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Review

Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review (SLR)

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Abstract: In this article, we focused on studying the current barriers to implementing innovations in order for the agricultural sector to become more sustainable. Through a systematic literature review (SLR), 73 scientific articles were obtained with a search equation in SCOPUS. Of these, 48 were analyzed because of the mention of an obstacle preventing the sector from implementing innovations towards sustainability. Information related to the publication year, abstract, authors, keywords, innovation, innovation type, relationship with Fourth Industrial Revolution (4IR), identified barrier, nature of the barrier (internal/external), agricultural subsector, country, and methodology of each article was identified, and with VantagePoint software, a technological surveillance technique was applied as a quantitative analysis of the information. The United States is the country with the most publications related to the subject. The most mentioned keywords were "Sustainable Agriculture", "Agroecology", "Climate Change", "Innovation", and "Organic Farming". Additionally, a qualitative analysis showed 43 types of innovations, 16 of them related to technology. "Organic Agriculture" is the most mentioned innovation, followed by "Genetic Engineering" and "Precision Agriculture". In addition, 51 barriers were identified, 28 external to farmers and 23 internal. "Lack of policies that promote that innovation Innovative Practices" is the most mentioned barrier, followed by "Epistemic Closure", "Unfavorable Regulation", Climate-Smart Agriculture, and "Unskilled Labor". This article is intended not only to show trends in the barriers to innovation that prevents the achievement of sustainability that the agricultural sector needs, but also to serve as an input for the development of policies that provide solutions to these impediments. It was shown that 17 out of the 28 external barriers are related to topics that could be solved by formulating policies, laws, incentives, guidelines, and regulations.

Keywords: sustainability; scientific articles; literature review; obstacles; agriculture

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1. Theoretical Context

Because of the Earth's ecosystem and service functions (regulatory and cultural), the biodiversity it offers, and because it is the supply and sink of greenhouse gases (GHG), this means that it plays an important role in the water and aerosol energy exchange between the Earth's surface and the atmosphere, which is needed in order to ensure the supply of food, fiber, wood, and energy [1].

In recent years, it has been noted that population growth and per capita changes in the consumption of goods supplied by the land have caused extraordinary rates of land and water use, with agriculture being one of the largest responsible sectors. The expansion of areas for agriculture, forestry, and commercial production has generated an increase in the productivity of these activities, ensuring consumption associated with the corresponding demand for food for the growing population [1]. However, this has also contributed to the increase in GHG, which translates into a change in the climate that reaches extremes, and consequently leading to the loss of ecosystems (forests, savannas, grasslands, and wetlands) and a decline in biodiversity. Sustainable land use can help reduce the negative impacts of these stressors [1], but sustainability cannot only be understood as environmentalism, it also concerns social equity and economic development [2].

The Food and Agriculture Organization (FAO) is an institution that seeks a more sustainable agriculture to combat global concerns, such as eliminating hunger, food insecurity, malnutrition, and reducing rural poverty. These are missions that were reinforced in 2015 with the creation of the Sustainable Development Goals (SDG), in which the commitment to end poverty and hunger by 2030 was established. However, climate change represents a challenge for the compliance of these goals, as slow-onset environmental change processes, increased climate variability, and more frequent and severe extreme weather events affect agricultural productivity and add pressure to already fragile ecological and food systems [3].

This is why innovation strategies, such as agricultural innovation systems (AIS), are key examples of potential ways to improve the economic, environmental, and social performance of the agricultural sector. Not only because agriculture contributes to about 30% of global gross domestic product and has high returns on investment [4], but also due to the long-term positive impact of agricultural research and development (R&D) on productivity growth that is well established, and the fact that technologies and practices can help improve the sustainability of the use of natural resources. Nevertheless, agriculture receives about 5% of investment for R&D activities [5].

Agricultural production will need to increase more rapidly to meet a larger and more diverse demand for food, fiber, and fuel from an ever-growing population, as well as for the development of non-food products of a biological origin. Meeting these demands in a sustainable way will require increases in agricultural productivity and efficiency in the use of natural resources (land, water, and biodiversity) in a context of increasing competition between agriculture and other uses of finite land and water resources, and the uncertainties associated with climate change. This will require changes in production methods, including the adoption of technological and other innovations, at every step of the agri-food chain [6].

However, innovation in the agricultural sector is affected by barriers to its adoption, and, as [7] states, these barriers inhibit or reduce innovative activities; therefore, it has become increasingly important to identify and understand them.

The purpose of this article is to carry out a systematic literature review in order to identify and analyze the global barriers that exist in the agricultural sector to implement innovative practices that lead to a transformation toward sustainable agriculture. The conclusions that are developed are intended to be useful for future research in the scientific community. To develop the systematic literature review, the keywords that were input to generate a search equation were required to produce at least 50 articles that document information related to the topic of interest. From the revision of the texts, it was sought to consolidate the most relevant information of the article related to the proposed innovation, identify the characterization of the barrier, identify the agro-industrial practice and where it is generated, and identify the geolocation and search method. With this information, VantagePoint software will be used to analyze the data to study trends and generate conclusions and recommendations for future investigations.

2. Theoretical Framework

Development must aim to reach the needs and aspirations of humans. However, today, this is not true for a large number of people in terms of food, housing, employment, and beyond. Most people have legitimate aspirations for a better quality of life. In a world where poverty and inequity are endemic, there will always be the possibility of ecological crises of multiple kinds. Sustainable development explores the connection between quality of life and the environmental state, considering, at the same time, economic development, social equity, and environmental quality [8].

Agriculture is one of the examples of human intervention in natural systems during this development process and, until recently, it was small-scale and with a limited impact. As of today, their intervention is considerable and drastic in scale and impact, and more threatening to life support systems. This has no reason to be, thus we speak of sustainable development, which should not endanger the natural systems that support life on Earth. For all this, the World Commission on Environment and Development invites you to assist this situation by re-examining critical issues of the environment and development and formulating action proposals to address them that are concrete, realistic, and, above all, innovative [9].

Innovation is understood as a new or improved product or process (or combination) that differs significantly from previous products or processes and that has been made available to potential users (product) or put into use by the unit (process). The key components include the role of knowledge as the basis for innovation, novelty, and usefulness, and the creation or preservation of value as the presumed goal of innovation, which is uncertain and can only be fully evaluated at some point after its implementation [10].

There are three types of innovations: product, process, organizational, and marketing. The value of innovation can also evolve and provide different types of benefits to different stakeholders and are necessary for the study of government policy initiatives to promote innovation that offers socially desirable outcomes such as inclusion, sustainability, employment, or economic growth [10].

In agriculture, as in other sectors, innovation is the main driver of productivity growth. It is estimated that public spending on agricultural R&D has significant impacts on the growth and competitiveness of the total productivity of agricultural factors, but innovation is highlighted as an action to improve the environmental performance of farms. Innovation will have a key role to play in helping the agri-food sector to produce more nutritious, diverse, and abundant food, and to provide the raw material for non-food uses, without depleting natural resources, and adapting to the expected changes in the natural conditions of a changing climate. In some regions, the challenge is to adapt agricultural production systems to more difficult natural environments (e.g., due to salinity and more frequent droughts) [6]. Accepting this reality, some countries are attempting to solve agricultural problems through mechanization, automation, and modernization. The Fourth Industrial Revolution (4RI) will serve as the opportune moment to accelerate the scale and commercialization of agriculture.

The Fourth Industrial Revolution, or 4IR, refers to the looming revolutionary era in which information and communication technologies (ICT) will converge. The revolution will spark new technological innovations in six areas: artificial intelligence, robotics, the Internet of Things (IoT), unmanned vehicles, 3D printing, and nanotechnology. The 4IR will include a variety of new technologies that use big data to incorporate the physical, biological, and digital worlds in a way that will affect all sectors of life [11].

Agriculture is greatly affected by climate, and, currently, science has no means to accurately predict and control it. For this reason, agriculture relies heavily on intelligence and wisdom, including human experience, making it difficult to standardize. 4RI technology can make decisions that exceed human wisdom and experience. It will solve certain problems that cannot be solved with current technology, such as livestock odors, the cost of too much processing, and the likelihood of pests occurring due to climate change. So, the 4IR can be seen as an "environmentally friendly" revolution, unlike our current revolution. At the same time, it will lead to greater technological innovations and far-reaching changes in the economy, society, and life [11].

Despite this, traditional social systems enforce community control over agricultural practices and traditional rights related to water, forests, and land; it does not necessarily impede growth and expansion. Instead, it limits the acceptance and diffusion of technical innovations [9], what we call barriers.

According to [12], the concept of a barrier to innovation is quite ambiguous in the literature. It states that it can be referred to as what prevents innovative activities in companies or as obstacles that can be overcome with effort, but it highlights that they appear to be largely relative and context-dependent (what constitutes a barrier and the degree to which it hinders innovative activities depending on the company and its characteristics).

The categorization of barriers to innovation can be provided by those that are external and those that are internal. This division makes it possible to recognize the barriers that a company can influence and the barriers that are partially or totally outside its influence. Internal ones originate within the context of activity and are related to its management and organization (e.g., financial resources, competencies, and mindsets). External barriers arise when there is an interaction with other organizations or actors in economic and innovation systems (e.g., competitors, customers, partners, and governments) [12].

In recent years, different studies have been carried out on barriers in different agricultural sectors. Ref. [13], in their paper on the barriers to the use of digital technologies for sustainable agricultural development and food security in Mali, identifies the barriers in three projects; the authors focused on the perceptions of and the reactions of users to the technologies, as well as the barriers to usability and sustainability of the technologies.

On the other hand, [14], in their study identifying the barriers and motivations for soil tests in the beef and sheep meat sector, as well as [15], present the evaluation of adoption barriers of the IoT smart agriculture of Brazilian farmers. The study sought to describe the main characteristics and resistances of smart agriculture that impede the adoption of innovations; the authors used stepwise regression to assess the rejection attributes of IoT innovation predicted by knowledge transfer barriers.

Likewise, [16], in their paper related to the review of financial barriers and strategies for nature-based urban solutions, identified more than nine financial barriers. Ref. [17] presents the barriers, challenges, and requirements for the use of information and communication technologies in the agricultural sector in Bangladesh. The authors detailed the barriers faced by these extension programs in the use of ICT; they propose the possible solutions, needs, and requirements that must be implemented during decision making.

Likewise, [18] analyzes what is related to soil and pest management in agricultural systems as well as drivers and barriers to the implementation of practices based on agroecological principles. Finally, [19] presents the classification of seven barriers related to nature-based urban solutions.

3. Materials and Methods

To determine the barriers that prevent the adoption of innovations focused on the sustainable development of the agricultural sector, a systematic literature review (SLR) was carried out, which was developed in the following stages (also shown in Figure 1).

3.1. Stage I: Elaboration of Search Equation

To narrow down the problem, a problem tree was built, which allowed for the identification of the keywords (sustainable, agriculture, innovation, and barriers) used in the search equation for scientific articles in SCOPUS. The equation was modified twice until the one that yielded a representative amount of bibliographic material related to the selected topic to be studied was obtained. The final equation was TITLE-ABS-KEY (sustainab* AND agriculture AND innovation AND barriers), obtaining 73 scientific articles.

3.2. Stage 2: First Reading of Bibliographic Material

As a first filter to determine the articles that would be a part of the study, the summaries of the 73 articles obtained with the equation were read to discard those that did not correspond to the context of the agricultural sector or did not address the issues related to the sustainable development of the sector through innovations. In total, 53 articles met the conditions.

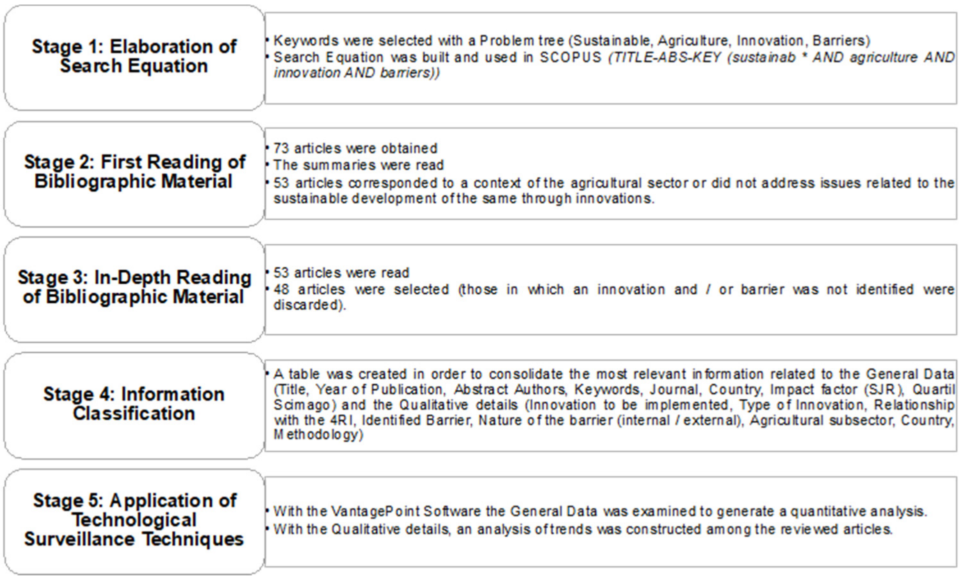

Figure 1. Stages of the used methodology.

3.3. Stage 3: In-Depth Reading of Bibliographic Material

As a second filter, a complete reading of the 53 articles was carried out to validate that the theme developed was related to the purpose of this article. In total, 48 articles were chosen to be used in the development of this paper (those in which an innovation and/or barrier was not identified were discarded).

3.4. Stage 4: Information Classification

A table was constructed to consolidate the most relevant information from each of the articles, which was classified into two sets as follows:

- General information: title, year of publication, abstract, authors, keywords, journal, country, the impact factor (SJR), and quartile Scimago.
- Qualitative details: innovation to be implemented, type of innovation, relationship with the 4RI, identified barrier, nature of the barrier (internal/external), agricultural subsector, country, and article.

3.5. Stage 5: Application of Technological Surveillance Techniques

The table filled out with all the information identified in the previous stage was used as the main input for the analysis of the literature review with VantagePoint Software. With the qualitative details in the information table, an analysis of the trends was constructed among the reviewed articles.

4. Results

The following results correspond to the analysis produced by the consolidated general information of the articles read. The tables were constructed from the data related to the years of publication of the articles, the countries of origin, and the most relevant keywords in the literature review.

As shown in Figure 2, the number of articles published by the established ranges shows a noticeable increase. It was observed that from 1992 to 2000, only 1 article was published, 20 were published between 2001 and 2015, and 27 were published between 2016 and 2020.

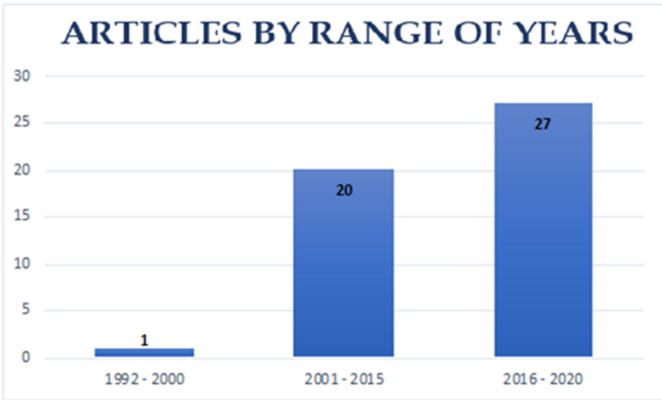

Figure 2. Number of papers published per year range.

For the first range, the upper limit was established by taking into account the adoption of the Millennium Declaration, which established the Millennium Goals (MDGs) in 2000 [20]. For the second range, 2015 was established as the limit because it is the year in which the new 2030 agenda was adopted by many countries, accepting the Sustainable Development Goals [21].

In the first range of the publication years, ref. [22] details the little communication and cooperation which took place between interdisciplinary researchers and the small amount of information available to policy makers focused on promoting sustainable agriculture on innovations focused on a decrease in pesticide use, crop rotation, and no-plow agriculture, which could anticipate consequences of its implementation in the country of the United States.

For the range from 2001 to 2015, ref. [23] details the technological integrations in innovative practices in Europe and exposes the few resources utilized and the fragmentation of research in the design and management of orchards, precision agriculture, green technology, genetic engineering, in vitro, and micropropagation. Organic agriculture is a topic addressed in five articles: Ref. [24] detected that in the United States, this innovation is perceived as unpredictable, and users relate it to extra costs and the limited availability of required products. Ref. [25] states that in Germany, this innovation received only a small amount of reception due to the few known success stories among farmers, the lack of specialized knowledge and expertise networks, and the difficulty of entering the network of organic agriculture actors which have already been established. Ref. [26] found that there is little market interest to pay extra for organic products; there is also little information on these products and a lack of support from the government. Ref. [27] detected that once again in the United States, there is a barrier to this innovation associated with the lack of policies for financing farmers and the opposition of farms to change their traditional model due to a high degree of uncertainty at the time of organic farming. Finally, ref. [28] concluded that the lack of prioritization of research associated with organic agriculture is the greatest barrier to this innovation in Canada.

Starting in 2015, trends focused on technological innovations began to be seen. Ref. [29] detected that the low priority within Malaysia of innovations in biogeographic species transplantation, plant and crop gene technology, aquaculture, urban agriculture, low-carbon crops, green technology, intelligent irrigation systems, and research exchange represents a barrier to the sustainable development of national agriculture. In Ref. [30], the authors studied precision agriculture and delved into how the size of farms, educational level, investment power, incompatibility with technology, no perception of benefit, high-risk perception, data security, few subsidies, and the uncertainty regarding receiving a return on an investment make up the barriers to adopt sustainable development in Chinese farms, while ref. [31] detected that in Italy, this same innovation presents a resistance to be implemented due to factors such as educational level, age, investment power, and the size of farmers' farms. Finally, ref. [32] details agroecology and exposes that the economic power of large industries prevents the deployment of this innovation at a global level.

Based on the geographical origin, 29 countries were the ones that commissioned the production of articles related to the theme developed. The United States leads the participation with 13 of them, followed by England, Australia, Italy, France, Netherlands, Argentina, Belgium, Canada, China, Germany, and Switzerland, respectively, thus making up the top 12 countries that participated in the publication of articles, as shown in Figure 3. On the other hand, the United States and Italy are the countries with the lowest percentage of collaboration at the time of publication, with 38.46% and 16.67%, respectively of their total articles, while Argentina and Switzerland only have publications in conjunction with other countries.

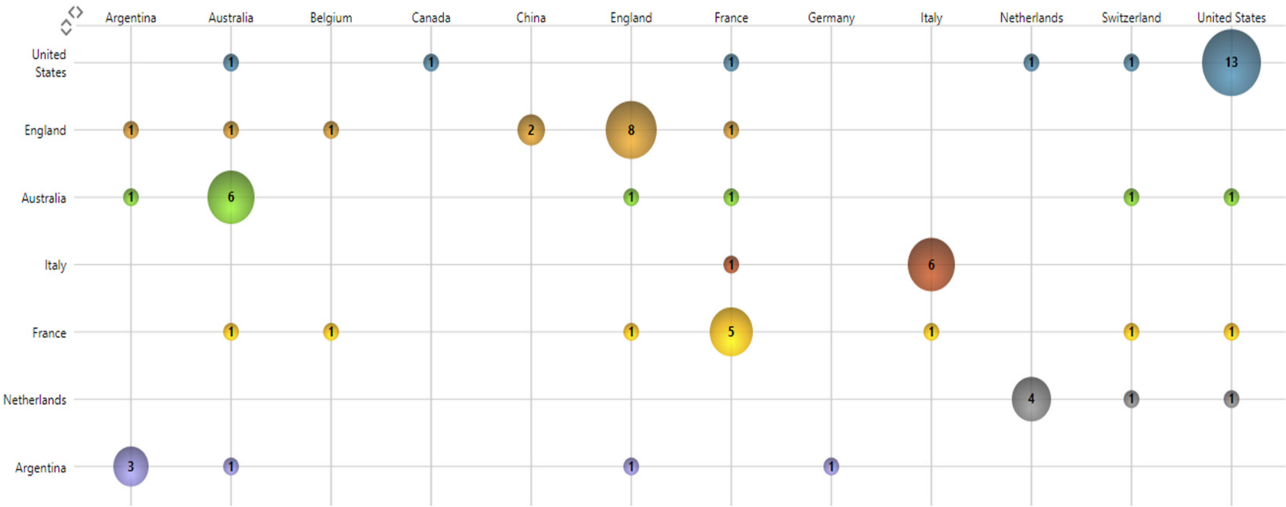

Figure 3. Number of papers published per country (top 12 countries).

In Figure 4 related to the cluster map of top 30 keywords, the most common in the articles were "Sustainable Agriculture", "Agroecology", "Climate Change", "Innovation", and "Organic Farming"; Sustainable Agriculture appeared in six articles (12.5%), while the next four each appeared in four articles (8.33%).

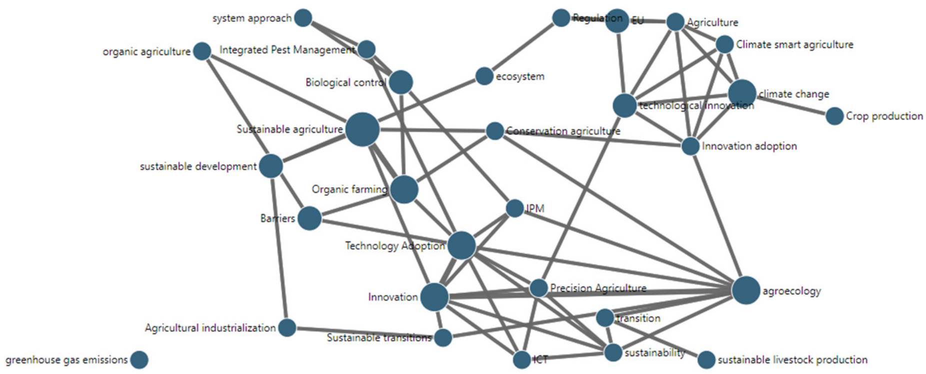

Figure 4. Cluster map of top 30 keywords.

5. Discussion

After qualitatively analyzing the articles read with the results of the VantagePoint Software, the analysis was complemented with 5 topics detected in each of the papers: the type of innovation, relationship with the Fourth Industrial Revolution, the barrier detected, the type of barrier (internal/external), and the method of analysis. Table 1 shows the consolidation of these five axes.

Table 1. List of innovations, barriers, and methodologies from articles.

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Agriculture adapted to climate change	Process innovation	No	Lack of policies that promote innovation [33]	External	Inferred SLR
Agroecology	Process innovation	No	Economic power in large industries impedes smaller farms to develop [32]	External	Inferred SLR
Agroecology	Process innovation	No	Lack of farmers' knowledge [34]	Internal	SLR not mentioned
Agroecology	Process innovation	No	Weak farmer's contact networks [34]	Internal	SLR not mentioned
Alternative food networks	Process innovation	No	Greater work effort with no visible Return on Investment [35]	Internal	SLR
Alternative food networks	Process innovation	No	Lack of policies that promote that innovation [35]	External	SLR
Aquaculture	Process innovation	No	Lack of policies that promote that innovation [36]	External	SLR and complements
Aquaculture	Process innovation	No	Lack of policies that promote that innovation [37]	External	Inferred SLR
Aquaculture	Process innovation	No	Low priority of the subject in the country [36]	External	Inferred SLR
Aquaculture	Process innovation	No	Little investment in research [29]	External	Inferred SLR
Biological nitrification inhibition	Product innovation	Yes	Lack of policies that promote that innovation [37]	External	Inferred SLR
Biotech crops	Product innovation	Yes	Unfavorable regulation [38]	External	Inferred SLR
Carbon-rich farming	Process innovation	No	Weak infrastructure [39]	Internal	Inferred SLR
Carbon-rich farming	Process innovation	No	Farmer's difficulty accessing credit [39]	External	Inferred SLR
Carbon-rich farming	Process innovation	No	Lack of technical assistance for farmers [39]	External	Inferred SLR
Carbon-rich farming	Process innovation	No	Low availability of materials [39]	External	Inferred SLR
Circular economy	Organizational model innovation	No	Return on investment uncertainty [40]	Internal	SLR not mentioned
Climate-smart agriculture	Process innovation	Yes	Unsuitable business model [41]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Complex financing [42]	External	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Farmer's investment power [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Return on investment uncertainty [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	High implementation costs [42]	External	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Long-term return on investment [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Lack of policies that promote that innovation [42]	External	SLR and complements

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Climate-smart agriculture	Process innovation	Yes	Unfavorable regulation [42]	External	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Sustainable standards are difficult to meet [42]	External	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Lack of farmers' knowledge [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Epistemic closure [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Problem not perceived by farmers [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Farmer's education level [42]	Internal	SLR and complements
Climate-smart agriculture	Process innovation	Yes	The market is not interested [42]	External	SLR and complements
Climate-smart agriculture	Process innovation	Yes	Unskilled labor [42]	Internal	SLR and complements
Collaborative approach in livestock	Organizational model innovation	No	Internal differences [42]	Internal	SLR and complements
Collaborative approach in livestock	Organizational model innovation	No	Hierarchies [42]	Internal	SLR and complements
Community-supported agriculture	Organizational model innovation	No	The market is not interested [24]	External	SLR not mentioned
Community-supported agriculture	Organizational model innovation	No	More expensive end product [24]	External	SLR not mentioned
Community-supported agriculture	Organizational model innovation	No	Low availability of products [24]	Internal	SLR not mentioned
Controlled environment agriculture	Process innovation	Yes	High implementation costs [43]	External	SLR not mentioned
Controlled traffic farming	Process innovation	No	Incompatibility with technology [44]	Internal	SLR
Crop mixtures	Process innovation	No	Incompatibility with technology [45]	Internal	SLR not mentioned
Crop mixtures	Process innovation	No	Greater work effort [45]	Internal	SLR not mentioned
Crop mixtures	Process innovation	No	Unskilled labor [45]	Internal	SLR not mentioned
Crop rotation	Process innovation	No	Lack of alignment between the scientific community and politicians [22]	External	Inferred SLR
Crop rotation	Process innovation	No	Lack of communication between interdisciplinary researchers [22]	External	Inferred SLR
Drip irrigation	Process innovation	Yes	Lack of policies that promote that innovation [7]	External	SLR not mentioned
Drip irrigation	Process innovation	Yes	Few subsidies for farmers [7]	External	SLR not mentioned
Drip irrigation	Process innovation	Yes	Complex financing [7]	External	SLR not mentioned
Drip irrigation	Process innovation	Yes	The market is not interested [7]	External	SLR not mentioned
Drip irrigation	Process innovation	Yes	Environment conditions [7]	External	SLR not mentioned
Drip irrigation	Process innovation	Yes	Unfavorable regulation [7]	External	SLR not mentioned

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Drip irrigation	Process innovation	Yes	Unskilled labor [7]	Internal	SLR not mentioned
Drip irrigation	Process innovation	Yes	Low educational level [7]	Internal	SLR not mentioned
Drip irrigation	Process innovation	Yes	Epistemic closure [7]	Internal	SLR not mentioned
Drip irrigation	Process innovation	Yes	Incompatibility with technology [7]	Internal	SLR not mentioned
Drip irrigation	Process innovation	Yes	Return on investment uncertainty [7]	Internal	SLR not mentioned
Drip irrigation	Process innovation	Yes	No perception of benefit [7]	Internal	SLR not mentioned
Eco-friendly nets	Process innovation	No	Lack of farmers' knowledge [46]	Internal	SLR not mentioned
Eco-friendly nets	Process innovation	No	Complex financing [46]	External	SLR not mentioned
Fire forecasting models	Process innovation	Yes	Lack of policies that promote that innovation [37]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Complex financing [47]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Information collection and reuse access [47]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Sustainable standards are difficult to meet [48]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Lack of policies that promote that innovation [43]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Low priority of the subject in the country [36]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	Little investment in research [29]	External	Inferred SLR
Genetic engineering	Product innovation	Yes	The market is not interested [26]	External	SLR not mentioned
Genetic engineering	Product innovation	Yes	Lack of farmers' knowledge [26]	Internal	SLR not mentioned
Genetic engineering	Product innovation	Yes	Lack of government support [26]	External	SLR not mentioned
Genetic engineering	Product innovation	Yes	Negative image generated by media/internet for farmers [26]	External	SLR not mentioned
Genetic engineering	Product innovation	Yes	Little international cooperation	External	SLR not mentioned
Genetic engineering	Product innovation	Yes	Little investment in research	External	SLR not mentioned
Genetic engineering	Product innovation	Yes	Research fragmentation [23]	External	SLR not mentioned
Green technology	Process innovation	Yes	Lack of policies that promote that innovation [29]	External	Inferred SLR
Green technology	Process innovation	Yes	Low priority of the subject in the country [29]	External	Inferred SLR
Green technology	Process innovation	Yes	Little investment in research [29]	External	Inferred SLR
Green technology	Process innovation	Yes	Little international cooperation [23]	External	SLR not mentioned
Green technology	Process innovation	Yes	Little investment in research [23]	External	SLR not mentioned
Green technology	Process innovation	Yes	Research fragmentation [23]	External	SLR not mentioned
Integrated crop–livestock systems	Process innovation	No	Return on investment uncertainty [49]	Internal	SLR not mentioned
Integrated crop–livestock systems	Process innovation	No	Difficulty accessing credit for farmers [49]	External	SLR not mentioned
Integrated crop–livestock systems	Process innovation	No	Weak infrastructure [49]	Internal	SLR not mentioned

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Integrated crop–livestock systems	Process innovation	No	Unskilled labor [49]	Internal	SLR not mentioned
Integrated crop–livestock systems	Process innovation	No	Unfavorable regulation [49]	External	SLR not mentioned
Integrated crop–livestock systems	Process innovation	No	Lack of policies that promote that innovation [49]	External	SLR not mentioned
Integrated pest management	Process innovation	Yes	Implementation costs [43]	External	SLR not mentioned
Integrated pest management	Process innovation	Yes	Lack of policies that promote that innovation [50]	External	Inferred SLR
Integrated pest management	Process innovation	Yes	Few subsidies for farmers [50]	External	Inferred SLR
Integrated pest management	Process innovation	Yes	Little investment in research [50]	External	Inferred SLR
Integrated pest management	Process innovation	No	Risk perception [25]	Internal	SLR and complements
Integrated pest management	Process innovation	No	Return on investment uncertainty [25]	Internal	SLR and complements
Integrated pest management	Process innovation	No	Epistemic closure [25]	Internal	SLR and complements
Integrated pest management	Process innovation	No	Weak contact networks [25]	Internal	SLR and complements
Integrated pest management	Process innovation	No	Lack of farmers' knowledge [25]	Internal	SLR and complements
Integrated pest management	Process innovation	No	Economic power large industries [25]	External	SLR and complements
Intensive clavipectoral systems	Process innovation	No	Lack of farmers' knowledge [51]	Internal	SLR not mentioned
Intensive silvopastoral systems	Process innovation	No	Lack of policies that promote that innovation [51]	External	SLR not mentioned
Less pesticide use	Process innovation	No	Lac caused by climate variability k of alignment of the scientific community and politicians [22]	External	Inferred SLR
Less pesticide use	Process innovation	No	Lack of communication between interdisciplinary researchers [22]	External	Inferred SLR
Low-carbon crops	Process innovation	No	Lack of policies that promote that innovation [29]	External	Inferred SLR
Low-carbon crops	Process innovation	No	Low priority of the subject in the country [29]	External	Inferred SLR
Low-carbon crops	Process innovation	No	Little investment in research [29]	External	Inferred SLR
Micropropagation	Process innovation	Yes	Little international cooperation [23]	External	SLR not mentioned
Micropropagation	Process innovation	Yes	Little investment in research [23]	External	SLR not mentioned
Micropropagation	Process innovation	Yes	Research fragmentation [23]	External	SLR not mentioned
Multi-resistant cultivars	Product innovation	No	No perception of benefit [52]	Internal	SLR and complements

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Multi-resistant cultivars	Product innovation	No	Unfavorable regulation [52]	External	SLR and complements
Multi-resistant cultivars	Product innovation	No	Epistemic closure [52]	Internal	SLR and complements
Multi-resistant cultivars	Product innovation	No	Badly formulated policy [52]	External	SLR and complements
Nanotechnology	Product innovation	Yes	Unskilled labor [53]	Internal	Inferred SLR
Nanotechnology	Product innovation	Yes	Lack of farmers' knowledge [53]	Internal	Inferred SLR
No-till agriculture	Process innovation	No	Unskilled labor [54]	Internal	SLR
No-till agriculture	Process innovation	No	Lack of policies that promote that innovation [37]	External	Inferred SLR
No-till agriculture	Process innovation	No	Lack of alignment between the scientific community and politicians [22]	External	Inferred SLR
No-till agriculture	Process innovation	No	Lack of communication between interdisciplinary researchers [22]	External	Inferred SLR
Orchard design and management	Process innovation	Yes	Little international cooperation [23]	External	SLR not mentioned
Orchard design and management	Process innovation	Yes	Little investment in research [23]	External	SLR not mentioned
Orchard design and management	Process innovation	Yes	Research fragmentation [23]	External	SLR not mentioned
Organic agriculture	Process innovation	No	Non-standardized regulations (global) [55]	External	SLR
Organic agriculture	Process innovation	No	Price competitiveness in markets [56]	External	SLR and complements
Organic agriculture	Process innovation	No	Lack of policies that promote that innovation [56]	External	SLR and complements
Organic agriculture	Process innovation	No	Unfavorable regulation [56]	External	SLR and complements
Organic agriculture	Process innovation	No	Little investment in research [56]	External	SLR and complements
Organic agriculture	Process innovation	No	Investigation prioritization [28]	External	Inferred SLR
Organic agriculture	Process innovation	No	Lack of policies that promote that innovation [27]	External	SLR and complements
Organic agriculture	Process innovation	No	Epistemic closure [27]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Return on investment uncertainty [27]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Weak infrastructure [27]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Incompatibility with technology [27]	Internal	SLR and complements
Organic agriculture	Process innovation	No	The market is not interested [26]	External	SLR not mentioned
Organic agriculture	Process innovation	No	Lack of farmers' knowledge [26]	Internal	SLR not mentioned
Organic agriculture	Process innovation	No	Lack of government support [26]	External	SLR not mentioned
Organic agriculture	Process innovation	No	Negative image generated by media/internet [26]	External	SLR not mentioned

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Organic agriculture	Process innovation	No	Risk perception [25]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Return on investment uncertainty [25]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Epistemic closure [25]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Weak contact networks [25]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Lack of farmers' knowledge [25]	Internal	SLR and complements
Organic agriculture	Process innovation	No	Economic power large industries [25]	External	SLR and complements
Organic agriculture	Process innovation	No	The market is not interested [24]	External	SLR not mentioned
Organic agriculture	Process innovation	No	More expensive end product [24]	External	SLR not mentioned
Organic agriculture	Process innovation	No	Low availability of products [24]	Internal	SLR not mentioned
Precision agriculture	Process innovation	Yes	Small farm size [31]	Internal	SLR and complements
Precision agriculture	Process innovation	Yes	Investment power [31]	Internal	SLR and complements
Precision agriculture	Process innovation	Yes	Poor data handling [31]	Internal	SLR and complements
Precision agriculture	Process innovation	Yes	Age is not compatible with new tendencies [57]	Internal	SLR and complements
Precision agriculture	Process innovation	Yes	Farmer's educational level [57]	Internal	SLR and complements
Precision agriculture	Process innovation	Yes	Small farm size [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	Farmer's educational level [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	Farmer's low investment power [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	Incompatibility with technology [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	No perception of benefit [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	High-risk perception [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	Data security paradigm [30]	External	SLR
Precision agriculture	Process innovation	Yes	Few subsidies for farmers [30]	External	SLR
Precision agriculture	Process innovation	Yes	Return on investment uncertainty [30]	Internal	SLR
Precision agriculture	Process innovation	Yes	Little international cooperation [23]	External	SLR not mentioned
Precision agriculture	Process innovation	Yes	Little investment in research [23]	External	SLR not mentioned
Precision agriculture	Process innovation	Yes	Research fragmentation [23]	External	SLR not mentioned
Rooftop agriculture	Process innovation	No	Unfavorable regulation [58]	External	SLR
Ruminant farming	Process innovation	Yes	Epistemic closure [59]	Internal	SLR and complements
Ruminant farming	Process innovation	Yes	Return on investment uncertainty [59]	Internal	SLR and complements
Ruminant farming	Process innovation	Yes	Problem not perceived by farmers [59]	Internal	SLR and complements

Table 1. *Cont.*

Innovation	Innovation Type	4IR Relation	Innovation Barrier to Overcome	Barrier Type	Methodology
Rural cooperative economic organizations	Organizational model innovation	Yes	Implementation costs [60]	External	Inferred SLR
Rural cooperative economic organizations	Organizational model innovation	Yes	Unskilled labor [60]	Internal	Inferred SLR
Smart irrigation systems	Process innovation	Yes	High implementation costs [60]	External	SLR not mentioned
Smart irrigation systems	Process innovation	Yes	Epistemic closure [60]	Internal	SLR not mentioned
Smart irrigation systems	Process innovation	Yes	High implementation costs [61]	External	SLR and complements
Smart irrigation systems	Process innovation	Yes	Epistemic closure [61]	Internal	SLR and complements
Smart irrigation systems	Process innovation	Yes	Lack of policies that promote that innovation [29]	External	Inferred SLR
Smart irrigation systems	Process innovation	Yes	Low priority of the subject in the country [29]	External	Inferred SLR
Smart irrigation systems	Process innovation	Yes	Little investment in research [29]	External	Inferred SLR
Soil conditioners from bioenergy	Product innovation	No	Unfavorable regulation [62]	External	Inferred SLR
Soil conditioners from bioenergy	Product innovation	No	No perception of benefit by farmers [62]	Internal	Inferred SLR
Soil conditioners from bioenergy	Product innovation	No	Little investment in research [62]	External	Inferred SLR
Sustainable agriculture	Process innovation	No	Epistemic closure [62]	Internal	Inferred SLR
Sustainable nutrient management	Process innovation	No	Unskilled labor [63]	Internal	SLR not mentioned
Sustainable nutrient management	Process innovation	No	Weak infrastructure [63]	Internal	SLR not mentioned
Sustainable supply chain management	Process innovation	No	Internal company policies not compatible with change [64]	Internal	SLR and complements
Sustainable supply chain management	Process innovation	No	Strategic management of companies [64]	Internal	SLR and complements
Transplantation of bio-geographical species	Process innovation	Yes	Lack of policies that promote that innovation [29]	External	Inferred SLR
Transplantation of bio-geographical species	Process innovation	Yes	Low priority of the subject in the country [29]	External	Inferred SLR
Transplantation of bio-geographical species	Process innovation	Yes	Little investment in research [29]	External	Inferred SLR
Urban agriculture	Process innovation	No	Unfavorable regulation [58]	External	SLR
Urban agriculture	Process innovation	No	Lack of policies that promote that innovation [29]	External	Inferred SLR
Urban agriculture	Process innovation	No	Low priority of the subject in the country [29]	External	Inferred SLR
Urban agriculture	Process innovation	No	Little investment in research [29]	External	Inferred SLR
Using reduced fertilizer rates	Process innovation	No	Badly formulated policy [65]	External	SLR and complements

5.1. Innovation Type

A total of 43 innovations were found, of which none of them were related to marketing innovation (following the Oslo Manual classifications).

Agroecology as process innovation is mentioned by [41] as a transition to alternative sustainable systems to mitigate the high environmental and social costs of agriculture of grains and rotational graziers in the region of Iowa, Mississippi. Additionally, ref. [32] projected it as a framework for action for global food systems that must migrate to sustainable systems that will open paths for the transition to new ways of seeing, experiencing, and obtaining food.

Additionally, it was found that no-till agriculture is another process innovation that ensures soil conservation and the remediation of erosion caused by agriculture. Ref. [22] mentions the investment of millions of USD in the United States to address soil erosion (which includes no-till agriculture) and the barrier when developing policies focused on promoting sustainable agriculture and anticipating consequences of its implementation due to the little information for the elaborators of these documents, as well as the non-cooperation between interdisciplinary researchers. Ref. [37] exposes Latin America as a region that must rapidly integrate innovations due to its high vulnerability to the consequences of climate change. No-till agriculture is proposed as an alternative to taking care of the natural resources of the agricultural farms of the region, which must be integrated with other technologies (also studied in the articles) such as fire prevention models and biological nitrification inhibition, but policies must be built to support sustainable practices that reduce negative environmental impacts while maintaining ecosystem function and services. Ref. [47], on the other hand, speaks of the high profitability of no-till agriculture in Brazil, but of its failure due to the low abilities of farmers to manage the practice.

Urban agriculture is another process innovation that involves the integration of the city in this hitherto rural process. Ref. [29] details this initiative as one of the solutions proposed to achieve agricultural sustainability in the country of Malaysia (an economy in transition) and the difficulty it has had due to the lack of policies to develop an effective scientific framework. Ref. [58] studies this new process of agriculture in the context of the European Union, and that it arises as a solution to land limitations. Despite its expansion across the continent, regulations did not provide a conducive environment for such an initiative to become a way for cities to cope with climate change, food and nutrition security, biodiversity management, and human prosperity.

In product innovations, the study of genetics for food improvement stands out. Ref. [23] mentions genetic engineering as an alternative to going from a performance-based model to one to improve the quality traits of products, ensure food safety, satisfy market demands and consumer rights, and the administration of agroecosystems and non-renewable resources such as soil and the environment. However, the European fruit sector must work to strengthen international cooperation for research, increase the resources allocated for it, and stop the fragmentation that it is receiving. Ref. [26] emphasizes the importance of this innovation in Australia, which has shown positive results for farmers, but it must confront public attitudes and the media that show a negative image of this advance. Ref. [48] states that in the United States, genetic engineering positively impacts the environment and society since it constantly produces more than organic systems and uses zero-tillage conservation methods, but regulations and accountability standards represent a difficult barrier to overcome. Ref. [47] outlines the importance of genetic resources research in the Brazilian agricultural sector, in which alleles and genetic combinations that are effective in certain environments but not in others have been highlighted. These data would be very useful to accelerate food production processes by maintaining a stable and diverse biosphere by expanding crop production in a reduced land area due to environmental degradation caused by the human invasion and climate change, while maintaining biodiversity. Access, collection, availability of information, and financing represent the most important barriers to overcome.

Nanotechnology is another product innovation that, according to [53], has the potential to improve efficiencies in the use of nutrients in fertilizers, control pests, understand parasite phenomena, develop biopesticides, strengthen natural fibers, eliminate contaminants from soil and water, improve the shelf life of vegetables and flowers, manage water precision, reclaim salt-affected soils, and stabilize erosion-prone surfaces. However, in the Indian agricultural sector, there is no willingness to invest in these initiatives because of a lack of education and knowledge in agricultural practices.

Organizational model innovations focus on collaboration throughout the agricultural production chain. Ref. [24] discusses community-supported agriculture that provides consumers with healthy, locally grown foods, revitalizes local food economies, and addresses the dissatisfaction of certain customers of large agricultural corporations in New York, the United States. The non-availability of products, their extra cost, and a market that is mostly not interested in the initiative are the impediments to these communities. Studies detailing the Rural Cooperative Economic Organizations in China that accelerate the agricultural industrialization process show that they do not have a skilled labor force and struggle with high implementation costs. Ref. [43] highlights that collaborative models of pig farming in the Netherlands result in smarter and more innovative solutions and provide support in the development of more sustainable agricultural concepts, but they must ensure that internal relationships are optimal and break with hierarchies in the market.

A circular economy is an organizational model innovation that [40] highlights in the case of a sustainable business model that integrates all the actors in the agricultural chain of rice and wheat production in Italy. Uncertainty regarding a return on investment is the main barrier that must be overcome to implement this type of initiative according to the results of this study.

5.2. Fourth Industrial Revolution Relation

Since 2006, innovations related to the Fourth Industrial Revolution have increased and, in this article, 17 innovations of this nature were identified.

Integrated pest management (IPM) was reviewed in three articles, of which two relate it to technologies and one does not. Ref. [25] studies this topic in German horticulture through biological methods. Ref. [50] details this innovation and how it should be integrated with technological practices to monitor the use of pesticides and fertilizers for decision making by farmers and present successful case studies of this good practice in Germany, the United States, and Canada in sugar beet, almonds, cotton, oranges, tomatoes, lettuce, carrot, and apple crops. Finally, ref. [43] highlights this innovation as a solution for flower and vegetable greenhouse areas in France where a large number of pesticides are used; the articles exposes the importance of designing more robust controlled crops where both technological and ecological approaches are integrated, which involves high-tech tools dedicated to IPM.

The 4IR-related innovations stand out for allowing the constant monitoring of resources for agriculture that generates efficiency and better decision making by farmers. For example, smart irrigation systems are a solution to save water in crops. In Malaysia, these types of innovations are affected by the lack of policies that support their implementation, the low priority they have in the country in the public agenda, and the low investment for related research [29]. In Australia [61] and Campania [60], these systems face a low level of implementation due to the high associated costs and due to the epistemic closure of farmers (they cling to their traditional beliefs of crop management).

Precision agriculture (PA) is another technological innovation that provides accurate information on the status of crops for the responsible use of resources. For fruit crops in Europe, research plays a fundamental role in the optimal deployment of these initiatives, but the lack of resources, international cooperation, and fragmentation of this academic sector are marked obstacles [23]. In China's agricultural sector, this technology is not expanded by factors such as farm size, educational level, farmer's investment power, incompatibility with technology, no benefit and risk perception, data security uncertainty, few subsidies, and return on investment uncertainty [30]. Finally, in Italy, the age of the farmers and their level of education are impediments to implementing PA [57] as well as farm size, farmer's investment power, and data handling [31].

Climate smart agriculture (CSA) is another technological option to monitor crop factors that can prevent negative consequences characteristic of climate change. In OECD countries such as Switzerland, the Netherlands, Italy, and France, the implementation of these initiatives is slow in agri-food supply chains [42]. Economic issues such as financing, the investment power of farmers, return on investment uncertainty, implementation costs, and long-term return on investment; politic issues such as a lack of policies regarding unfavorable regulation, which makes it difficult to meet sustainable standards; and social issues such as the lack of farmers knowledge, epistemic closure, the problem not being perceived, educational level, unskilled workforce, and an uninterested market are the reasons why there is no optimal deployment of these new systems. On the other hand, in crops from France, Switzerland, Italy, and the Netherlands, the problem with the correct execution of CSA is that this is an unsuitable business model for the context in which it is desired to be implemented within [41].

5.3. Barriers and Types

A total of 51 barriers were consolidated from the review of the articles. The classification of these was defined from the recognition of those factors that a farmer influences to generate a change and those that are partially or totally outside his influence " . . . Internal barriers originate within a firm and are closely related to its management and organization and include issues relating to, for example, financial resources, competences, and mindsets. External barriers originate from a firm's external environment and emerge when a firm interacts with other organizations or actors in economic and innovation systems; these include issues relating to, for example, the behavior of competitors, customers, partners, and governments..." [12].

A lack of policies that promote innovations was the external barrier with the highest recurrence in the review. Ref. [37] mentions it as an impediment to implementing biological nitrification inhibition, fire forecasting models, and no-till agriculture in Latin America, innovations that are proposed to manage the increase in greenhouse gases associated with the agricultural sector. Ref. [49] mentions it when analyzing integrated crop–livestock systems to intensify sustainable agriculture and livestock farming in Brazil. Ref. [7] detected it in their study of sustainable water management for food production in Australia through drip irrigation. Ref. [35] highlights it as an obstacle in alternative food networks in the United States for both farmers and consumers. Ref. [56] highlights it in the study carried out in the country of Argentina on organic beekeeping models to generate transitions towards sustainable agriculture. Genetic engineering, aquaculture, green technology, low-carbon crops, smart irrigation systems, the transplantation of bio-geographical species, and urban agriculture also represents a challenge in Malaysia, according to [29], to create a scientific framework for the sustainability of the agricultural sector. Aquaculture as a solution for the fish farming sector in the European Union, despite presenting an important contribution to the economic sphere, lacks policies that promote the practice [36]. Ref. [42] also highlights this in the agri-food supply chains of Switzerland, the Netherlands, Italy, and France to achieve a correct deployment of climate-smart agriculture innovations. In Africa, they also face these types of barriers to implementing agriculture adapted to climate change when they wish to generate solutions for the consequences caused by climate variability [40]. In Colombia, the intensive silvopastoral systems must have a strategy to spread this type of practice, which must go hand in hand with a political framework that they lack [51]. In terms of the sectors of agriculture, livestock farming (dairy), poultry farming, and floriculture in the United States, ref. [27] alludes to the lack of policies to implement innovations focused on organic agriculture processes. Finally, ref. [50] mentions this as an impediment to advance in integrated pest management systems in sugar beet, almonds, cotton, oranges, tomatoes, lettuce, carrot, and apple crops in the countries of Germany, the United States, and Canada.

On the other hand, epistemic closure (or lock) is the inertia and resistance to unfamiliarity [59] and was the internal barrier with the highest repetitions. Ref. [25] speaks of this barrier in the horticulture and agriculture of Germany for the individual decision making of farmers when adopting organic practices and integrated pest management systems in the production process. Ref. [27] details this in her study of the adoption of organic farming practices in farmers in the United States dedicated to agriculture, livestock farming (dairy), poultry farming, and floriculture. Ref. [66] focuses on this again in the context of the North American country, but in terms of progressing with the implementation of sustainable agriculture. In Belgium, ref. [52] studies a case of multi-resistant cultivars for wheat and answers the question of its slow commercial implementation through the barrier in question. Ref. [61] finds that in Australia, smart irrigation systems are not correctly adopted due to this resistance from farmers. Ref. [42] shows that in Switzerland, the Netherlands, Italy, and France climate-smart agriculture in the agri-food supply chain is not diffused correctly by the internal barrier. In Campania, smart irrigation systems emerge as a solution to the consequences of climate change, but the paradigms of farmers themselves are the main barrier to their implementation [60]. In Australia, efficient water use through drip irrigation innovations faces resistance from those who work the land [7]. Last, in England, initiatives such as ruminant farming are proposed in agriculture, recreation, education, and research as eco modernization solutions for "greening" the economy [59,67].

Taking into account the update of results for the period 2021–2023, several reviews were found; however, only two of them mention specific barriers to the adoption of innovations for sustainable development in agriculture. Ref. [16] identified two barriers for urban nature-based solutions (NBS): coordination between public and private funders and integration of NBS benefits into valuation and accounting methods; they also discussed strategies found in the literature that address these barriers. In this paper, nine financial barriers were found: uncertainty and long-term return on investment, little investment in R&D, difficulty accessing credit, complex financing, farmer's investment power, high implementation costs, few subsidies for peasants, null perception of benefits, and investment power. Some of these barriers are more related to the findings of [16] in terms of financial barrier 2; on barrier 1, the authors found no similarities.

In this same period, the paper by [19] was found, in which seven barriers were identified: limited collaborative governance, knowledge, data and awareness challenges, low private sector engagement, competition over urban space, insufficient policy development, implementation and enforcement oriented around NBS, insufficient public resources (incl. maintenance challenges), and citizen engagement challenges. In the results of our paper, nine barriers directly relate to those identified by [19], these are summarized as: a lack of policies, lack of farmer knowledge, data security paradigm, internal policies of non-compatible companies with the change, strategic management of companies, lack of policies, few subsidies, little investment in research and badly formulated policy in the citizen engagement challenges grouping. We concluded that this not achieve a relationship with our paper.

5.4. Methodologies Used in the Articles Analyzed

A systematic literature review (SLR) was the methodology used by certain authors of the articles read to study specific cases of innovations. However, there were papers in which its implementation was not specified and others in which it was complemented with methods such as interviews, surveys, and calls, among others.

Ref. [38] studied the unfavorable regulation of the United States to implement biotech crops in food production systems through a historical review of this innovation in the country, but the study does not specify the SLR methodology as a method to do so. Likewise, ref. [62] evaluates the conflicts that occur between science, regulation, perception, and environmental impact when attempting to implement solutions for the generation of soil conditioners from bioenergy processes through an exhaustive review of documentation, but the term SLR is not explicitly found. Finally, ref. [32] talks about the importance of agroecology in global transitions towards sustainable agriculture and how the economic power that large industries have is the greatest impediment to achieving this objective, not specifically mentioning an SLR.

On the other hand, some complemented their search with other methodologies. Ref. [66] studied the reasons why sugarcane growers in Australia have been reluctant to modify their fertilization practices using reduced fertilizer rates to suit environmental objectives through a literature review; 82 interviews took place with representatives of the sugar industry in the region and other stakeholders interested in the environmental performance of the industry. Ref. [64] studied the barriers to the sustainable supply chain management of agriculture in Pakistan, collecting important information through the literature and expert discussions, the results of questionnaires, and information from large companies to build a model using the fuzzy AHP technique. Ref. [31] exposes the factors that interfere with the adoption of precision agriculture in Italy through the help of a case study in which a considerable amount of information was collected from the literature and later complemented with the construction of a statistical model using ISTAT.

Throughout the review, innovations studied with an explicitly declared SLR were identified. Ref. [35] used the methodology to determine the challenges faced by farmers and consumers within alternative food network initiatives in the United States. Ref. [58] studied the current state of urban agriculture in the European Union by reviewing the literature associated with existing projects, of which it is found that unfavorable regulation does not allow for this type of innovation to be extended. Ref. [44], through a literature review, exposes some of the benefits that may result from the adoption of controlled traffic farming in grain crops in Australia and thus reaches the fact that the region's incompatibility with this type of technology represents the main barrier that prevents its correct deployment.

6. Conclusions

Through the methodology, it was possible to identify that in the agricultural sector, there is more tendency to innovate processes implemented throughout the production chain, which aim to promote sustainable practices. From the 43 cases found, 33 were process innovation, 6 were product innovation, and 4 were organizational models. The innovation that had the highest number of related articles was organic agriculture with seven publications, followed by genetic engineering with five and precision agriculture with four, reassuring that the most popular innovations correspond to some change in the process of production followed by innovation in product change. Additionally, suggesting that innovations not related directly to the core activity of the subsector are less developed in the agricultural sector and should be studied in detailed.

Technology begins to gain strength in the sector as a mechanism for improvement through innovations for sustainable development. Its study has tended to rise since 2006. There is a trend in the use of monitoring mechanisms that optimize decision making in the use of resources and inputs for the maintenance of products, as well as their genetic modification. Of the 43 types of innovations, 17 were related to the technologies of the Fourth Industrial Revolution and 27 were not; this number is expected to grow exponentially as the world continues to develop more technological skills. However, it is important to highlight the great work that has to be made to train and sensitize farmers and encourage young people to continue working in the fields, as it was concluded that the farmer's educational level, age, and indifference were some of the barriers that appeared in the investigation.

The review allows us to conclude that external barriers are the ones with the highest incidence, within which the lack of policies or their unfavorableness are identified as those that affect the correct implementation of innovations that promote sustainable development in the agricultural sector. A total of 51 barriers were detected, of which 28 were classified as external and 23 as internal. The "Lack of policies that promote that innovation" is the barrier that presented the most mentions (in 12 articles, it was identified as an impediment to the implementation of innovations), which is external; followed by epistemic closure with 9 mentions (being internal), and unfavorable regulation and unskilled labor with 8 mentions each and being external and internal, respectively. This finding could be a call to action for governments to start developing more definitions of the agricultural sector, which is one of the main economic activities for most countries.

The systematic literature review is a highly accepted methodology in the formulation of scientific articles. The articles reviewed present different development methodologies that were classified according to their level of relationship with SLR. Of the 48 articles, 13 did not correspond to a literature review, 15 did not specify the methodology, but it is inferred that it is SLR, 14 used this methodology, complementing it with interviews or surveys of interest groups detected in the articles, and 6 articles specified the SLR as the methodology used. However, it was used to study the specific topics and there was no article reviewed with a comparison or an analysis of the trends between the case studies.

The results of this article are intended not only to show trends in the barriers to innovation that prevent achieving the sustainability that the agricultural sector needs, but they also serve as an input for the development of policies that provide solutions to these impediments. It was evidenced that 17 out of the 28 external barriers are related to topics that could be solved by formulating policies, laws, incentives, guidelines, regulations, benefits, and prioritization in the public agenda, among others (badly formulated policy, data security, difficulty accessing credit, few subsidies, financing, implementation costs, investigation prioritization, lack of alignment of the scientific community and politicians, lack of government support, lack of promotion policies, little international cooperation, little investment in research, low priority of the subject in the country, non-standardized regulations (global), price competitiveness in markets, sustainable standards difficult to meet, and unfavorable regulation). Additionally, being able to break down these barriers with these types of means would provide an optimal basis for other obstacles to be solved in the long term (those related to knowledge, integration of academia, research, and the uncertainty of farmers).

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