Systematic Review

Agroforestry Systems: A Systematic Review Focusing on Traditional Indigenous Practices, Food and Nutrition Security, Economic Viability, and the Role of Women

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Abstract: This study aimed to identify from the literature review whether agroforestry systems have been an agricultural practice adopted by indigenous peoples for income generation and food and nutritional security. For this, a systematic review was conducted in the period from 2010 to 2020 of 92 articles, dissertations, and theses. Thus, it is found that agroforestry practices are traditional indigenous forms of farming that provide food security, income generation, and medicines, in addition to preserving biodiversity. Indigenous agroforestry is fundamental to indigenous culture, strengthening spiritual practices and the relationship with nature. Women have vital importance in the management of agroforestry practices because, through this productive practice, they ensure the food consumption of the family, besides generating income. However, women still face many difficulties in the countryside because their working hours are longer than those of men; besides not participating in decisions on the choice of species and form of management, in some countries, they still face difficulty accessing and owning land. The studies provide evidence on the economic viability of agroforestry systems. However, research gaps are identified that verify the economic and financial analysis of agroforestry models, which address the concerns of indigenous communities, aiming at food security. These analyses are essential for the implementation and continuity of the production system.

Keywords: bioeconomy; indigenous communities; sustainable development; food security; agroforestry system

1. Introduction

With the increase in the world population and the need to expand food production, the Green Revolution began in the 1950s, which increased productivity through monocultures, seed improvement, and the dissemination of chemical fertilizers and pesticides [1–4]. Monoculture has promoted an increase in productivity, reduction of labor, and expansion of agricultural borders. However, it has not solved the problem of food insecurity. On the contrary, in more vulnerable populations, food insecurity has been aggravated [4–6].

In Brazil, as a process of colonization and expansion of the agricultural border, the Brazilian state created the Indigenous Reserves to accommodate the indigenous population in a particular location and make land available for the purpose of economic development and agricultural expansion. The intention was to "colonize" the indigenous peoples and turn them into farmers and farmworkers. In this process, the natural resources of the villages were becoming scarce through the increase of the population and adoption of monocultures and logging in the reserve by external agents [7,8].

The indigenous population suffers from greater food insecurity than the non-indigenous population. Their traditional food systems provided a healthy diet, but with the monoculture and loss of traditional knowledge, they live in a condition of vulnerability [5,6].

Traditional indigenous knowledge is based on agrobiodiversity, which is crucial for food security. The indigenous population's relationship with nature symbolizes a higher connection with religiosity; their practices represent the conservation of biodiversity, and such practices must be reclaimed since they correspond to ways to reduce food and socio-environmental impacts [9,10]. In this context, agroecological practices by small farmers and vulnerable populations, such as the indigenous population, must be encouraged in order to ensure food security and rural poverty reduction and sustainable development [11,12].

Therefore, the production of food in an agroecological system could ensure food sovereignty in developing countries. In this productive approach, there is a diversification of crops, which makes this system more efficient in small properties, with a higher income compared to monoculture. It is also a sustainable and fairer system for small farmers that use local resources for management, with less dependence on external resources, being more ecologically efficient [11–15].

Agroecological agroforestry systems are productive systems that integrate agricultural cultivation in the same space as tree species and/or animal husbandry [16]. This food planting system is more sustainable and is capable of restoring degraded ecosystems, in addition to preserving agrobiodiversity, allowing family farmers and traditional communities to grow more resilient and self-sufficient [17]

In addition to the food issue, indigenous populations are extremely vulnerable given their extreme poverty and marginalization conditions. These peoples are historically susceptible to diseases, in addition to problems such as violence and suicides that also affect this population [5,6,8,18–20].

In this aspect, the role of indigenous women has a fundamental importance in changing this scenario. Women's participation is essential, as already highlighted by Sen [21] and many other authors, to ensure female well-being and development; women become agents of transformation, improving the lives of men and women. According to Robinson, Diaz-Carrion, and Hernandez [22], the empowerment of indigenous women in Mexico brings an awareness of their role at home and in society. Furthermore, many benefits are identified, both social and economic, in the group in which they are included, reducing extreme poverty and assisting in gender equality.

Many studies have been carried out to analyze agroforestry systems with an emphasis on food security, through the literature review, highlighting Chamberlain et al. [23], Duffy et al. [24], Moreno-Calles et al. [25], Reed et al. [26], and Smith et al. [27]. Most studies verified the improvement of food security using agroforestry systems. Although some studies did not identify evidence of improvement in food security, they found ecosystem services and improvements in income and productivity compared to monoculture. However, studies of agroforestry systems, focusing on indigenous communities, food security, economic viability, and the role of women, have not been carried out. Thus, the contribution of this study is to analyze all these aspects in five databases, covering different countries, to seek evidence and identify research gaps.

Considering the context of vulnerability experienced by indigenous peoples, the following research questions emerge: Is the agroforestry system an agricultural practice adopted by indigenous peoples? Could the agroforestry system contribute to the improvement of food security? Is the agroforestry system economically viable according to capital budget techniques? What is the role of women in agroforestry?

Therefore, this study aimed to identify from the literature review whether agroforestry systems have been an agricultural practice adopted by indigenous peoples for income generation and food and nutritional security.

To conduct the study, we used a systematic review according to the protocol of Sampaio and Mancini [28], analyzing 92 articles published between 2010 and 2020. In this sense, this work may contribute to future research on agroforestry systems, food security, indigenous communities, and economic viability, in addition to contributing to public policies aimed at indigenous and vulnerable communities.

The article is structured in five sections, including this introduction. The second section contains the methodology applied to the study. Next, the results of the research are presented, followed by the discussion of the proposed theme. Finally, the concluding remarks and the references that supported the study are presented.

2. Material and Methods

A systematic review with a qualitative and quantitative approach was conducted to verify agroforestry practices in indigenous communities, focusing on food security, women's participation, and economic viability analysis. In this context, studies will be mapped to synthesize the knowledge on the subject in order to identify gaps and provide future research opportunities that contribute to scientific advances.

The systematic review consists of a summary of scientific evidence of selected studies, according to systematized methods, with a previously defined protocol [28–31]. The research was developed based on methods and protocols established by Sampaio and Mancini [28], organized into five steps: defining the question, searching for evidence, reviewing and selecting studies, analyzing the methodological quality of the studies, and presenting the results.

2.1. Article Selection

The systematic review was developed from September to November 2020. As a way to reduce the sample of articles, limiting filters were established as the period, considering a time scale of 10 years (2010 to 2020). Two databases, Web of Science and Scopus, were used to identify how the topic has been proposed internationally. The search strings were checked in the title, abstract, and keywords.

In Web of Science, the following search strings were used: "agroforestry systems" AND "economic viability" OR "agroforestry systems" AND "investment analysis" OR "agroforestry systems" AND "economic analysis"; "agroforestry systems" AND "food security" OR "agroforestry systems" AND "food safety"; "agroforestry systems" AND indigenous; agroforestry AND "indigenous knowledge" OR agroforestry AND "indigenous peoples" OR agroforestry AND "aboriginal peoples" OR agroforestry AND "indigenous populations" OR agroforestry AND "indigenous communities"; agroforestry AND wom*.

In the Scopus database, the descriptors were as follows: "agroforestry systems" AND "economic viability"; "agroforestry systems" AND "investment analysis"; "agroforestry systems" AND "economic analysis"; "agroforestry systems" AND "food security"; "agroforestry systems" AND "food safety"; "agroforestry systems" AND indigenous; agroforestry AND "indigenous knowledge"; agroforestry AND "indigenous peoples"; agroforestry AND "aboriginal peoples"; agroforestry AND "indigenous populations"; agroforestry AND "indigenous communities"; agroforestry AND wom*.

To verify how the subject has been addressed in Brazil, the Scielo database was also consulted by searching strings by title, abstract, and keywords. Additionally, a scan of the Brazilian Digital Library of Theses and Dissertations (BDTD) was made in order to investigate more broadly how it has been addressed in the country.

In Scielo, the following search strings were used: ("agroforestry systems" AND "food security"); ("agroforestry systems" AND "economic viability"); ("agroforestry systems" AND indigenous); ("agroforestry homegardens"); agroforestry AND women. In the Digital Database of Theses and Dissertations, the following strings were used: agroforestry system AND food security; agroforestry system AND economic feasibility; agroforestry system AND indigenous; agroforestry homegardens; agroforestry AND women.

Moreover, an advanced search on Google Scholar was conducted, specifically of the event Agroecol, to analyze the articles published from papers presented at this event, with the objective of verifying how the research on productive agroforestry practices in the state of Mato Grosso do Sul are. The descriptors used were agroforestry system "food security" OR indigenous OR "economic viability" source: agroecol.

The languages selected were English and Portuguese. After searching for the descriptors mentioned above, in the respective databases, a total of 786 articles or theses and dissertations resulted. From this total amount, 316 duplicate articles, theses, and dissertations were excluded, with the support of the StArt (State of the Art through Systematic Review) tool developed by the Software Engineering Research Laboratory (LaPES) of the Computer Department of the Federal University of São Carlos (UFSCar). Subsequently, the title, abstract, and keywords of 470 articles, theses, and dissertations were read, and 378 were excluded because they were not relevant to achieve the study's objective. Thus, the total number of publications included in the quantitative analysis of this article was 92 articles, theses, and dissertations, which corresponds to 11.70% of the initial publications. It is worth noting that the 92 articles, theses, and dissertations that comprise the final sample were all read in their entirety.

It is noteworthy that Brazilian publications are included in the total sample, which corresponds to 92 articles, theses, and dissertations. In addition, studies carried out in Brazil were found in all national and international databases. Brazilian studies indexed in the Web of Science and Scopus databases were classified in the international databases.

As a result of this screening, only the subjects focused on agroforestry practices in indigenous communities were selected, focusing on food security, the role of women, and analysis of economic feasibility. Exclusively, this study prioritized only empirical articles, dissertations, and theses, with quantitative methodologies, rejecting bibliometric, systematic reviews, and meta-analyses. Consequently, the results are detailed in Figure 1:
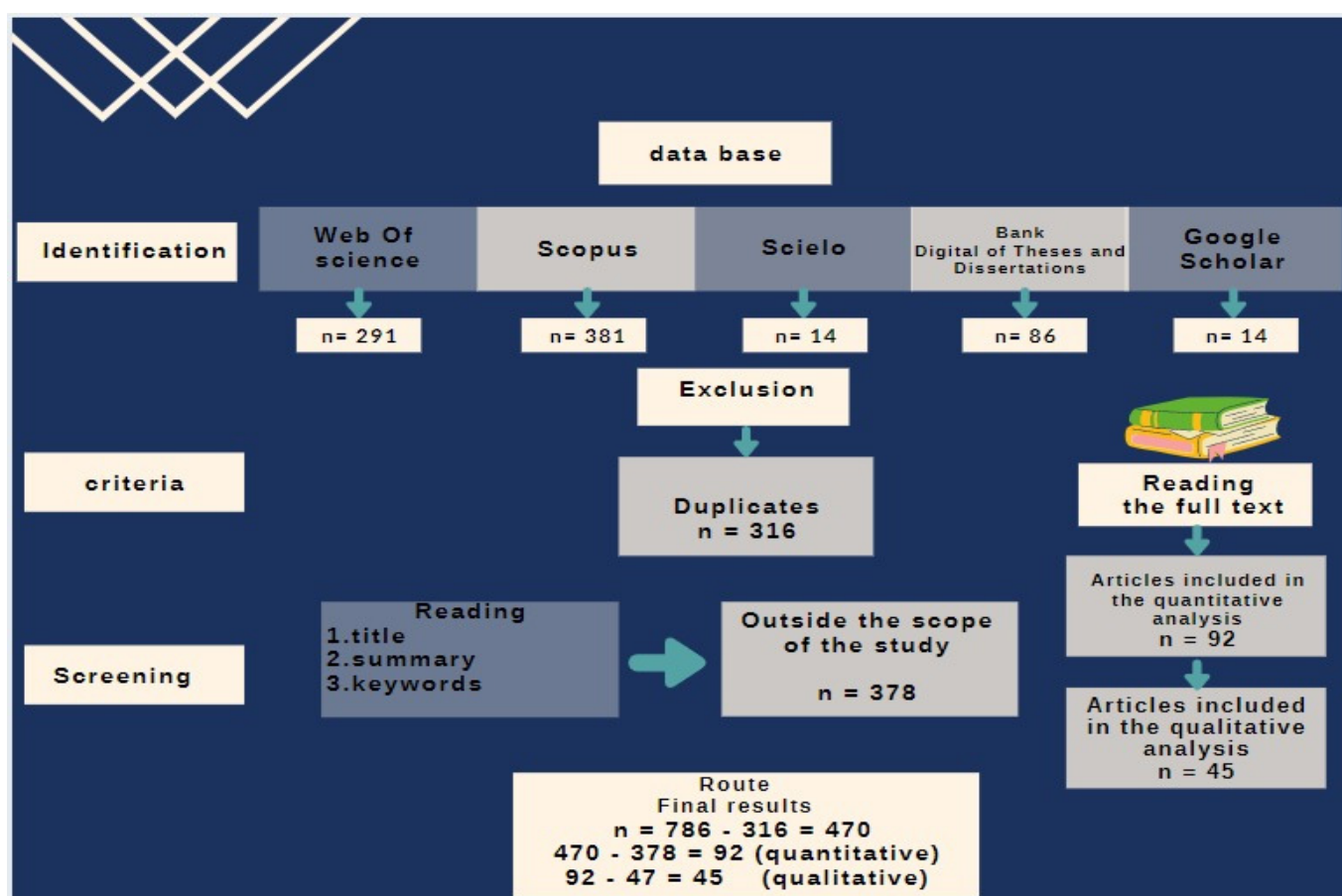
Figure 1. Protocol followed for sample selection. **Source:** Prepared by the authors, based on the research results, with the support of Canva software (2020).

2.2. Data Analysis

The data analysis followed a quantitative approach, contemplating a sample of 92 articles, theses, and dissertations. Subsequently, a qualitative analysis was performed, with a sample of 45 articles, theses, and dissertations. The reason for this is that in the qualitative analysis, the articles were structured according to the methodology applied; thus, only quantitative methodologies that measured the agroforestry systems from an environmental and economic perspective were included in the sample. The quantitative analysis was extracted specifically from each article, thesis, or dissertation, the year of publication, most cited articles, number of articles cited by journals, word cloud, and geographic area where the study was developed.
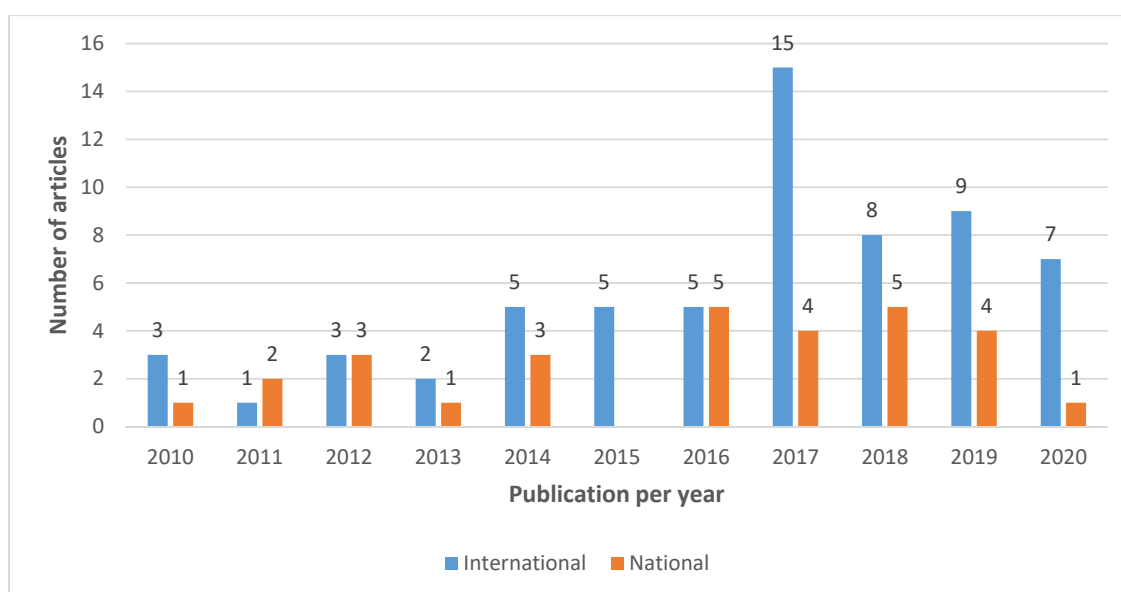
3. Results

This section presents the results of the quantitative and qualitative analysis. In the quantitative analysis, it will be possible to verify the performance of research, by publication per year, in addition to identifying the databases that have more research on the proposed subject. In addition, the most cited articles in other journals, journals with more publications on the topics, by topic researched, and their impact factor, the geographic location of the studies, and the keyword cloud are verified. For the qualitative analysis, the methodologies applied to the studies and the main results were analyzed.

3.1. Quantitative Analysis

The quantitative analysis presents the results after filtering articles, theses, and dissertations in five databases, two international and three national. For this, an analysis was prepared in order to map the scientific production on the adoption of agroforestry systems by indigenous peoples, focusing mainly on food security, income generation, and the role of women in this community. As a result, after applying the filters and criteria illustrated in Figure 1, the study sample resulted in 92 articles, theses, and dissertations.

In Figure 2, it is possible to observe that the number of articles, theses, and dissertations on the subject does not follow a linear trend; on the contrary, increases and decreases occur over time. It is also noted that articles published in international databases prevail, corresponding to a percentage of 68.48% when compared to national publications. In 2017, 2018, and 2019, a higher volume of published papers occurred, with 2017 standing out as the year with more articles published in a time scale of 10 years.
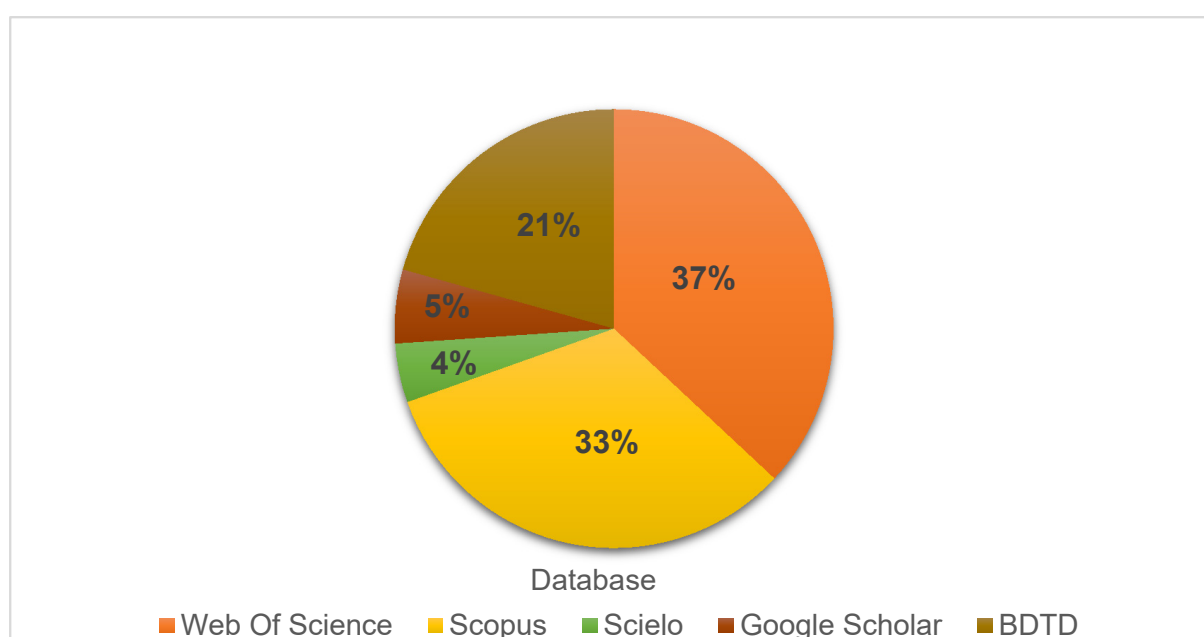

Figure 2. Number of selected articles, dissertations, and theses per year from 2010 to 2020. **Source:** Prepared by the authors based on research results.

As shown in Figure 2, the subject is relatively recent, which could occur because studying systems with crop diversity in the same space involves greater difficulty in the analysis because they are complex systems.

This spike in publications in 2017 could be explained by the concern to produce food while maintaining productive yields combined with agricultural practices that would minimize degradation of the environment. In Brazil, the number of hectares of forests has decreased; in 2017, they were 528,187,482 hectares, and in 2019, 4,469,110 hectares were reduced, compared to the year referred to in [31]. These environmental impacts suggest the search for alternatives that can reduce and recover degraded areas, such as agroforestry systems. Figure 3 shows that the articles, theses, and dissertations in the Web of Science database stand out compared to the others, with 34 indexations, while Scopus holds the second position in the ranking, totaling 30 publications. In contrast, the database with the least focus on the subject is Scielo, totaling four articles.

Figure 3. Number of articles selected for the research by databases, international and national, from 2010 to 2020. **Source:** Prepared by the authors based on research results.

In this sense, most of the articles were found in the Web Of Science database, with a percentage of 37%, followed by the Scopus database, with 33%. In the national Scielo database, few articles were found, with a percentage of 4%. Dissertations and theses corresponded to 21% of the total of selected studies, and the articles from the Agroecol event resulted in 5%.

Additionally, the study also portrays the 10 most cited articles in other journals (Table 1), considering the total sample of 92 articles. The paper with the highest number of citations was published in 2016 in the Journal Agricultural Systems. It corroborates to highlight that the year of publication does not determine the volume of citations, as the paper with 46 citations was published first, in 2013.

Table 1. Articles with the highest number of citations in other journals.

Title	Citations
Field-scale modeling of tree–crop interactions: Challenges and development needs.	53
Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation.	46
Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification.	39
The legacy of 4500 years of polyculture agroforestry in the eastern Amazon.	31
Selection of native trees for intercropping with coffee in the Atlantic Rainforest biome.	22
Plant management and biodiversity conservation in Nahuatl homegardens of the Tehuacan Valley, Mexico.	21
Traditional agroforestry systems and biodiversity conservation in Benin (West Africa).	20
Cocoa And Total System Yields of Organic And Conventional Agroforestry vs. Monoculture Systems In a Long-Term Field Trial In Bolivia.	18
Agroforestry species of the Bolivian Andes: An integrated assessment of ecological, economic, and socio-cultural plant values.	18
Enhancing the food security of upland farming households through agroforestry in Claveria, Misamis Oriental, Philippines.	17

Source: Prepared by the authors based on research results.

Table 2 was prepared considering the journals that had at least two articles published; consequently, the JCR of each journal is also presented. Another differential in evidence, which should be highlighted, is the topics on food security, indigenous communities, economic viability, and the role of women, separately, as shown below:
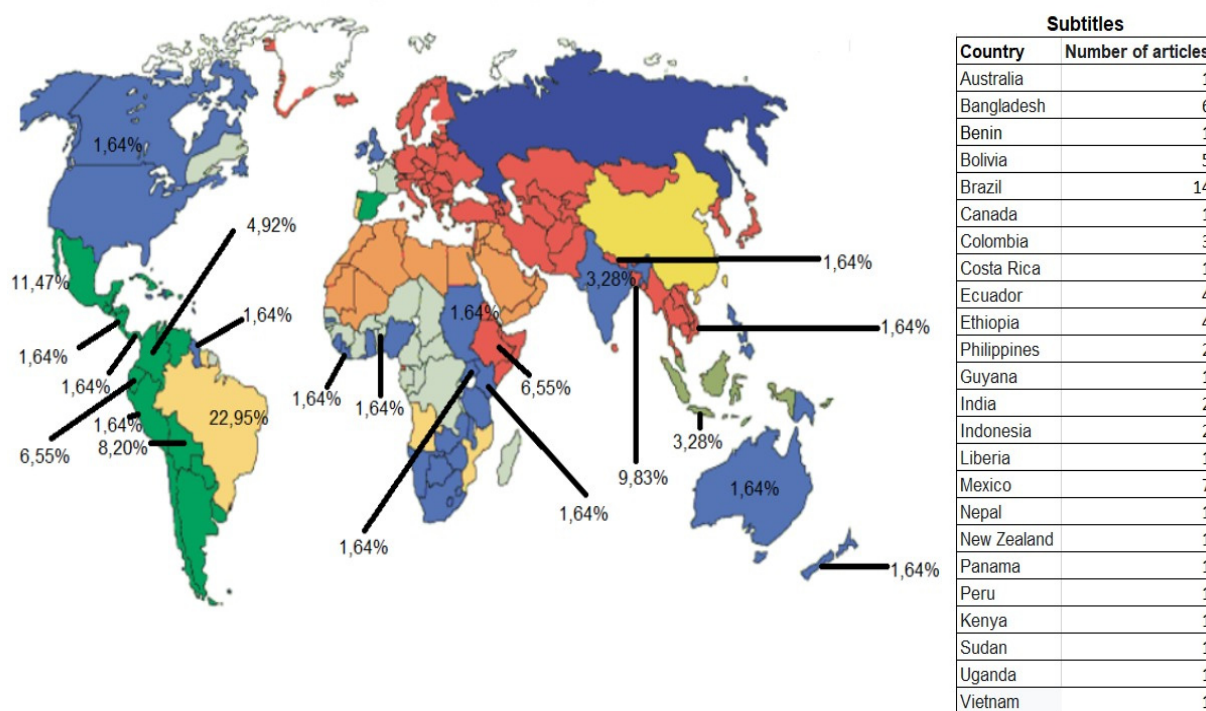
Table 2. Journals according to their JCR classification, with more than two publications, by research subject.

Agroforestry Systems and Food Security		
Journal	**Number of Articles**	**JCR**
Agroforestry Systems	13	1.973
Sustainability	4	2.576
Forest Policy And Economics	2	3.139
Land	2	2.429
Small-Scale Forestry	2	1.453
Agroforestry Systems and Indigenous Communities		
Journal	**Number of Articles**	**JCR**
Agroforestry Systems	5	1.973
Sustainability	3	2.576
Forest Policy And Economics	2	3.139
Land	2	2.429
Agroforestry Systems and Economic Viability		
Journal	**Number of Articles**	**JCR**
Cerne	2	0.774
Revista Árvore	2	0.382
Agroforestry Systems and the Role of Women		
Journal	**Number of Articles**	**JCR**
Agroforestry Systems	2	1.973
Small-Scale Forestry	2	1.453

Source: Prepared by the authors based on research results.

It is noted that although the journals Agroforestry Systems and Sustainability do not present the highest JCR, the indexations of the articles prevail in both, while the subject that stands out among the four is food security.

Analyzing the geographical location of the studies, that is, the area of concentration in which this was applied, of course, the sample was reduced to 63 articles, since it represents the articles indexed in the international databases, Web Of Science and Scopus. As such, the map illustratively indicates this, briefly (Figure 4).

Subtitles	
Country	**Number of articles**
Australia	1
Bangladesh	6
Benin	1
Bolivia	5
Brazil	14
Canada	1
Colombia	3
Costa Rica	1
Ecuador	4
Ethiopia	4
Philippines	2
Guyana	1
India	2
Indonesia	2
Liberia	1
Mexico	7
Nepal	1
New Zealand	1
Panama	1
Peru	1
Kenya	1
Sudan	1
Uganda	1
Vietnam	1

Figure 4. Location of the study area for each of the articles analyzed. **Source:** Prepared by the authors based on research results.

It is noteworthy that two studies were not inserted in the map, since both analyzed more than four locations simultaneously, for example, Cerda et al. [32], which covers Panama, Costa Rica, Honduras, Guatemala, and Nicaragua, and Lehmann et al. [33], which includes Denmark, United Kingdom, Poland, Romania, and Italy.

Finally, in the quantitative analysis, all the keywords described in the 92 articles were presented, so the keywords that appeared most frequently in Figure 5 stand out in contrast to the others, whose size indicates the importance of the term in the context in which the keywords were combined in the databases.

The cloud of keywords highlights the following terms: "food security", "agroforestry", "agroforestry systems", and "family farming", identifying the concern of researchers with the topic of food security and the importance of agroforestry systems and family farming to ensure food production. Furthermore, the relationship of the subject agroforestry and agroforestry systems with family farming is verified.

Figure 5. Keywords cloud. **Source:** Prepared by the authors based on research results.

3.2. Qualitative Analysis

In the qualitative analysis, with the objective of reducing the number of articles in the total sample (92), two inclusion criteria were created: (a) using methodologies to measure environmental aspects, only quantitative metrics, exclusively focused on food security; this choice occurred because the topic of food security is broad and covers the role of women in the context of indigenous peoples; (b) using methodologies to measure economic aspects, and quantitative metrics were also part of the sample. Therefore, the sample for the qualitative analysis focusing on criteria a and b resulted in 45 articles, theses, and dissertations.

3.2.1. Empirical Methodologies for Environmental Measurement

For this analysis, a sample of 27 articles, theses, and dissertations was considered; of these, 24 are scientific articles, and the rest focus on dissertations because theses have not yet been developed on the subject. Only three dissertations obtained results using statistical metrics, for example, Machado [34] collected soil samples in agroforestry homegardens in a settlement located in Manaus. Bezerra [35] developed a model using ANOVA and cluster analysis in a settlement in Pium in the northeast of Brazil.

Moreover, finally, indexes were applied, such as Shannon and Wienner (H'), Pielou's index (J), and Jaccard's similarity, in Pará. All three studies commonly have a study area in rural settlements, specifically in forest homegardens occupied by family farmers [36].

As for the articles that measured some environmental aspects using a quantitative method, there were 24 articles. It is possible to observe that studies that use semi-structured interviews, questionnaires, and visits for descriptive analysis are predominant.

However, Gosling et al. [37] used a mathematical model to simulate the decisions of a risk-averse farmer with the support of the participatory method based on multi-criteria decision analysis (MCDA). It was found that to adopt a production system, small owners can limit themselves to choosing the one who is able to meet the family's consumption. The option for land use is given by the immediate possibility of food and income for the family, therefore without considering the long-term benefits.

Rayol, Vale, and Miranda [38] verified floristic composition using detrended correspondence analyses (DCA) and environmental fit analysis (ENVFIT), developed in the state of Pará. Among the species found, most were fruit, in 61% of the plants, followed by ornamental plants, 28%, medicinal plants, 8%, and wood, 3%. It was identified that the main objective of cultivating agroforestry backyards is for food consumption in 70%

of respondents, followed by the wellbeing provided by the shade of trees and only 3% indicated income.

Cardozo et al. [39] measured the abundance of species using the Simpson and Shannon–Wiener indices and Pielou's equitability index, using the FITOPAC software also in Pará, but with the addition of Maranhão. The sample was based on 38 families. Twenty-seven agroforestry sites were identified, with 83 species, distributed in 73 genera and 34 plant families. In agroforestry systems, the richness of biodiversity is found more in home gardens than in commercial production. Of the 83 species, 4% were exclusively commercial, 23% were for family consumption and commercialization, and 73% of the non-productive species provided ecosystem services.

Cerda et al. [32], on the other hand, analyzed a more extensive study area containing five Central American countries with a high number of agroforestry systems, totaling 179. Species diversity was estimated using the Shannon (H) and Simpson (D) methods and socioeconomic indicators. A differential of the study was the calculation of the value of domestic consumption (VDC), which considers the market price and the number of agroforestry products for domestic consumption. The study points out that the greatest benefits of cocoa agroforestry systems were the generation of income and products for family consumption. For the implementation, only the family's labor was used, and little money was spent.

Larios et al. [40] used the same indicators, but the study was replicated in Mexico. A total of 281 plant species were found in 12 categories, 115 ornamental, 92 edible, and 50 medicinal species. These agroforestry backyards have a high diversity of species and contribute to the livelihood of these families, generating income and guaranteeing food.

Tadesse et al. [41] and Fifanou et al. [42] also analyzed species diversity and abundance through indicators, exploring different criteria when compared to the studies of Cerda et al. [32] and Larios et al. [40]. These joined Fisher's α index and species-area relationship (SAR) six villages in Assosa, western Ethiopia. A Poisson regression was executed to identify the set of variables affecting the density and species abundance in agroforestry parks in the northwestern Benin Republic with 118 families in seven villages.

The main benefits of agroforestry systems were identified as the contribution to the supply of food for families, followed by the supply of fiber, fodder, wood, firewood, medicines, and other products of commercial value. All species were identified by improving the microclimate [41]. Fifanou et al. [42] found that in the Pendjara Biosphere Reserve, 85% are native species, and 65% of the families were making efforts to plant more trees. The motivations of these families were contributions to food in 65% of respondents, followed by the marketing potential of 30% and its use for construction materials 5%. This reserve has a wealth of woody species, which can contribute to regional, national, and international diversity.

To understand the structural and floristic diversity of agroforestry homegardens, by indigenous communities, in the Attappady valley, George and Christopher [43] conducted a study with three ethnic groups: Irula, Muduga, and Kurumba in Attappady, India. Species diversity was analyzed using the Shannon–Wiener index, Margalef index, evenness index, and Simpson index. High species diversity and abundance were found, with a total of 182 species from 160 genders and 67 families in the 104 homegardens analyzed in eight villages. The species most found are for the family's food consumption with 39%, followed by medicinal plants with 25%, ornamental plants with 24%, those used in rituals with 5%, and the remaining 7% contribute with firewood, wood, shade, fences, and products for sale. The species used for food correspond to fruits with 47%, leaves and immature sprouts with 26%, pods with 12%, and seeds and tubers with 7%. The agroforestry homegardens of these indigenous peoples contribute significantly to food security, and a biodiversity characteristic of their traditional knowledge is found.

In this context, Brandt et al. [44] conducted a study in the indigenous community located in Tapacarí, Cochabamba, Bolivia. They conducted a vegetation survey and environmental studies, sampling, and classification of ethnobotanical data. They found that

their agroforestry practices are fundamental to their subsistence; the species are used for food for the families, medicinal purposes, rituals, fuel, and construction materials. Biodiversity is vital to the culture of these people, and indigenous agroforestry systems are traditional practices, which are essential for the survival of this population, bringing well-being to the families.

Cotta [45], meanwhile, researched three indigenous villages: Brillo Nuevo, Nuevo Peru, and Boras de Pucaurquillo, Bora, 120 km from Iquitos, Peru. Three methods were used to evaluate the agroforestry systems, household income survey, free lists, and fallow inventories. Pearson correlation analyses were used to verify the relationships between income and plant diversity and family variables. These agroforests have great species diversity; a total of 126 economically relevant plants were found in only three villages. Of these plants, 76 are fruits and foods that ensure the food security of this population all year round. The diversity of plants guarantees an alternative to economic losses such as loss of income, labor scarcity, and a drop in commodity prices. In these analyzed villages, the handicrafts made from chambira and seasonal fruits are responsible for guaranteeing income when agricultural or livestock losses or labor scarcity occur.

In Mexico, in the Tehuacán Valley—Cuicatlán, a study was conducted through interviews and field observation with indigenous farmers. Additionally, species diversity was calculated using Simpson's and Shannon's indices. Seventy-nine tree and bush species were registered. These agroforestry systems contribute to food security and biodiversity conservation. The main reasons for farming through agroforestry systems are the use for food, shade, firewood, and fodder [46].

In the various locations studied, the practice of agroforestry systems contributes to food security. In Lawachara National Park, one of the most diverse forests in Bangladesh, it was found that several indigenous communities live around the park and depend on it for their subsistence. Field research, field observation, and walking along the tracks were carried out. Species diversity abundance was analyzed using Shannon–Wiener (H) index. Agroforestry has the potential to preserve the biodiversity of Lawachara National Park in Bangladesh, and this practice also mitigates greenhouse gases and reduces forest degradation. These management practices are traditional to indigenous communities and are used by the indigenous Khasia community of Lawachara National Park and are crucial to the subsistence of these families [47].

In Liberia, it was found that families that adopted agroforestry practices reported greater food security compared to families that adopted monocultures. Among the families with agroforestry practices, 22% reported consuming three meals a day; as for monoculture, none of the families reported consuming all three meals. In addition, 70% of families with agroforestry practices report always having enough food, in contrast to 31% of families who adopt monoculture [48].

Generating income and productivity also makes it possible to improve food security for families. There has been an increase in income and food security for families who cultivate agroforestry systems in the Philippines. Productivity increased from 42% to 137% with agroforestry practices, which caused an increase in family income, compared to the low income generated by annual monoculture [49].

Cordova, Hogarth, and Kanninen [50] verified that the agroforestry system presents greater biodiversity than conventional agricultural systems, and in agroforestry, this diversification is 20% greater than in conventional agricultural systems, identifying that this system contributes to food security. Among agroforestry farmers, livelihoods are more complex and varied than the conventional farmer. In addition, agroforestry farmers are demonstrated to receive a higher income, while conventional farmers are shown to receive a low income. For Salim [51], agroforestry homegardens contribute to the food security of families. In this study, the shrub-three floristic composition of the Terra Firme agroforestry homegardens of the Kwatá-Laranjal Indigenous Land in Amazonas was conducted. In addition to evaluating the contribution of this system to food security, the Shannon index (H') and the density of individuals were used. In the 15 yards analyzed, 2024 arboreal

individuals were found: 75 species, 56 for food use, and 28 for medicinal use. Most of the production is used for consumption. However, 73.3% of families generate income from the sale of products.

In the state of Mato Grosso do Sul, it was found that among the main reasons for adopting agroforestry systems were food security, climate improvement, and income generation. In this context, this production system brings several benefits to these farmers, being essential for the well-being of these people [35,52,53]. Padovan et. al. [54] stated that for 96.4% of the interviewed farmers, the main reason for the implementation of agroforestry systems was the production of food for consumption; in addition, an improvement in the food security of these families was identified. Nascimento et al. [53] and Mayer [55] identified other benefits of this production system, such as the recovery of degraded areas.

3.2.2. Empirical Methodologies for Economic Measurement

Considering the sample of 92 articles, only 18 have the objective of economically evaluating the advantage or not of an agroforestry system. Among these, 12 are articles, and six are theses and dissertations. Thus, there is a lack of studies with this focus. To measure the economic performance of an agroforestry system, investment evaluation techniques are used, such as net present value (NPV), internal rate of return (IRR), and cost–benefit ratio (CBR).

This small number of articles may be explained by the complexity of developing an arrangement and monetarily evaluating its return on capital since climatic situations, soil types, and biomes do not follow a standard. Thus, the absence of this type of result hinders a farmer's decision-making because the diversity of crops requires different farming treatments in the same space, unlike monoculture, for example [16].

Commonly, the 12 articles prioritize crop diversity because the risk tends to be lower when several species can be commercialized, generating income. In this case, the SAF could satisfy both personal needs (food security) and generate income (commercialization) [56].

Another situation observed is that the crops are selected according to the study area. In the study by Coelho [57], the system analyzed was a silvipastoral system, in which interaction with animals is allowed. In addition, it had perennial crops such as citrus, banana, acai, yerba mate, and coffee. In the work of Martinelli et al. [16], a system composed of several perennial, semi-perennial, and annual species was evaluated, such as feijão-pombo, corn, cassava, pineapple, bean, caupi bean, nanica banana, formosa papaya, tahiti lemon, pêra orange, dwarf coconut, ponkan tangerine, and native species of the cerrado biome, according to the crops produced by local farmers.

Whereas Alves et al. [58] prioritized the interaction with only two crops, coffee and banana, in particular, this agroforestry system could be considered less complex than that of Martinelli et al. [16]. However, both had a positive return, where the NPV was above 1.

It should be noted that despite the effort of researchers in developing studies that measure and project the return on investment of agroforestry systems, this is still incipient. The arrangements need to be structured to generate income in three time scales: the short, medium, and long term. Therefore, the number of agroforests may arouse interest in adopting them, especially from small farmers.

While theses and dissertations focus on agroforestry systems that recover agricultural areas together with productive yield, due to overexploitation of this precious asset "land", for Filippin [59], Mayer [55], and Garcia [60], agroforestry should serve to recover legal reserves and permanent preservation areas. Therefore, one of the limitations of studies on economic viability is the absence of statistical analyses that show standard error in order to minimize future risks.

To verify the economic viability of agroforestry systems, Martinelli et al. [16] analyzed an agroforestry arrangement modeled with two perspectives: the first, where the family farmer does not own the land, and the second option, where the farmer owns the land. The authors used the following capital investment techniques: net present value (NPV), internal rate of return (IRR), equivalent uniform annual value (EUAV), payback, profitability index

(PI), modified internal rate of return (MIRR), cost–benefit ratio (CBR), and the capital asset pricing model (CAPM). It was found in the study that the agroforestry system modeled in the two hypotheses is a viable alternative that contributes to the recovery of degraded areas through the diversification of native trees with potential environmental services. In the situation where the farmer owns the land, the economic performance is higher, because in this case, there was no inclusion of land value in the investment without the need for the use of third-party capital [16].

Joaquim et al. [61] conducted a study in an area belonging to Votorantim Siderurgia, in Vazante, Minas Gerais. The company provided the data. The method proposed by Copeland and Antikarov for rainbow options was used. For the viability analysis, the net present value (NPV) and the discount rate (WACC) were used. For the economic viability analysis, using real options or net present value, the results showed no difference, so it would be necessary to use historical series. The NPV was $1063.78, with a WACC rate of 9.95%, demonstrating the economic viability of the agroforestry system analyzed.

For Fahmi et al. [62], farmers must adopt agroforestry systems to ensure food security and income generation. The authors conducted structured interviews with 281 household chiefs, 145 in El Dali and 136 in El Mazmum, South Sudan. To verify the economic viability of the productive systems, the net present value (NPV) and the cost–benefit ratio were analyzed. Among the four cropping systems analyzed, three monocultures and one agroforestry system, the agroforestry system is the most economically viable. Additionally, this system presented the best conditions to provide subsistence and income generation for the families. However, many farmers were not willing to adopt this system. Land ownership is a barrier for many farmers to adopting agroforestry systems. This is due to insecurity in the property because farmers believe that the land could be purchased by the government at any moment, as part of government forest parks.

Finally, it is verified that agroforestry systems, besides guaranteeing food security, could generate income. They are vital to reduce economic risks and more suitable for small farmers, besides being economically viable [16,21,33,63–66].

4. Discussion

This section presents three important topics that correspond to the keywords adopted in the five databases used in this study.

4.1. Food Security

As a result of the evolution of the human species, some problems such as food security, less unsustainable production systems, and the population's vulnerability are being reflected but still need to be solved. Some alternatives can be identified to reduce these food impacts, such as increasing diversified agricultural systems and reducing food waste. It appears that, in the 21st century, 1.3 billion tons of food are wasted annually, when considering all stages of the production chain [67].

Although the world produces enough food to supply the demand of its population, at least until the present moment, food insecurity still affects about 690 million people in the world, that is, 8.9% of the world population is food insecure, in addition to 750 million people who face severe food insecurity [68,69]. Unfortunately, in Brazil, this situation is no different from the rest of the world, and access to food still occurs at an unequal pace, especially in poor communities, such as the indigenous peoples.

Consequently, maintaining food security for individuals involves not only economic issues but also ethical ones [70]. Data reveal that 77.4% of Brazilian households do not suffer from food insecurity, while the rest face food and nutrition insecurity, being distributed as 14.8%, 4.6%, and 3.2% of low, moderate, and severe insecurity, respectively [19].

This situation has led to the creation of strategies at the global level (e.g., Agenda 2030—Goal 12) as well as at the national level (e.g., National Food and Nutrition Security Policy—CAISAN) in order to minimize food insecurity. The aggravating factor is that the population keeps growing and food production cannot stop. Thus, agroforestry

systems are possible options for the production of diversified foods. For the indigenous population, this agricultural practice guarantees subsistence; in addition, it can generate incomes [45,47,71–73].

Therefore, agroforestry systems provide biodiversity capable of guaranteeing food security for indigenous peoples. Through this agricultural practice, food security could be achieved through product diversification and income generation. Another contribution is the reduction of economic risks through product diversification [74–77]. These systems, in addition to contributing to food security, also contribute to food sovereignty, while food security fulfills nutritional requirements; sovereignty has a role in guaranteeing the right to food to people through sustainable production, as well as defining their food and agricultural cultivation [17].

The decision of farmers to adopt agroforestry systems is made by the possibility of food consumption and immediate income generation for their families, without considering the long-term benefits such as reducing economic risks [37]. This way, public policies focused on adopting agroforestry systems should consider arrangements with plant or animal species that promote a more immediate return [35,54].

When considering the state of the art of this study, 31 articles, theses, and dissertations address the subject of food security and agroforestry systems, while another 16 cover adoption of agroforestry practices by the indigenous population, food security, and economic performance, jointly.

4.2. The Role of Women

Another relevant issue that can be observed by reading the studies is that women play a fundamental role in management, education, teaching, and income generation in indigenous communities. Among the sample, eight articles, theses, and dissertations analyze the role of women in agroforestry productions.

Agroforestry systems are agricultural practices also performed by women, ensuring the family's food, income generation, and microclimate improvement, among other benefits. Moreover, they generate the empowerment of these women in the countryside, bringing well-being to them and their families [43,78–80].

Nevertheless, men are mainly responsible for the cultivation of trees, while women are in charge of subsistence crops. Therefore, despite representing the majority of the labor force, in Africa, for example, they are still ignored by agricultural and extensionists public policies. This gender difference may contribute to poverty and social inequalities [48].

In Colombia, the decision power to choose the species that will compose the arrangement is also held by the man. Women are responsible for domestic services and some services such as grinding and packaging. The commercialization of products in local markets is practically exclusive to women [49]. Working together, without this discrimination, that is, gender equality in agroforests, would be fundamental for their well-being, tending to provide better living conditions for the family, corroborating the development for the whole community [79]. Santafe-Troncoso and Loring [81] contribute by mentioning that food sovereignty provides women's empowerment, raising their well-being and that of their families.

In many countries, women face difficulties accessing land ownership because the system favors land registration to men [82,83]. Therefore, public policies focused on gender equality must be a priority, which may contribute to the improvement of family nutrition, rural development, and the well-being of women and their families [48].

Indigenous women are responsible for feeding and cultivating agroforestry yards in the state of Mato Grosso do Sul, as men are in charge of services outside the village. They play a fundamental role in the food security of their families. In addition, when preparing food, there is the transmission of ancestral knowledge, essential for the strengthening of indigenous culture [84].

Finally, it can be noted that regardless of where the study was conducted, there is still a submission of women to men when it comes to making decisions about the

farming treatments and choice of species, but women have increasingly gained space and contributed to the production and subsistence of food. In northern Vietnam, women have stronger preferences than men when it comes to food production through agroforestry systems. In the beginning, men were restricted and afraid to change the method of production or the land use, since they believed that the soil was not suitable for the production of perennial and biennial crops [85].

4.3. Indigenous Communities

Agroecological agroforestry systems are millennial indigenous practices, and these productive practices provide food and materials for crafts, medicines, and income generation [86,87]. The indigenous population's form of farming was based on polyculture and agroforestry practices, and this form of farming was vital to ensuring the food security of these people for many years [36].

Indigenous agroforestry, besides providing food, medicine, and income generation, has a significant role related to the indigenous way of "living" with their spiritual practices, where the land is not seen as private property; on the contrary, they have a relationship of belonging to the land [88,89]. For indigenous peoples, agroforestry also has a spiritual value, representing an entity populated by souls and spirits. Consequently, more than a form of cultivation, these practices have great value for their cultural survival. Therefore, there is concern and care for nature, because the consequences of environmental degradation will have repercussions for human beings [90]. The indigenous peoples were the first inhabitants of Brazil and had their traditions and cultural heritage. For them, the land is much more than just a means of subsistence, and it is part of cultural rites. Whether in Brazil or India, agroforestry homegardens promote firewood, wood, organic matter, and food, in addition to promoting shade [16,43].

Generally, what is cultivated in agroforestry systems relates to the need for consumption, combined with each species' nutritional and market value [43,91]. As a result, indigenous communities could develop strategies to encourage the adoption of more sustainable productions, as is the case with agroforestry; the composition of the arrangement may encourage these peoples to consume more nutritious indigenous foods, mainly reducing the malnutrition of women and children, in addition to providing ecosystem services and biodiversity conservation [92,93].

Handicrafts could be a subproduct generated by agroforestry systems. According to Cotta [45], 50% of income is generated through handicrafts, and another product widely used by this community is handmade medicines. However, Cotta [45] identified the decrease of medicinal species in the villages of Brillo Nuevo, Nuevo Peru, and Boras de Pucaurquillo, in Peru; this can be explained by the proximity of local medicine markets. The use of medicinal plants, through indigenous traditional knowledge, represents a viable form of cure for several diseases; these species can also be cultivated in agroforests, which favors access for these peoples [94].

The traditional knowledge used by indigenous farmers, that is, the vast empirical knowledge, could contribute to increased profitability and food security for families [95]. Vallejo et al. [46] reinforce that indigenous knowledge is favorable to biodiversity. However, land ownership, agricultural intensification, and history of land use are factors that influence agroforestry management. Another fundamental aspect that interferes with species diversity and agroforestry practice is ethnicity. Thus, the implementation of agroforestry systems in indigenous communities should observe the customs and traditions of cultivation of each ethnic group [93]. Given the traditional knowledge of indigenous peoples, through agrobiodiversity, the exchange with these communities could contribute to practices for the recovery of areas where biodiversity is being lost [46].

The diversity of crops in the same place has been part of indigenous culture since the early days [88]. However, the results are not always positive. As an example, we can cite Canada, where Indigenous communities suffer from food insecurity due to inadequate diets. Unsustainable farming systems were being inserted into the community, which

resulted in an inadequate diet. However, over time, rearranged agroforestry systems have been analyzed, resulting in productive and climatic benefits, mainly favoring the sustainable development of communities, increasing resilience [96,97].

In Brazil, due to the colonization process and the expansion of agricultural borders, the Brazilian State accommodated the indigenous peoples in some areas. This way, natural resources were becoming scarce due to the increase in population and the adoption of monoculture [8]. Thus, small areas became incompatible with mechanized agriculture. However, agroforestry systems are able to provide food on small farms for farmers and their families. The studies identified the agroforestry management area with the following measures: Lima [75]—the crop areas ranged from 0.3 to 2.6 hectares; Magcale-Macandog et al. [49]—the analyzed areas had an average of 2.35 hectares; and Agostinho et al. [52]—the study areas ranged from 0.5 to 1 hectare. Padovan et al. [54] identified that on most of the analyzed farms, the agroforestry management site had an area of up to 0.25 hectares. In all these studies, the improvement of food and nutritional security of farming families by the adoption of agroforestry practices was verified.

5. Concluding Remarks

It was identified that indigenous communities have adopted agroforestry practices for many years and that this constitutes a traditional knowledge of these peoples. These indigenous agroforestry systems contribute to food security and income generation, in addition to providing medicine, materials for handicrafts, wood, firewood, and the improvement of the microclimate, providing the well-being of this population. This process is reinforced by the diversity of species found in their yards, fundamental for preserving biodiversity. Besides providing ecosystem services, these production systems are more resilient to the effects of climate change.

One of the most significant benefits of agroforestry systems is their contribution to food security since most of the species found in these productive systems are used for food, for family consumption, and for the sale of surplus. This food security comes from the diversity of species and higher productivity since studies show that the total income of agroforestry systems is higher when compared to monoculture; another advantage is the distribution of risk since the small farmer is not subject to only one crop. Additionally, this system's other benefits could be identified compared to monoculture, such as pest control, pollination, and other ecosystem services, such as the recovery of degraded areas, welfare, and aesthetic, health, and cultural values offered to its owners. The potential to mitigate greenhouse gases, biodiversity conservation, and social and recreational services are also highlighted.

Agroforestry systems present economic viability. Among the 18 articles evaluated, only one did not identify viability when comparing different spacings of agroforestry production of eucalyptus and soy, in which two arrangements with different spacings did not present economic feasibility. However, the third arrangement showed economic feasibility. Two studies that compared agroforestry systems with monoculture found that agroforestry systems were more economically viable. Although agroforestry systems are essential to ensure food security and cultural identity for indigenous peoples, none of these studies analyzed the economic viability of these systems for this population.

Many studies show the importance of women in the cultivation of agroforests through the improvement of family food and income generation, contributing to the well-being of women and their families. This method of producing food has the potential to empower women, although they still face many challenges in the countryside, as they often work much harder than men, since, in addition to housework, they need to work on the farm, making their working hours longer than those of men. Furthermore, the decision making on how to manage and commercialize the products is often taken by the men alone, so the women are left with only the execution of the services.

Public policies should be implemented for the implantation of agroforestry systems due to their potential to contribute to food security, income generation, poverty reduction, and the sustainable development of indigenous farming families.

One of the limitations found was not having included other databases, such as Science Direct, in this study. Consequently, other articles that are also relevant to the proposed subject may not be included in the sample of this study. Future studies could use other databases to seek evidence on the contribution of agroforestry systems to food production, in addition to analyzing other benefits of this production practice. To ensure food security, indigenous farming families must seek agricultural practices that include their traditional knowledge, with the diversification of species, such as agroforestry systems. Economic viability is fundamental for the continuity of the production system. In this context, future studies are suggested that analyze the economic viability of agroforestry systems, which contribute to the food security of the indigenous population according to their cultivation practices and species needs. Furthermore, analyzing the reasons for implementing agroforestry systems, as well as the reduction in the adoption of these production practices, can be essential for the formulation and implementation of public policies.

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