Agrociencia

SPATIAL-TEMPORAL ANALYSIS OF SCIENTIFIC PRODUCTION ON AGROBIODIVERSITY OF CROPS WITH FOOD VALUE

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ABSTRACT

The analysis of agrobiodiversity helps to understand the traditional and agroecological production systems that communities have developed to produce their food and conserve the diversity of their species. However, there are still few studies that examine research advances in the spatial-temporal scale of agrobiodiversity. The objective of this study was to conduct a bibliometric analysis of scientific production related to the agrobiodiversity of crops of food interest. Furthermore, the analysis methodologies used, the main findings reported, and areas of opportunity for generating new knowledge were identified. The literature search was conducted using the keywords "agrobiodiversidad" and "agrobiodiversity" in academic publishers (Elsevier, Scopus, Frontiers, MDPI, and Springer), open access databases (Scielo, Redalyc, Latindex, Clarivate Analytics, PeerJ, and DOAJ), and the Google Scholar web search engine. Between 2000 and 2023, 445 publications were identified, whose frequency showed a linear growth trend ($R^2 = 0.77$; $p < 0.0001$). The countries with the highest publication frequency were the United States (36 publications), Mexico (34), India (31), Brazil (29), Colombia (25), and Ecuador (25). The crops most frequently analyzed in Asian countries were rice and sugarcane; in North America, corn and beans; in South America, potatoes and coffee; and in Europe, wheat, grapes, and tomatoes. The most commonly used methodologies included diversity indices (Shannon-Wiener, Margalef, and Simpson) and statistical techniques: descriptive analysis (frequencies), inference (Pearson and Spearman correlations, analysis of variance, mean tests such as Tukey and Duncan), and multivariate analysis (clustering and principal components). Sixty-seven point eight six percent of the articles were limited to describing agrobiodiversity, leaving room for opportunity to develop research on genetic diversity aimed at productivity and conservation.

Keywords: Agroecology, content analysis, bibliometrics, family gardens, Mayan milpa.

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INTRODUCTION

The genetic diversity of agricultural species and their wild relatives constitute an economic, agricultural, biological, and cultural heritage that is fundamental to food security and the well-being of local communities (Dzib-Aguilar *et al*., 2016). Agrobiodiversity is based on the variety of plants cultivated and harvested for food (Pérez-García, 2023). The concept of agrobiodiversity is not limited to cultivated species, but rather to the interaction of biological, social, and cultural components that converge in agricultural and food practices (Dyer y Taylor, 2008; Wood *et al.*, 2015).

Agricultural activities are fundamental to the identity, relationships, history, and culture of many communities, especially in rural areas. Agriculture not only provides food and livelihoods, but is also deeply intertwined with people's traditions, customs, and ways of life, so that crops and agricultural practices can reflect a region's history, ancestral knowledge, and connection to the land (Poot-Pool *et al.,* 2015).

The influence of ethnic groups has been crucial for the domestication of wild species, as they have preserved the diversity of their germplasm over time (Santillán-Fernández *et al.,* 2021a). Agrobiodiversity analysis helps to understand the traditional and agroecological production systems that communities have developed to produce their food and conserve the diversity of their species. (Dzib-Aguilar *et al.,* 2016).

In agrobiodiversity analyses, seed selection, agronomic management, and ethnocultural factors influence crop heterogeneity, which in turn enhances their resilience and conservation in the face of external factors that are difficult to control, such as pests, diseases, and climate variations (Orozco-Ramírez *et al*., 2017). It is therefore essential to preserve ancestral agricultural systems, which integrate agroecological principles aimed at sustainable production and the responsible use of plant genetic resources (Ford-Lloyd *et al.,* 2008).

In agrobiodiversity analyses, it is essential to assess biological and cultural diversity and understand the spatial-temporal nature of agroecosystems as mechanisms for food security and ecological services (Jahrl *et al*., 2021). However, despite the importance of agrobiodiversity for food sovereignty (Ramírez-Juárez, 2022), resilience to climate change (de Sadeleer, 2024), and cultural identity (Isakson, 2009), there is little research evaluating the scope of what has been developed around the agrobiodiversity of crops with nutritional value.

Bibliometric analyses are useful tools for evaluating scientific research, as they examine published scientific articles and apply quantitative and qualitative methods to generate indicators and mathematical models that enable the development and evolution of a specific topic to be determined (Peng, 2017). They also enable areas of opportunity to be identified in order to generate new knowledge and thereby improve the quality of research (Martínez-Santiago *et al.,* 2017).

There are bibliometric analyses in the agricultural sector for specific crops such as corn (Santillán-Fernández *et al*., 2021b), wheat (Giraldo *et al*., 2019), and rice (Sun and Yuan, 2020), in sustainable agricultural systems (Rocchi *et al*., 2020), and environmental services of agroecosystems (Liu *et al*., 2019). However, few studies analyze agrobiodiversity as a component of sustainable agricultural production that affects food security (Liu *et al.,* 2022).

In this context, the objective of this study was to conduct a bibliometric analysis of the agrobiodiversity of crops with nutritional value. Furthermore, the analysis methodologies used, and the main results obtained were identified, as well as areas of opportunity for generating new knowledge were detected. The study was based on the hypothesis that agrobiodiversity has been analyzed on a spatial-temporal scale according to the nutritional importance of crops.

MATERIALS AND METHODS

Source of information and data preparation

From January to May 2024, scientific articles were collected whose object of study were the analysis of agrobiodiversity in crops with nutritional value. Articles from January 2000 to December 2023 available from major publishers (Elsevier, Scopus, Frontiers, MDPI, and Springer), open-access journal article databases (Conricyt, Scielo, Redalyc, Latindex, Clarivate Analytics, PeerJ, and DOAJ), and the free-access web search engine Google Scholar were considered. The keywords used to search for articles were "agrobiodiversity" and "agrobiodiversidad," associated with sustainable agricultural production and food security.

Following the methodology of Santillán-Fernández *et al*. (2021b and 2023), through a content analysis of each publication, those studies whose main object of study was not the agrobiodiversity of crops with nutritional value were discarded. This analysis made it possible to identify the authors, year of publication, keywords, journal, title, bibliographic citations, language, institution of origin of the first author, country of origin of the first author, crops analyzed, data collection techniques, and analysis methodologies for each article.

To capture all variables, a spreadsheet was used, and the original language of each article was respected. To facilitate analysis, special characters such as ñ (replaced by n), accents, superscripts, subscripts, ® and ©, among others, were removed or changed. This information served as the basis for developing a spatial-temporal analysis, frequencies of research topics, impact of publications, bibliometric indicators, frequency of crops with greater relevance in the analysis of agrobiodiversity and author networks, keywords, data collection techniques, and analysis methodologies (Figure 1).

Spatial-time analysis

A graph of scientific production over time was constructed using the variables year of publication and number of citations. For the variable frequency of scientific articles per year, an ordinary least squares regression model was estimated to determine the trend in publication frequency (Fiallos, 2021). Furthermore, the countries of origin of the first author were spatially located to determine where research on the agrobiodiversity of crops with nutritional value has been conducted from 2000 to 2023. The ARGIS® geographic package was used for spatial representation (ESRI, 2015).

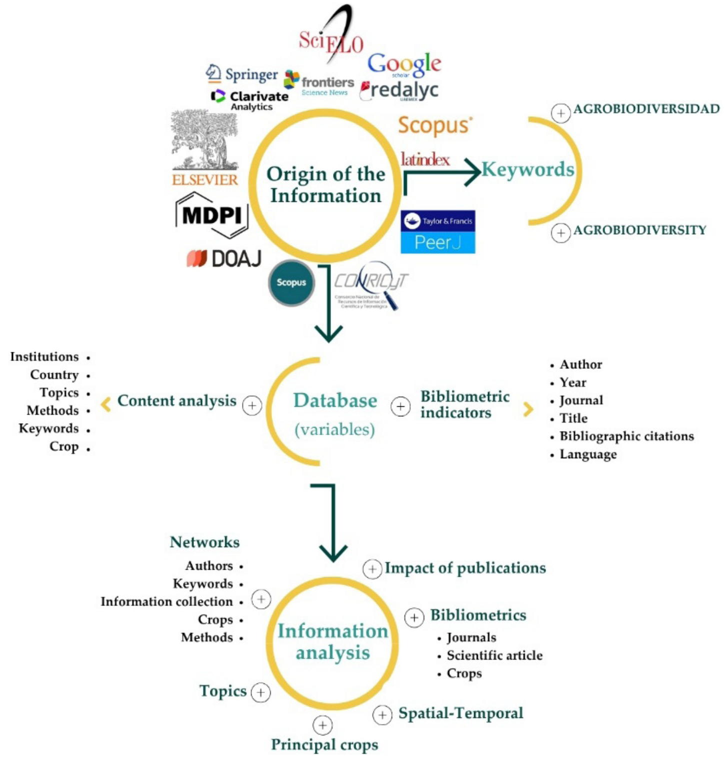

Figure 1. Flowchart of activities for the spatial-temporal analysis of scientific production on agrobiodiversity of crops with nutritional value from 2000 to 2023.

Research topics

Based on the titles of scientific articles, their abstracts, keywords, and with the help of specialists from the Autonomous University of Chapingo and the College of Postgraduates, Montecillo Campus, the subject matter addressed in each article was determined. Six categories were defined: 1) agronomy (articles related to crop productivity, backyard crops, family gardens, and crop management, including pests, diseases, nutrition, and irrigation), 2) ecology (articles associated with conservation, sustainable production, and use of plant genetic resources), 3) anthropology (works associated with cultural and social aspects of farmer-crop interaction), 4) health (articles focusing on crop production for curative purposes and/or alternative medicine for communities), 5) botany (works that described and/or identified plant species associated with crops), and 6) others (climate, genetics, geography, economics, biotechnology, rural development, and agroforestry). Once the articles were classified by topic, a graph of the topics was constructed according to the country of origin of the first author.

Impact of publications

With the help of variables such as bibliographic citations, scientific articles, and the country of origin of the first author, the number of publications and bibliographic citations per country was determined. Based on this information, a graph was constructed to associate them. Countries were grouped heuristically according to the number of publications and their impact, determined by the sum of their bibliographic citations.

Bibliometric indicators

Bibliometric indicators were generated, including: the journals with the highest publication frequency, the articles with the highest number of bibliographic citations, and the most relevant species in the analysis of agrobiodiversity for each continent.

Network analysis

Using Gephi software (Bastian *et al*., 2009), networks were constructed of co-authorship (to identify the main researchers), keywords (to identify the most recurrent concepts in the analysis of agrobiodiversity of crops with nutritional value), and networks of the crops studied, information collection methodologies, and information analysis techniques.

Prospects in Mexico

Finally, to identify new areas of research on the analysis of agrobiodiversity of crops with nutritional value in Mexico, the institutions affiliated with the first author were spatially located. Furthermore, networks of co-authorship, keywords, crops, methodologies for information gathering, and analysis techniques documented in scientific articles compiled from Mexican authors were constructed.

RESULTS AND DISCUSSION

Spatial-temporal analysis

From 2000 to 2023, 445 scientific articles were collected, which gave rise to 6,565 bibliographic citations. The annual frequency of publications showed an upward trend ($R^2 = 0.77$, $p < 0.0001$), with 83.59% of publications (372) concentrated in the period from 2010 to 2023 (Figure 2). This trend is consistent with reforms in international agricultural policies aimed at sustainable agricultural practices, conservation of genetic resources, and crop diversification, promoting the agrobiodiversity of local resources as a measure of adaptation to climate change (de Sadeleer, 2024).

Bibliographic citations showed a downward trend from 2016 to 2023. According to Santillán-Fernández *et al*. (2021b), when the highest productivity of articles is concentrated in current periods, and the highest number of citations is grouped in the oldest works, it is because the research topics analyzed are emerging, with ample room for the generation of new knowledge.

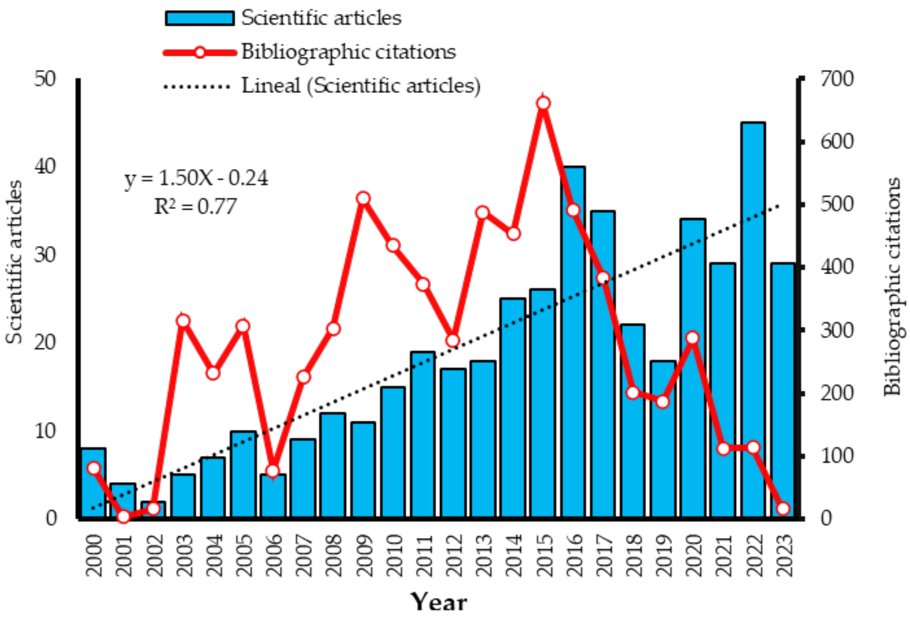

Figure 2. Temporal evolution of scientific production and bibliographic citations on agrobiodiversity issues of food crops from 2000 to 2023.

The 445 scientific articles originated in 73 countries; however, 344 articles (77.3%) of the total were concentrated in 17 of them (Figure 3). The countries with the highest frequency of publication were the United States (36), Mexico (34), India (31), Brazil

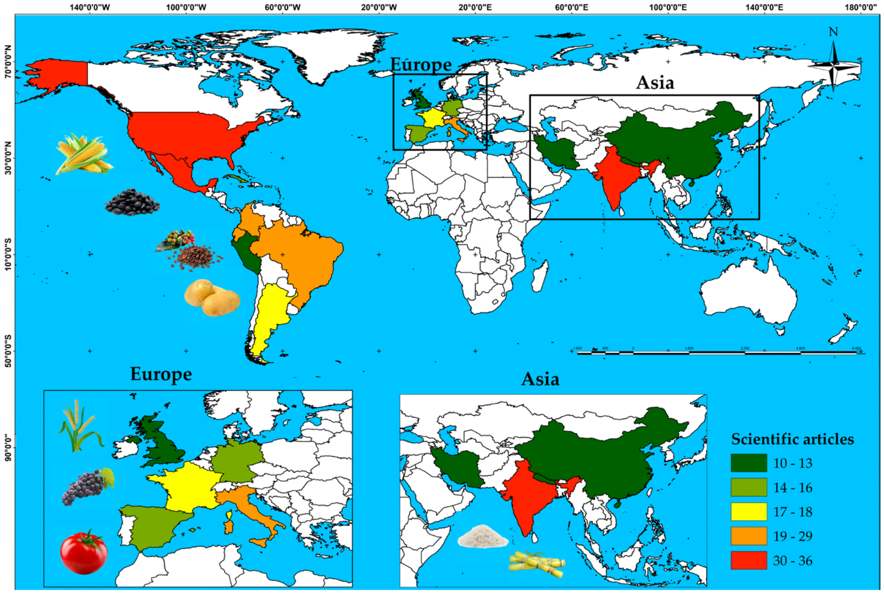

Figure 3: Spatial relationship of scientific production on agrobiodiversity topics related to crops with nutritional value from 2000 to 2023.

(29), Colombia (25), Ecuador (25), Italy (23), France (18), and Argentina (17). The most studied crops in Asian countries were rice and sugarcane; in North America, corn and beans; in South America, potatoes and coffee; and in Europe, wheat, grapes, and tomatoes. According to FAOSTAT (2025), these crops are the basis of human nutrition in each of the identified regions, which results in greater research on them, taking into account the economic context, food security, and food sovereignty (Ramírez-Juárez, 2022).

Research topics

In the main countries that recorded scientific production on agrobiodiversity of crops with nutritional value from 2000 to 2023, the most recurrent research topics were those associated with the analysis of agronomic factors that influence production systems (266 articles, 59.78%), ecology (62, 13.93%), anthropology (51, 11.46%), health (30, 6.74%), and botany (23, 5.17%) (Figure 4). In Latin American countries such as Mexico, Brazil, Colombia, and Ecuador, research was documented on the influence of agrobiodiversity on the lifestyle of indigenous peoples (anthropology).

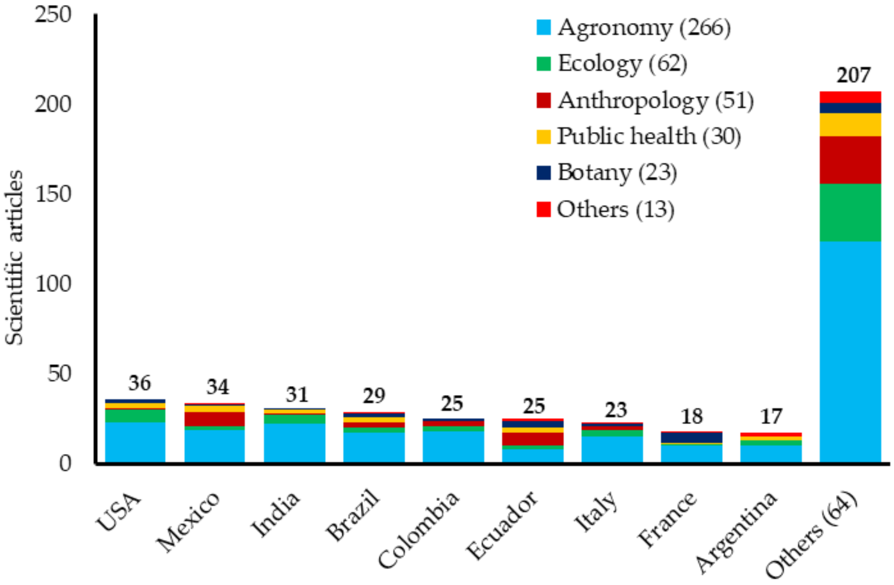

Figure 4. Main nations and research topics, according to the country of origin of the first author of scientific articles on the agrobiodiversity of crops with nutritional value from 2000 to 2023.

Isakson (2009) documented a strong influence of the milpa agricultural production system (combining corn with beans and squash) on the geopolitical customs of the indigenous peoples of Guatemala and Mexico, in their quest to guarantee food sovereignty and conserve their plant genetic resources. This is common in Latin

American countries where there is a wide variety of ethnic groups (Ortega-Ortega *et al*., 2017). Similarly, Narloch *et al*. (2013) found that issues related to ecology are increasingly frequent in the analysis of crop agrobiodiversity because agrobiodiversity allows for the conservation of genetic resources and promotes more sustainable production systems.

Impact of publications

The analysis of the impact of publications (measured by the number of citations) differentiated four groups (Figure 5). The first group consisted of countries that conducted research sporadically. In group two, publications were more consistent, but without high impact. In group three, publications were consistent and had medium impact, and this was the group where Latin American countries with a long agricultural tradition were concentrated (FAOSTAT, 2025). Group four (made up of the United States) had the highest number of research projects and bibliographic citations. According to Santillán-Fernández *et al*. (2021b), the agricultural policy adopted by the US, which promotes technological innovations to improve productivity in conjunction with research and development, has enabled it to become a global benchmark in the analysis of the agrobiodiversity of crops with nutritional value. However, much of this research has focused on demonstrating the competitiveness of monoculture versus polyculture systems (agrobiodiversity). Conversely, studies conducted in Latin American countries have prioritized agrobiodiversity as a mechanism for food sovereignty and resilience to climate change.

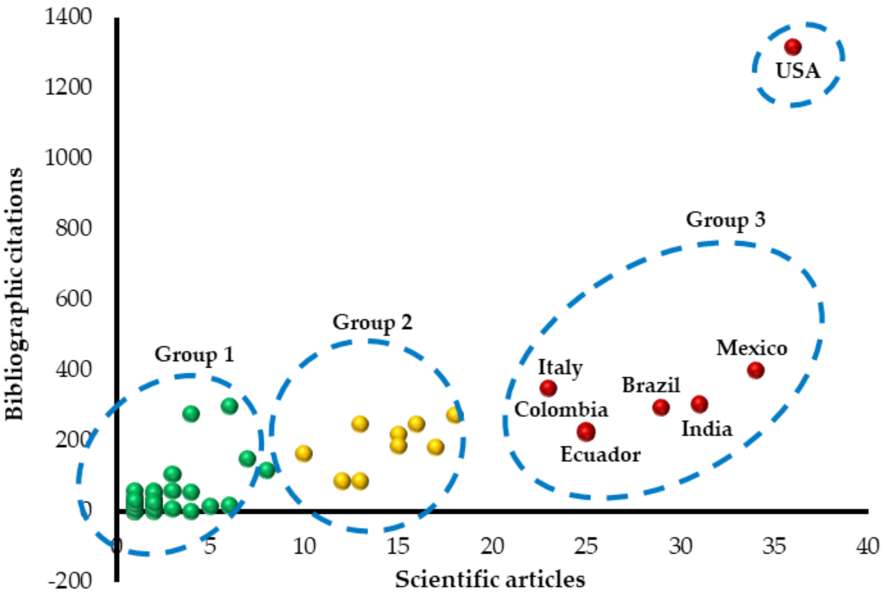

Figure 5. Impact of publications by country of origin of the first author on agrobiodiversity of crops with nutritional value from 2000 to 2023.

Another factor that helps explain the impact of US publications is the fact that they are published in English, which increases their likelihood of dissemination among the scientific community, as it is the most popular language in this community (Santillán-Fernández *et al*., 2023). Research carried out in Latin American countries is usually published in Spanish and in institutional journals, which limits constructive criticism and the impact of publications (Santillán-Fernández *et al*., 2021b). Publishing in English presents an opportunity for Spanish-speaking countries, where agrobiodiversity is often an ethnocultural issue (Oyarzun *et al*., 2013).

Bibliometric indicators

The 445 scientific articles analyzed were published in 296 journals, with an average of 1.5 articles, which implies that, apparently, there is no specialized journal for the topic analyzed. Ten journals accounted for 13.93% of the publications (62 articles) (Table 1), specializing in agriculture, agroecology, and genetic resources. The journals with the

Table 1. Bibliometric indicators of the main journals that published scientific articles on agrobiodiversity of crops with nutritional value from 2000 to 2023.

Journal	Country	Publisher	Impact factor[¶]	Subject	Articles	Citations
Indian Journal of Plant Genetic Resources	India	Indian Society of Plant Genetic Resources	--	Genetic resources	10	23
Agriculture and Human Values	.	Springer	4.2	Agriculture	7	162
Cultivos Tropicales	Cuba[†]	Instituto Nacional de Ciencias Agrícolas	--	Agriculture	7	105
Genetic Resources and Crop Evolution	Netherlands	Springer	1.7	Genetic resources	6	138
Journal of Agroecology	Iran	Universidad Ferdowsi de Mashhad	--	Agroecology	6	22
LEISA Revista de Agroecología	Peru[†]	Asociación Ecología, Tecnología y Cultura en los Andes	--	Agroecology	6	72
Agroecology and Sustainable Food Systems	United Kingdom	Taylor and Francis	3.3	Agroecology	5	47
Agroforestry Systems	Netherlands	Springer	2.5	Agroforestry	5	122
Sustainability	Switzerland	MDPI	3.3	Natural Sciences	5	39
Tropical and Subtropical Agroecosystems	Mexico[†]	Universidad Autónoma de Yucatán	--	Agroecosystems	5	27
Otras (286)					383	5808
Total					445	6565

[†] Journals published in Spanish.

[¶] According to the journals indexed in the Journal Citation Reports (WoS, 2022).

highest number of bibliographic citations were those published in English and with impact factors, indexed in the Journal Citation Reports (WoS, 2022). The impact factor plays a crucial role in deciding where to publish, as journals with a high impact factor increase the chances of reaching a wider audience (Santillán-Fernández *et al.*, 2021b). Of the 10 most cited articles on agrobiodiversity of crops with nutritional value, five belong to a first author whose affiliated institution is located in the US, and only one paper corresponds to a researcher in Latin America (Ecuador). All have been published in English and in Anglo-Saxon journals (Table 2). Gersbach and Schneider (2015) documented that consolidated economies such as those of the US, Canada, Australia, Spain, and the United Kingdom invest more in their research centers, which allows them greater technological and economic development, unlike Latin American economies.

Table 2. Bibliometric indicators of the main scientific articles on agrobiodiversity of crops with nutritional value from 2000 to 2023, ranked according to the number of bibliographic citations.

Author		Journal		Scientific article				
Name	Country	Name	Citations	Subject	Crop	Region	Methods	Results
Isakson (2009)	Canada	The Journal of Peasant Studies	255	Economy	Milpa	Guatemala	Surveys	Conservation, genetic resources
Kerr (2014)	USA	Annals of the Association of American Geographers	151	Productivity	African Millet Sorghum	Malawi	Surveys *in situ* assesment	Margalef index, Shannon index
Zimmerer (2003)	USA	Society and Natural Resources	148	Rural development	Ulluco potato	Peru	Surveys	Seed flow, production, conservation
Perreault (2005)	USA	Human Organization	131	Productivity	Family garden	Ecuador	Surveys Ethnographic	Food safety
Oyarzun *et al.* (2013)	Ecuador	Ecology of Food and Nutrition	129	Anthropology	Local resources	Ecuador	Ethnographic	Margalef index, Shannon index
Zimmerer (2004)	USA	Progress in Human Geography	124	Agroforestry	Local resources	USA	Surveys Snowball	Geographic information system, remote sensing
Calvet *et al.* (2012)	Spain	Ecology and Society	116	Rural development	Family garden	Spain	Surveys *in situ* assessment	Producer network, *in situ* conservation
Gunn *et al.* (2010)	Australia	American Journal of Botany	108	Genetics	Walnut tree	China	Markers Molecular	Morphometry, genotypic variation
Zimmerer *et al.* (2015)	USA	Current Opinion in Environmental Sustainability	107	Rural development	Local resources	USA	Surveys *in situ* assessment	Producer network, *in situ* conservation
Narloch *et al.* (2013)	United Kingdom	Land Use Policy	94	Economy	Local resources	Bolivia Peru	Surveys	Payment for ecosystem services

Among countries with established economies that invest in research, it is common for them to conduct research outside their borders in order to generate new knowledge that will help improve their quality of life (Gersbach and Schneider, 2015). This explains why researchers from Canada, the US, and the UK focused their studies on Latin American countries such as Ecuador, Peru, Bolivia, and Guatemala. Among the 10 most cited articles, interviews, surveys, and *in situ* assessments were the most frequently used data collection techniques, which enabled them to generate diversity indices to promote the conservation of agrobiodiversity. This trend was no different in the total number of articles analyzed, as surveys, interviews, and *in situ* assessments were recurrent in 61.57% of the articles (274). Diversity indices such as Shannon-Wiener, Margalef, and Simpson were common in 119 publications (26.74%).

Other common analysis methodologies were frequency counting (14.15%, 63 articles), Pearson and Spearman correlation (11.46%, 51), analysis of variance and Tukey and Duncan mean tests (9.67%, 43), and multivariate cluster and principal component methods (4.27%, 19). Sixty-seven point eight six percent of the articles (302) limited themselves to describing agrobiodiversity as a mechanism for food production and resilience to climate change, leaving room for opportunity to develop research on crop genetic diversity aimed at productivity and conservation.

Species of greatest relevance in the analysis of agrobiodiversity

In Europe, studies focused on wheat, grapes, and tomatoes; in America, corn and potatoes; in Asia, rice; in Africa, sugarcane; and in Oceania, wheat (Table 3). In most cases, the areas of study were the regions described by Vavilov as centers of origin (Boege, 2009). America, Asia, and Europe accounted for 94.61% of publications (421 articles). Hummer and Hancock (2015) explain that these continents are home to a large number of research centers, as they are the geographical regions with the highest concentration of the world's population.

Backyard production (family gardens) was the most analyzed system (23.37%, 104 articles). The sustainable food production systems promoted by governments have increased the establishment of family farming, as they contribute to food sovereignty (Saediman *et al*., 2021), allow families to save on expenses, and guarantee access to quality and safe products (Jahrl *et al*., 2021). Backyard farming favors the cultivation of seeds, vegetables, and fruits in small outdoor spaces, usually for self-consumption and continuously throughout the year, by combining two or more crops in the same space and time. In this way, it rewards agrobiodiversity and contributes to adaptation to climate change (Tomatis *et al.,* 2023).

Table 3. Main crops with nutritional value by continent, documented in scientific articles compiled from 2000 to 2023.

Continent	Crop		Frequency		Authors
	General	Scientific	Number	%	
Africa (15, 3.37 %)	Family garden		4	0.90	Semu (2018)
	Sugarcane	*Saccharum officinarum* L.	2	0.45	Netondo *et al.* (2010)
	Rice	*Oryza sativa* L.	2	0.45	Bathe *et al.* (2019)
	Others		7	1.57	
America (214, 48.09 %)	Family garden		40	8.99	Poot-Pool *et al.* (2015)
	Corn	*Zea mays* L.	31	6.97	Ortega-Ortega *et al.* (2017)
	Potato	*Solanum tuberosum* L.	25	5.62	de Haan *et al.* (2010)
	Coffee	*Coffea arabica* L.	9	2.02	Méndez *et al.* (2013)
	Bean	*Phaseolus vulgaris* L.	8	1.80	Abbott (2005)
	Squash	*Cucurbita* spp.	8	1.80	dos Santos *et al.* (2012)
	Rice	*Oryza sativa* L.	6	1.35	Schoenly *et al.* (2003)
	Chili	*Capsicum annuum* L.	6	1.35	Castillo-Aguilar *et al.* (2021)
	Sorghum	*Sorghum* spp.	5	1.12	Kerr (2014)
	Tomato	*Solanum lycopersicon* L.	5	1.12	Moya-López *et al.* (2016)
	Prickly pear cactus	*Opuntia* spp.	4	0.90	Reyes-Agüero y Aguirre-Rivera (2011)
	Otros		67	15.05	
Asia (93, 20.90 %)	Family garden		26	5.84	Gopi *et al.* (2016)
	Rice	*Oryza sativa* L.	17	3.82	Na *et al.* (2014)
	Sugarcane	*Saccharum officinarum* L.	10	2.24	Trinh *et al.* (2003)
	Squash	*Cucurbita* spp.	5	1.12	Nassiri *et al.* (2017)
	Potato	*Solanum tuberosum* L.	4	0.90	Singha y Ullah (2020)
	Others		31	6.98	
Europe (114, 25.62 %)	Family garden		34	7.64	Signore *et al.* (2019)
	Wheat	*Triticum* spp.	16	3.60	Costanzo y Bàrberi (2016)
	Grapevine	*Vitis vinifera* L.	14	3.15	Bonhomme *et al.* (2021)
	Tomatos	*Solanum lycopersicum* L.	11	2.47	Socies-Fiol y Cuéllar-Padilla (2017)
	Apple	*Malus domestica* Borkh	7	1.57	Pfiffner *et al.* (2019)
	Chestnuts	*Castanea* spp.	7	1.57	Beccaro *et al.* (2020)
	Rice	*Oryza sativa* L.	4	0.90	Ford-Lloyd *et al.* (2008)
	Corn	*Zea mays* L.	4	0.90	Stagnati *et al.* (2022)
	Others		17	3.82	
Oceania (9, 2.02 %)	Wheat	*Triticum* spp.	4	0.90	Bardsley y Thomas (2005)
	Walnut tree	*Juglans regia* L.	2	0.45	Gunn *et al.* (2010)
	Others		3	0.67	
Total			445	100.00	

Author network

The 445 scientific articles were written by 393 lead authors and 841 co-authors, with a total of 1,234 different authors (Figure 6). The main authors were: Gauchan_D (seven articles) from the Bioversity International Research Center in Kathmandu, Nepal, who developed topics on the conservation of grains and seeds from local breeds through agrobiodiversity; Zimmerer_KS (six) from Pennsylvania State University (USA), a specialist in environmental geography, whose studies have focused on sustainable food

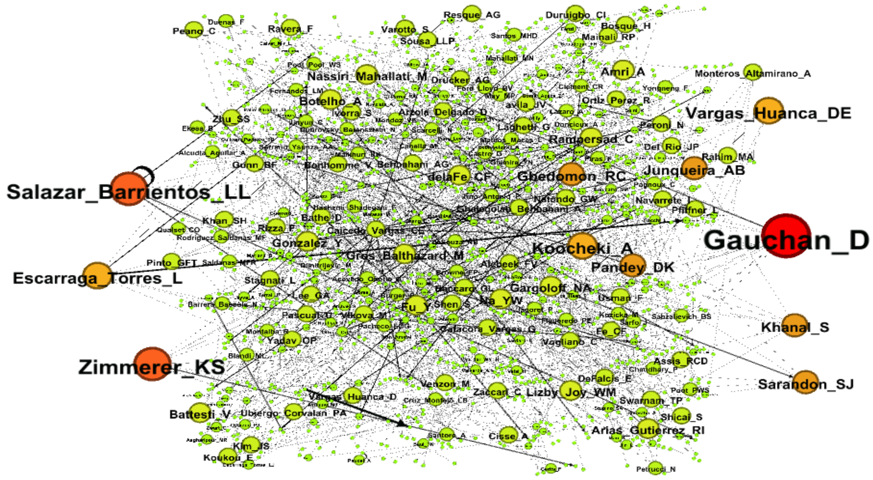

Figure 6. International network of authors who published scientific articles on agrobiodiversity of crops with nutritional value from 2000 to 2023.

production as a mechanism for resilience to climate change through agrobiodiversity; and Salazar-Barrientos_LL (four) from the Conkal Institute of Technology (Mexico), who has conducted research on agrobiodiversity in backyard production systems (family gardens) and Mayan milpa.

In bibliometric analyses, author networks provide information about leading researchers in the topic in question, enabling the planning of research synergies (Santillán-Fernández *et al*., 2021b). However, author network analysis does not usually analyze the number of links between authors or the density of the network (Santillán-Fernández *et al*., 2023). Links are important for authors because they provide ideas, knowledge, and information from geographically distant locations, while density is an indicator of how much the nodes interact with each other. Mathematically, it is a value within the range [0 to 1]; the closer to one, the greater the interaction in the network (Aguilar-Gallegos *et al*., 2016). In the case of this study, the network was composed of 1,234 nodes (authors) with 1,108 links and a density of 0.0001, which opens up an area of opportunity to develop synergies with other national and international researchers, which tends to improve the quality of research by rewarding constructive criticism (Santillán-Fernández *et al*., 2021b).

Prospects in Mexico

Thirty-four scientific articles on the subject were published in Mexico. The spatial distribution of institutions (Figure 7) showed that agrobiodiversity studies are concentrated in the center and south of the country. According to Santillán-Fernández *et al*. (2021a), this trend coincides with the greater wealth of ethnic groups in the region, which have influenced the domestication of species and maintain agrobiodiversity as the basis of their subsistence systems, mainly with crops such as corn, beans, chili

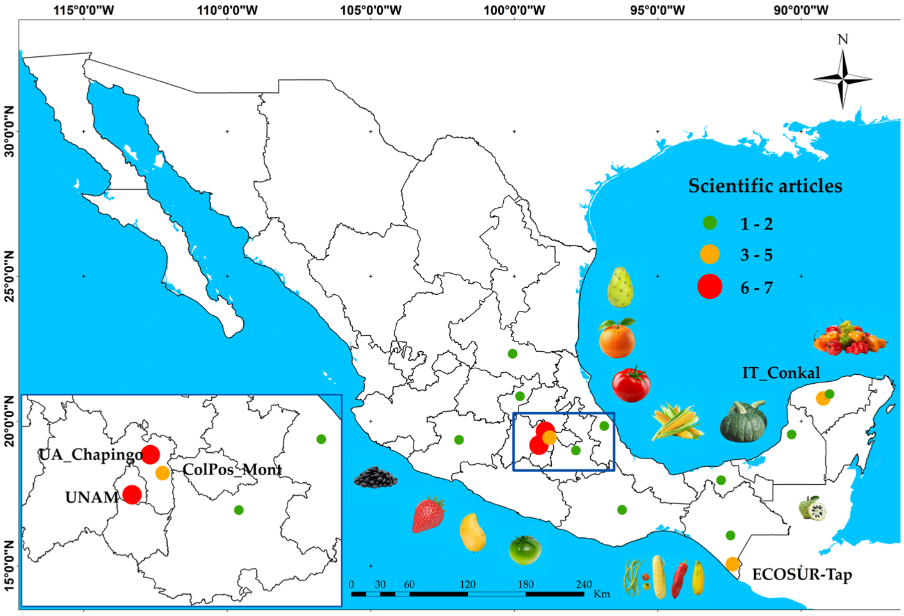

Figure 7. Spatial location of institutions in Mexico with productivity of scientific articles on agrobiodiversity of crops with food value from 2000 to 2023.

peppers, tomatoes, squash, and fruit trees (mango and citrus). In contrast, the highest agricultural productivity is located in central and northern Mexico, in intensive systems geared toward the competitiveness of monocultures (SIAP, 2025).

The highest number of publications was concentrated in institutions in the center of the country: Chapingo Autonomous University (UA_Chapingo), National Autonomous University of Mexico (UNAM), and Montecillo Campus Graduate School (ColPos_Mont). The centralization of research in Mexico has been described by Santillán-Fernández *et al*. (2021b, 2023), who found that the territorial gap between production areas and research centers limits technology transfer, which in turn affects national agricultural productivity. However, researchers were registered in the south of the country, where the greatest diversity of population and cultivated species is concentrated, such as Salazar-Barrientos_LL from the Conkal Institute of Technology, Ubiergo-Corvalan_PA and Cruz-Montejo_LB from the Autonomous University of Chiapas, and Alcudia-Aguilar_A, Poot-Pool_WS, and Serrano-Ysunza_AA from the Tabasco campus of the Colegio de la Frontera Sur (Figure 8).

Authors tend to form research synergies among researchers from the same institution (77 nodes, 77 links, density of 0.1) (Figure 8), which limits constructive criticism of research and affects its quality. Furthermore, no researcher with consistent output was found during the period analyzed. According to Santillán-Fernández *et al*. (2021b), agricultural research in Mexico responds to scientific trends based on national agricultural policy. In the context of food sovereignty and climate change, the

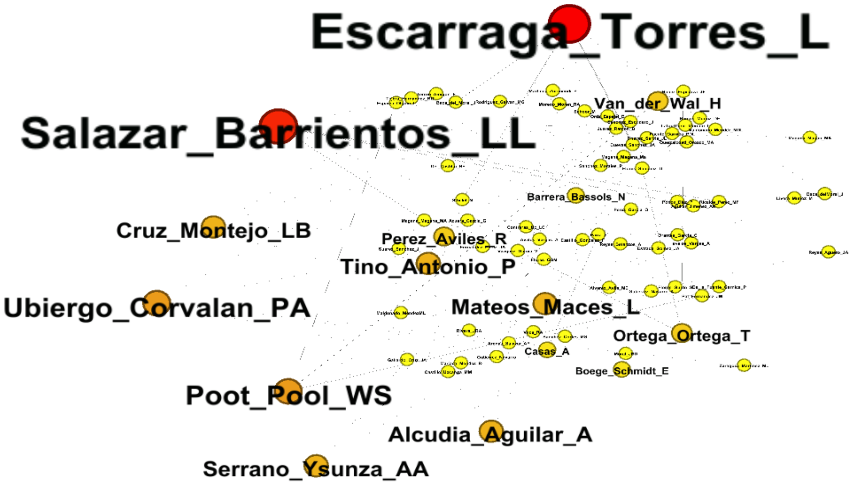

Figure 8. Network of authors in Mexico who published scientific articles on agrobiodiversity of crops with nutritional value from 2000 to 2023.

analysis of agrobiodiversity of crops with nutritional value presents itself as an area of opportunity to develop research and synergies with researchers from other national and international institutions.

Finally, in the analysis of keyword networks, main crops, information collection methodologies, and information analysis techniques (Figure 9), it was found that the

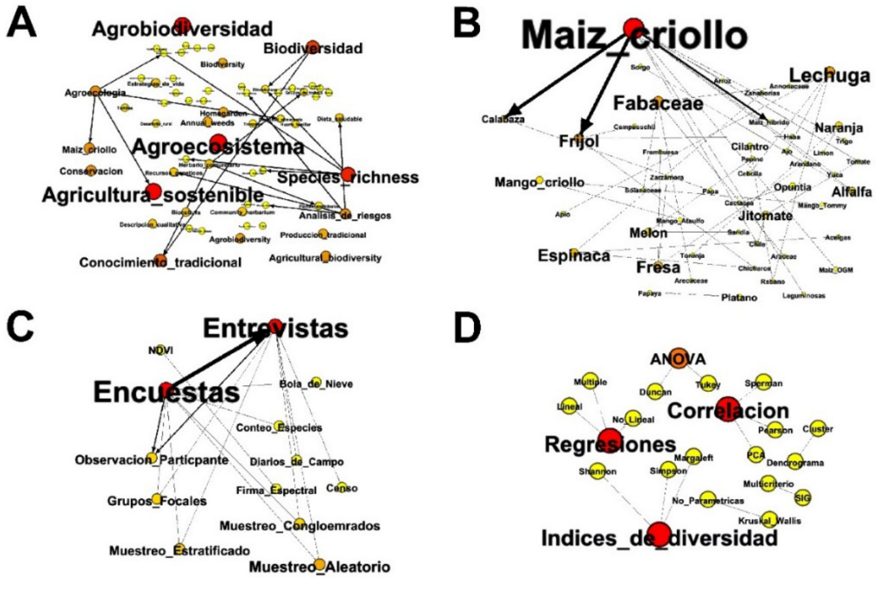

Figure 9. Keyword networks (A), main crops (B), information collection methodologies (C), and information analysis techniques (D) documented in scientific articles compiled from 2000 to 2023.

most used concepts to describe the agrobiodiversity of crops with nutritional value were agroecosystem, sustainable agriculture, agrobiodiversity, and species richness (Figure 9A). Leyva-Galán and Lores-Pérez (2012) found that agrobiodiversity analysis is based on the principles of agroecology and is often understood as a mechanism for resilience in the face of environmental crisis.

The crops most frequently analyzed were corn in association with squash, beans, and some species of domestic chili peppers (Figure 9B). This association is traditionally known in south-central Mexico as milpa Maya (Isakson, 2009), and it constitutes the food base for the indigenous peoples in these regions of the country (Santillán-Fernández *et al*., 2021a). Some vegetable species (lettuce, spinach, cilantro, and tomato), cyclical fruit trees (melon and strawberry), and perennial fruit trees (mango and orange) are beginning to be the subject of study in agrobiodiversity analyses, which is why agroforestry systems are presented as an opportunity for research (Corella-Saborío, 2016).

In terms of data collection methodologies, the most commonly used were surveys and interviews with producers (Figure 9C). Qualitative techniques that integrate social perceptions were also applied, such as participant observation, focus groups, and field diaries, as well as quantitative methods, including sampling (random, stratified, and cluster), species counting, and morphometric analysis of germplasm in situ. Together, these tools made it possible to calculate diversity indices (Simpson, Margalef, and Shannon), apply regression models (linear and nonlinear), perform correlations (Pearson and Spearman), and carry out variance analyses with mean tests such as Tukey and Duncan (Figure 9D).

The use of new technologies such as remote sensing, geographic information systems, and satellite imagery in the analysis of agrobiodiversity in Mexico was not documented, nor were multivariate techniques such as principal component and cluster analysis, even though they allow for a reduction in the number of variables analyzed, which is usually large in agrobiodiversity studies. According to Santillán-Fernández *et al*. (2023), new technologies improve the quality of research, so the use of geostatistical models to assess agrobiodiversity would allow the addition of territorial and social components that have been little explored until now.

Bibliometric techniques proved to be an effective tool for identifying areas of opportunity in the development of knowledge about the agrobiodiversity of crops with nutritional value. However, the theoretical nature of the findings should be considered as a way of expanding the state of the art. Therefore, it is recommended that future research delve deeper into the practical application of scientific results, incorporating a greater diversity of crops and considering their interaction with ethnic groups in relation to the territory. It is also pertinent to explore the use of new technologies, such as remote sensing, to determine agrobiodiversity parameters aimed at both productivity and conservation.

CONCLUSIONS

Agrobiodiversity has been studied on a spatial-temporal scale, considering the nutritional relevance of crops. However, much of the research has been limited to its description, which opens up an area of opportunity to delve deeper into genetic diversity for productivity and conservation purposes. The southeast of Mexico is identified as a strategic region for this type of study, since it concentrates the greatest diversity of crops and ethnic groups. Although corn and beans have been the most analyzed crops, it is possible to expand the knowledge frontier to species such as chili peppers, squash, fruit trees, and vegetables.

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