evident that there are five clusters of authors with co-authorship relationships ranging from 0 to 32 collaborations.

This diagram shows the authors with the highest number of publications (Netherlands) and who, in turn, work collaboratively, highlighting the importance of Dr. Klerkx, L., in the first cluster, who has 33 contributions with a FGE of 32 and whose most important collaborative relationship is with the researcher Leeuwis, which makes them the main references in the thematic research. The second cluster (formed by four authors) could be explained by the continuity of the papers published in the journal *Cultivos Tropicales* del Proyecto de Innovación Agropecuaria Local, which was created and led by Professor Ortiz-Pérez, where he has ten papers published and twelve of FGE. The third cluster is formed by the New Zealand researchers Turner and Botha, with five collaborative contributions. Therefore, it can be determined that the research developed on AgIn is mostly co-authored in an organized manner with established research groups, regardless of their affiliation or place of origin.

Therefore, scientific collaboration has become an important aspect at the international level as it contributes to the generation and transfer of new knowledge. The 11 countries, forming two groups, with the highest number of contributions (≥15) are listed in Table 5. Netherlands and United States are the leaders of these groups, both in number of publications (78 and 57, respectively) and number of citations (3 824 and 1 208, respectively). However, Latin America is far from global production standards, especially in regions such as North America and Europe.

Therefore, the dominance of the European continent could be due to the diverse research carried out in different universities such as Wageningen (Netherlands) and Bonn (Germany). North America, on the other hand, concentrates its publications in the United States (University of California) and Canada (McGill University). This situation could also be explained by the fact that the headquarters of several international institutions are located in Western Europe and North America (Pretty et al., 2010), which facilitates the research and dissemination of these papers.

Figure 3. Distribution of the number of authors per AgIn publication for the period 2003-2022.

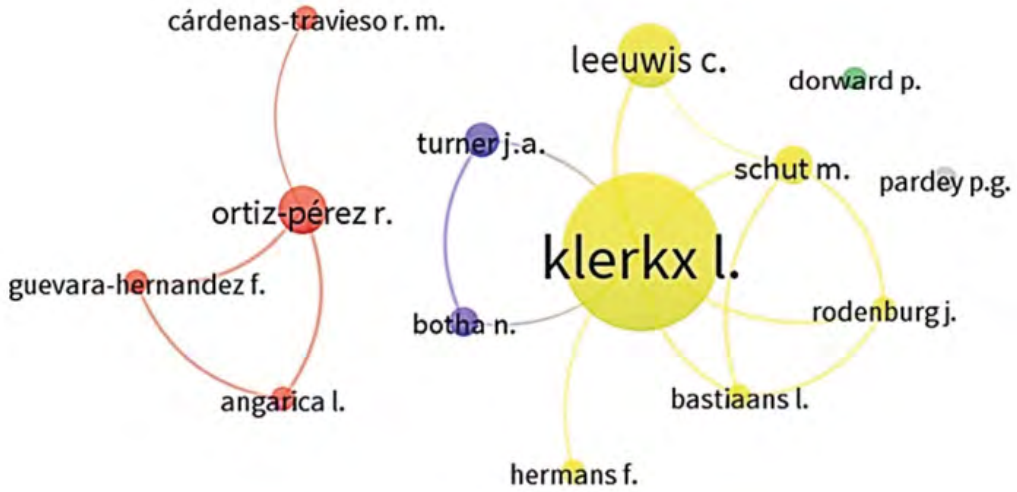

Figure 4. Density diagram of the co-authorship network on AgIn papers.

Table 5. Bibliographic matching groups by country, from documents referring to AgIn.

Cluster	Countries	Documents	Number of citations	Average number of citations per document
I	Netherlands	78	3824	49.03
	Germany	38	598	15.74
	Australia	27	406	15.04
	France	21	213	10.14
	New Zealand	20	464	23.20
	Canada	18	493	27.39
II	United States	57	1208	21.19
	United Kingdom	37	692	18.70
	Kenya	25	462	18.48
	India	19	248	13.05
	Uganda	15	315	21.00

Regarding existing collaborations between the countries leading the groups formed, it was found that Netherlands has 86 collaborations with 33 countries, and United States has 42 collaborations with 26 countries (Table 6). In both cases, collaboration with countries on the African continent stands out, since the main objective of the research carried out on that continent is the adoption of technical innovations to improve food production and improve the nutritional level of its inhabitants.

Authors' productivity was analyzed by considering the number of papers. This parameter is commonly used to identify the most active and published core group of researchers. Table 7 shows the main researchers referring to the AgIn topic and the corresponding h-index, showing the productivity, cumulative impact and relevance of their publications.

The h-index value of the main authors who published on AgIn in Scopus journals ranged from 6 to 25, with marked differences between authors. Regarding the Scielo database, Dr. Ortiz-Perez reported an h-index of 1 with a total of 10 publications and 5 citations. According to the analysis, the research platform where the papers are published directly influences the index. Scopus is one of the largest databases with worldwide visibility, while Scielo focuses mainly on Latin American countries and its visibility is lower.

On the other hand, Lotka's Law (1926) indicates that there is an unequal distribution because most of the articles are concentrated in a small subset of highly productive authors, such is the case of Dr. Laurens Klerkx, Professor of Agri-Food Innovation and Transition at the Knowledge, Technology and Innovation Group of Wageningen University in Netherlands. He has 33 publications, 2 639 citations and an h-index of 25. This author can be considered and selected as a reference if one wishes to carry out any study related to AgIn, since the perfection of research involves the inclusion of pioneering and recognized authors in the subject.

Identifying lines of research

Setting research priorities in agriculture over the past 20 years can be subjective and vary depending on the perspective and criteria used. However, there are three areas that received significant attention in agricultural research in this period:

The analysis of the indexed keywords associated with the scientific production analyzed allows the identification of research approaches addressing the subject matter described in this study. A total of 35 terms were selected using the VOSviewer tool with the bibliometric technique co-occurrences (cutoff point ≥8) from the automatically generated index terms of the selected articles, organizing them into three clusters. Each of them represents the relationships between the same terms and their association in thematic groups (Figure 5).

Table 8 shows the name assigned to each line of research according to the central research topics from which they emerged, as well as their main methods of analysis.

Cluster 1: Promoting agricultural innovation

Fostering agricultural innovation includes promoting and supporting new technologies, methods and approaches

Table 6. Main collaborations between countries related to the AgIn.

Country	Type of relationship		Number of collaborations	Number of countries
Netherlands	Collaborating country	Benin	10	28
		Rwanda	8	
		Ghana	6	
		Others	45	
	Country of collaboration	New Zealand	7	5
		Germany	4	
		Canada	3	
		Others	3	
	Total		86	33
United States	Collaborating country	Kenya	5	25
		India	4	
		United Kingdom	4	
		Others	28	
	Country of collaboration	South Africa	1	1
	Total		42	26

Table 7. Main authors writing about AgIn.

Author	H index	Number of publications	Citations	Database
Klerkx L.	25	33	2,639	Scopus
Leeuwis C.	11	13	1,257	Scopus
Ortiz-Pérez R.	1	10	5	Scielo
Schut M.	8	8	396	Scopus
Turner J.	6	7	257	Scopus

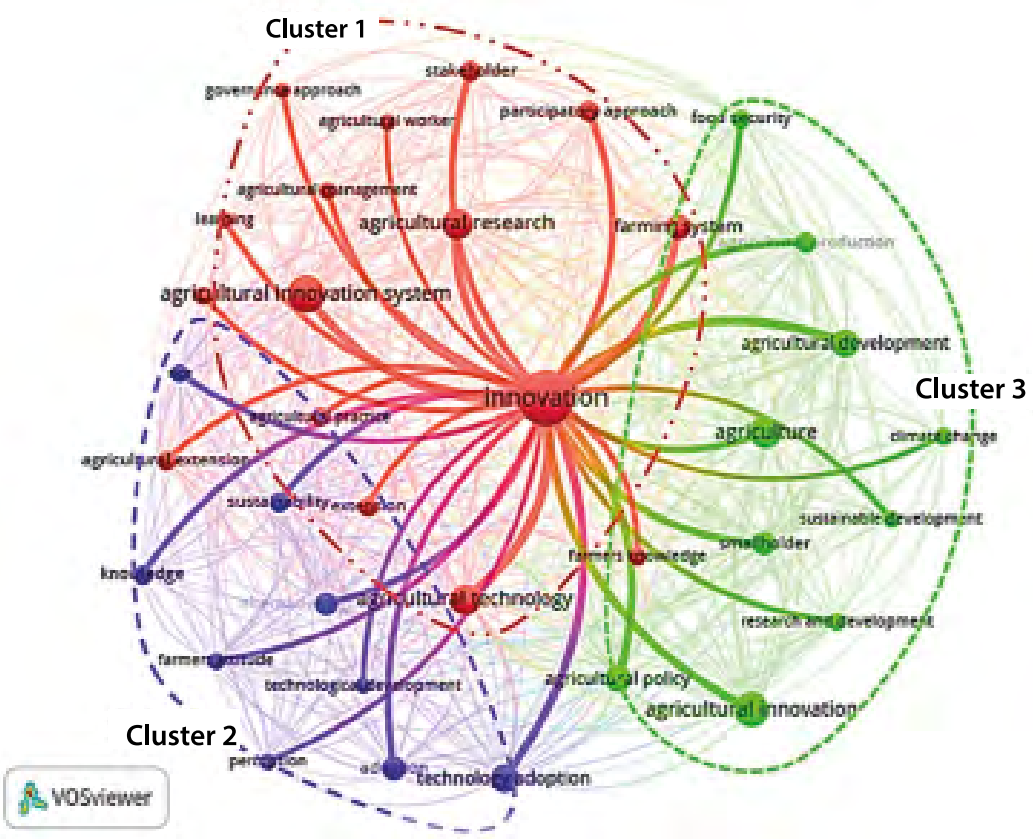

Figure 5. Bibliometric map of network of co-occurrences of keywords on AgIn.

Table 8. Content details of thematic groups of co-occurrences of articles published in Scielo and Scopus on AgIn.

Cluster	Main line of research	Research topics	Method of analysis
1. Red	Agricultural innovation promotion (14, 40 %)	Innovation institutions	Case studies
		Innovation platforms	Case studies
		Innovation intermediaries	Review / Discussion
2. Blue	Adoption and impact of agricultural innovations (11, 32 %)	Innovation/dissemination networks	Regression / Case study
		Analysis of critical and key aspects for the adoption of innovations	Level of adoption / Case study
3. Yellow	Sustainable food systems (10, 28 %)	Innovation and development reviews and future trends	Review / discussion of concepts and trends
		Food security, current models and evolution	Review of support programs / Baseline vs. end line
		New innovation implementation analysis	Bibliometric analysis

in the agricultural sector to improve productivity, sustainability and resilience in food production. In addition, it is important to foster cooperation between different actors in the sector, such as farmers, researchers, companies and governments, to share knowledge and experiences, and to develop policies and programs that promote agricultural innovation.

Research in this area promotes the development of small and medium-sized producers by providing intangible incentives (research, development of new technologies and training of certified human resources) and tangible incentives such as technical assistance or demonstration modules to facilitate the integration of agrifood chains, especially in developing countries. Therefore, the United Nations (2009) mentions that promoting agricultural innovation is an important step in the fight against poverty.

Hall et al. (2001) mention that partnerships in fostering innovation are important because of the benefits in innovative performance derived from productive relationships between organizations engaged in formal research and those who make use of new knowledge in agricultural production. Sometimes the link between creator and user cannot be direct due to different factors, and this is where innovation managers or intermediaries can help to relieve several of the limitations that have arisen for both the demand and supply of agricultural innovations, in addition to being an important link in the integration of the network for the transmission of innovations (Klerkx et al., 2009).

Cluster 2: Adoption and impact of agricultural innovations

The adoption and impact of agricultural innovations has been a central theme of agricultural research in recent decades. Agriculture faces challenges such as increasing demand for food, scarcity of natural resources and climate change effects. Against this background, agricultural innovation plays a key role in promoting sustainability, increasing productivity and ensuring food security.

The adoption of innovations involves the use of technology that allows for greater productive capacity and thus increases competitiveness (Pérez Guel et al., 2016), so assessing the impact of these technologies is important for research and development (R&D) institutions, as it allows them to demonstrate the efficacy of the products developed and justify the investments made (Feinstein, 2012).

It should be mentioned that this cluster, unlike the previous one, is represented by large and medium-sized producers, where it is possible to measure the impact of agricultural innovation thanks to adequate management and constant training and technical advice, which is regularly paid for by the producers themselves.

However, to ensure that all farmers, especially smallholders, share the benefits of innovation, it is important to address the challenges of diffusion, such as accessibility and transfer of innovations. Facilitating the effective introduction of innovations to address current and future challenges in agriculture requires collaboration between researchers, governments, international organizations and society in general.

Cluster 3: Sustainable food systems

This last group is distinguished by providing a comprehensive and balanced response to current challenges in food production and consumption. For these objectives to be achieved, it is essential to conserve and manage pollinators, since one of the fundamental elements of agriculture, i.e., pollination, depends on them. Some researchers also promote the use of sustainable agricultural practices, with the aim of achieving equitable access to healthy food, a conscious diet and the appropriate use of natural resources.

In addition, this group is characterized by the smallest number of papers, because the main topics are relatively new. Despite the continued presence of concepts such as technology adoption and agricultural practices, there is a change of trend in the establishment of a scientific approach to this topic, which is becoming increasingly specific, such as sustainable development, sustainable intensification and governance. This could be explained by the fact that most of the research developed in recent years should be focused on the pact signed by 193 member countries of the United Nations (including Mexico), where they committed to meet the 17 Sustainable Development Goals (SDGs) stipulated in the pact, eight of which are directly related to agriculture (United Nations, 2015).

Thematic evolution of articles published in Scielo and Scopus

The evolution of the thematic structure of articles on agricultural innovation published in Scielo and Scopus databases has undergone significant changes in recent years.

Keywords were analyzed according to their source. It is necessary to emphasize that the scientific production on AgIn in Latin America and the Caribbean published in journals of the Scielo platform is not voluminous, which leads to a low density of the keyword network, compared to the Scopus database. Latin American researchers have little integration with authors from other regions, which causes studies to be developed in isolation and to focus on local problems, which could be influenced by political, social and environmental conditions. Figure 6 shows a comparison between the articles published in the journals housed in the Scopus database and those in Scielo. In gen-

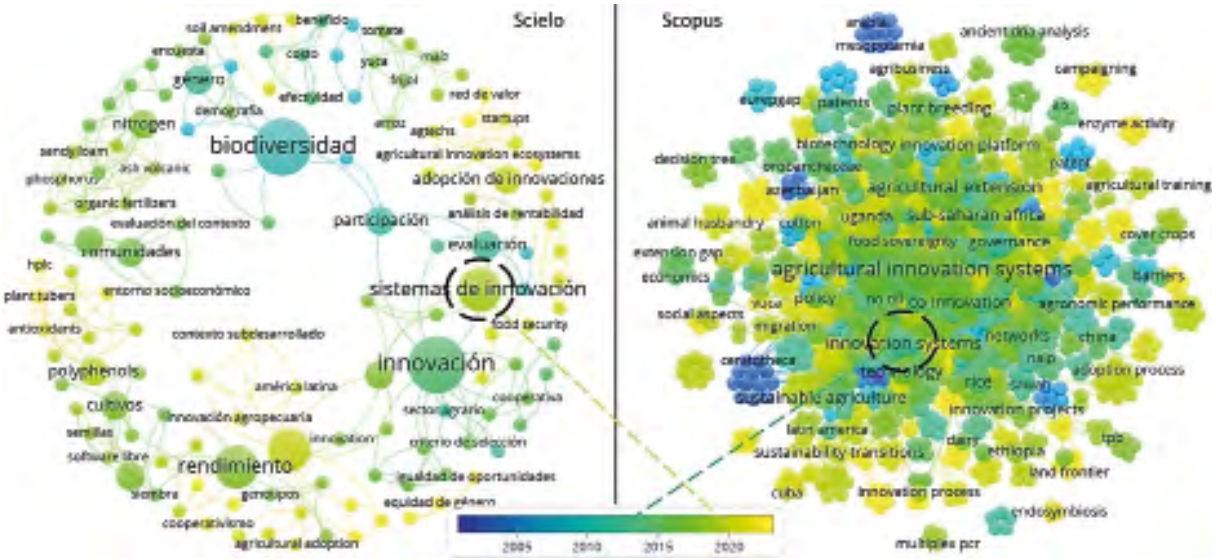

Figure 6. Thematic network and impact of articles published by Scielo and Scopus on AgIn.

eral, there is a greater evolution of the topic in the Scopus journals and a lag of approximately 7 years in the research conducted in Latin America and the Caribbean, where innovation systems in the study of production chains and their socioeconomic environment continue to be the topics of interest.

These thematic trends reflect the growing importance of sustainability, technology and climate change adaptation in agricultural research. It is important to note that thematic developments may vary with time and geographic region.

Conclusions

The current panorama of AgIn research shows how the development of agricultural innovation has accelerated significantly in recent years. This is reflected in the constant increase in the number of scientific publications related to this area. This trend is driven by the need to address global challenges in agriculture, such as the growing demand for food, the shortage of natural resources, the impact of climate change and the need to promote sustainability and food security. The results confirm that these studies will continue to be a topic of interest in the coming years.

One of the main findings has been to visualize a clear dominance of the topic in two regions, Europe and North America, by authors, journals and scientific articles, with little evidence of participation of Latin American countries, despite the inclusion of the Scielo database. Thus, research in AgIn represents an area of opportunity for Latin American authors with the possibility of disseminating their publications in journals of greater diffusion or making use of social networks aimed at the scientific community to enhance the visibility of their results at the international level.

On the other hand, the results obtained allow visualizing the main research approaches related to AgIn, emphasizing in recent years the importance of sustainable food systems, where the proper care and management of pollinators will be very important, since a third of the world's food production depends on them. Therefore, further documentation is required by means of case studies that make it possible to observe the behavior of the actors involved, the relationships that are built and the role of the state in the AgIn process in beekeeping to create a methodology that can be replicated in different parts of the world, keeping in mind the development logic of each country.

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