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Systematic Review

Global Evolution of Research on Silvopastoral Systems through Bibliometric Analysis: Insights from Ecuador

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Abstract: Scientific studies on silvopastoral systems have led to permanent changes oriented toward better silvopasture practices, as well as to policy strategies to respond effectively to the global objectives of restoration and sustainable development. In this work, we performed a bibliometric analysis with the purpose of identifying changes associated with different silvopastoral systems. We applied Bibliometrix in R to analyze 5708 documents published between 1983 and 2022 by including the terms "silvopastoral" and "silvopasture", among others. The results showed a longitudinal and exponential increase in silvopasture studies over the last 20 years. We adjusted the growth to an S-Curve function with an R^2 of 96.06%. The interest of researchers regarding knowledge about silvopasture has evolved; initially, it focused on the characterization of silvopasture, whereas recently, it has focused on the search for strategies to improve the sustainable use of silvopasture, including ecosystem restoration and the implementation of better practices. The following countries stand out as those with the largest scientific production of studies on silvopasture: The United States, Brazil, Mexico, Colombia, and Argentina in the Americas; China and India in Asia; and Spain; and Germany, and the United Kingdom in Europe. In the case of Ecuador, cited leaders in silvopasture facilitated the construction of a group of experts who contribute to the development of public policies. The most cited publications appeared in journals published by the Springer group, Elsevier, and MDPI Journals, mostly in open-access systems. In the future, the disruptive contribution of open-access systems in the global dissemination of knowledge, breaking through the economic constraints of countries, universities, and researchers, should be evaluated.

Keywords: livestock; silvopasture; bibliometric analysis; Ecuador

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1. Introduction

Bibliometric analysis (BA) is a robust tool that can be used to systematically assess changes in the concept of silvopasture. In addition, it can be used to identify research leaders and the most relevant collaboration channels and networks, and it can even be used to evaluate the quality of institutions and peer reviewers themselves [1–6]. This type of study has received wide coverage in recent years [7,8]. Scientific researchers use BA to analyze current and historical trends in articles, journals, collaboration patterns, and research components to explore the intellectual structure of a specific domain in the existing scientific literature [7]. Bibliometrics can identify important literature, providing keywords, institutions, and links between countries and distribution characteristics in the form of knowledge maps [8]. Generally, as more references are incorporated into bibliometric

methods, we become more able to understand the field of research [9]. Thus, many studies include bibliometrics for the analysis of various academic disciplines, such as land use and land cover in tropical forests [10], forest carbon sequestration [11], and ecosystem services provided by pastoral husbandry [4], among others.

The objective of this study was to perform an exploratory review of the evolution of research focused on silvopasture from 1983 to 2022, with a special emphasis on the case of Ecuador. We analyzed the evolution of the concept from a quantitative and qualitative point of view, focusing on modifications in the approach over time. Moreover, in this work, we classified countries depending on their interest in these systems. We also addressed key questions, such as the following: Which countries are leaders in this kind of research? Which journals play a strategic role in this field? How are research networks developed? Looking to the future, we analyzed the challenges and possible future lines of research that are socioeconomically linked to these production systems.

2. Materials and Methods

We developed this bibliometric analysis based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, which can facilitate a quick, efficient, and transparent analysis of collected scientific documents [12]. In this sense, we divided this study into four phases for the optimal analysis of scientific production globally and in Ecuador in relation to silvopastoral systems, as follows (Figure 1): (1) database selection and search criteria; (2) exclusion criteria; (3) software and data selection; and (4) data interpretation.

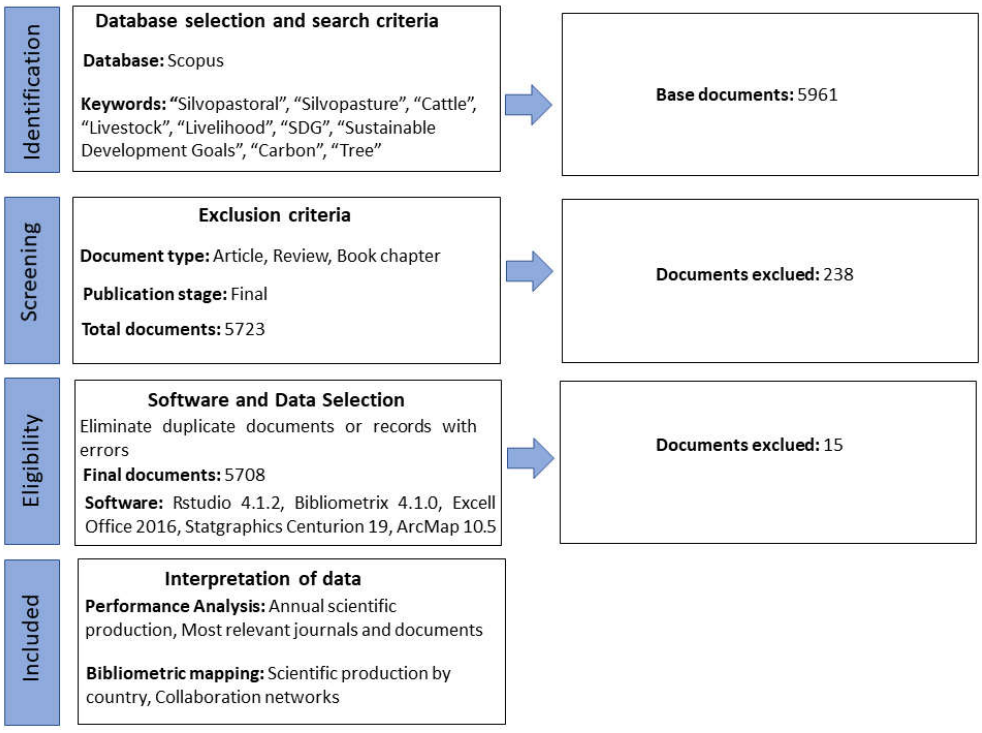

Figure 1. Diagram based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, depicting the four phases of bibliometric research methodology.

I. Database Selection and Search Criteria

A successful BA is based on the collection of scientific information from comprehensive and reliable academic research data [13]. In academia, WOS and Scopus are the most widely used and accessible scientific databases in recent decades [14]. Scopus was initiated in 2004 through the publishing organization Elsevier Science and is currently recognized as one of the most relevant scientific databases [15]. Such recognition is attributed to the fact that it

provides broad coverage of topics in various disciplines with scientific information that can be further processed by bibliometric software [16,17]. Although WOS offers similar services, its coverage of educational disciplines is less than that of Scopus [18]. In addition, Scopus provides information corresponding to author affiliation, journals, keywords, and quality indexes of scientific production, such as the Scimago Journal Rank (SJR) [14,17]. Therefore, in this study, we used Scopus to generate a database that incorporated as many documents as possible to understand the historical evolution of scientific research focused on the analysis of silvopastoral systems.

We carried out the search and collection of Scopus documents in December 2022, using information from titles, abstracts, and keywords. To perform this process, we used the following syntax with the advanced search settings in the Scopus scientific database: TITLE-ABS-KEY (silvopastoral OR silvopasture) AND (cattle OR livestock OR live-lihood OR SDG OR "sustainable development goals" OR carbon OR tree). The search returned 5961 documents.

II. Exclusion criteria

Initially, we selected documents according to their type and retained only scientific documents classified as articles, book chapters, or reviews. These selected categories are among the most widely used documents in the scientific field because they provide greater depth on the analyzed subject and because they are more extensive and have been subjected to a rigorous process of blind peer review, providing greater reliability for the represented information [7,8]. In addition, for our analysis, we only considered documents that had already completed the peer review process and that were published before December 2022, i.e., documents that had the final publication status. Under these criteria, we excluded 238 documents, resulting in 5723 documents.

III. Software and Data Selection

In this bibliographic review, we used four types of software for the analysis of the collected scientific information:

RStudio 4.1.2: This open-access software allows for the analysis and processing of big data.

Bibliometrix: We used the Bibliometrix 4.1.0 package, a new tool developed for the R environment to process and obtain bibliometric indexes [19]. This package offers different functionalities for the use of various bibliographic sets obtained from scientific databases, allowing for the development of multiple bibliometric analyses considering the information presented in a wide variety of scientific articles.

Microsoft Excel Office 16: This software allows for the analysis and interpretation of data. Regarding its use in bibliometric analysis, it facilitates the handling of large sets obtained from scientific databases.

Statgraphics Centurion 19: This software facilitates the analysis and interpretation of data by means of different statistical metrics. We used it to analyze annual scientific production and future trends.

ArcMap: This software is used in the design and interpretation of geographic information. We used version 10.5 for this study, enabling via maps the representation of contributions by country and consolidated global collaboration networks.

Once we collected the data from the Scopus database, we exported them in the CSV and BibTex formats. The BibTex format includes bibliographic information, citations, abstracts, keywords, and references. We used the CSV format in a Microsoft Excel Office 16 sheet. During the review, we cleaned the data by eliminating duplicate files and incomplete or erroneous records. Under these considerations, we eliminated 15 documents, obtaining 5708 documents.

Finally, to carry out the analysis for Ecuador, we classified the documents by country. The database for Ecuador compried 17 scientific articles.

IV. Interpretation of Data

Performance analysis

Initially, we used the BibText file format with the Bibliometrix 4.1.0 package in Rstudio 4.1.2 [19]. Subsequently, we obtained the annual scientific production, including the number of documents and citations per year. We exported this information in the XLS format, processed it in Microsoft Excel Office 16, and subsequently entered it into Statgraphics Centurion 19. We compared quantitative variables using an analysis of variance (ANOVA) and established four fixed periods (Period I: from 1983 to 1993; Period II: from 1994 to 2003; Period III: from 2004 to 2013; Period IV: from 2014 to 2022). We used Duncan's multiple range test to determine significant differences between groups ($p < 0.001$). Subsequently, we related the number of publications found (dependent variable) to the years of study (independent variable) according to ordinary least squares (OLS) multiple regression. We verified the normality of the distribution using the Kolmogorov–mirnov, Cramer–von Mises, and Anderson–Darling tests. In addition, we performed Bartlett's test to verify the equality of the variance of the data (homoscedasticity). We used the coefficient of determination (R^2) and the mean square error (MSE) to select the best model.

Furthermore, we examined scientific journals with the highest number of papers published in relation to silvopastoral systems. To enrich the analysis, we considered the name of the journal, country of origin, publisher, SJR 2021, and quartile. Subsequently, we identified the most relevant scientific papers in the last decades on the analyzed subject. Hence, we constructed a ranking, including the names of the authors, the title of the article, the name of the journal, and the number of citations obtained.

Bibliometric Mapping

We obtained data on scientific productions at the country level, which, according to this Bibliometrix analysis, was determined by the country of affiliation of each author. We processed the obtained data using ArcMap 10.5 for the design of the cartography. Finally, for the global analysis, we examined collaborations between different authors from different countries to obtain the frequency of scientific collaborations. We represented this information by means of a frequency network map in the Bibliometrix graphical user interface.

3. Results and Discussion

3.1. Annual Scientific Production by Period

Scientific publications focused on silvopastoral systems at the global level comprise 5708 papers during the last 39 years (1983–2022) (Figure 1). Table 1 shows the means of publications and citations for each of the periods previously defined in the methodology.

Table 1. Comparation of publications and citations per year among periods.

Period (y)	Publications (y)			Citations (y)		
	Mean	SD [1]	CV [2]	Mean [1]	SD [1]	CV [2]
I 1983–1993	4.3 [a]	3.4	79	103.7 [a]	72.0	69
II 1994–2003	25.1 [a]	15.0	60	718.2 [a]	543.6	76
III 2004–2013	139.6 [b]	61.4	44	4503.5 [b]	1496.1	33
IV 2014–2022	446.4 [c]	168.9	38	4751.2 [b]	1965.1	41

[a–c] Means with different letters show significant differences among groups within the same column ($p < 0.001$). [1] Standard deviation, [2] Coefficient of variation, %.

The number of publications increased over time, although Periods I and II showed similar behavior compared with Periods III and IV, with three different homogeneous groups ($p < 0.001$). However, as the number of publications increased, the dispersion of the variable decreased, reaching a 38% coefficient of variation in Period IV. The number of citations is distributed in two homogeneous groups: Periods I and II vs. Periods III and IV ($p < 0.001$). Figure 2 shows the joint behavior of both curves by period.

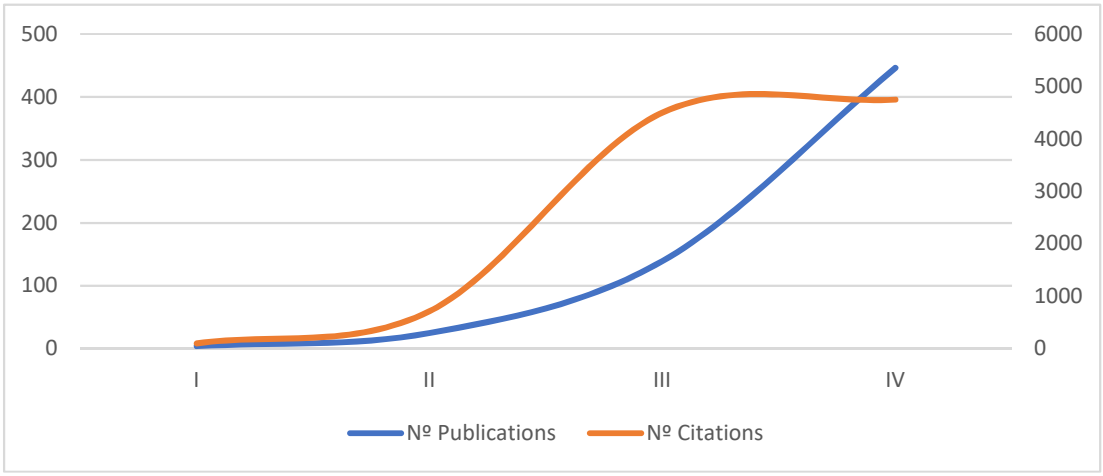

Figure 2. Evolution of number of publications and citations by period.

Assessing the number of citations given by all the analyzed documents enabled us to determine the impact generated by the findings of the research and how this contributed to scientific advances and innovation in silvopastoral systems. The number of publications increased over time, whereas the number of citations increased in the first phases and then started to decrease.

Figure 3 shows the results of the fitted regression model. We compared 14 alternative models, and in more than 10 of them, the coefficients of determination were higher than 70%. For the following models, the R^2 was higher than 90%: S-Curve, Multiplicative, Logarithmic-Y-Squared Root-X, Exponential, Log-Y-Squared-X, X-Squared-X-Squared Root, Double-Squared Root, Y-Squared Root Log-X, and Inverse Y-Squared Root of X. The equation of the best model adjusted for the period 1983–2022 was that of S-Curve: $Y = \exp(a + b/X)$, with an R^2 of 96.06%, where Y is the number of publications; X is the year (from 1983 to 2022); parameter a is 342.662; and parameter b is 678.911.

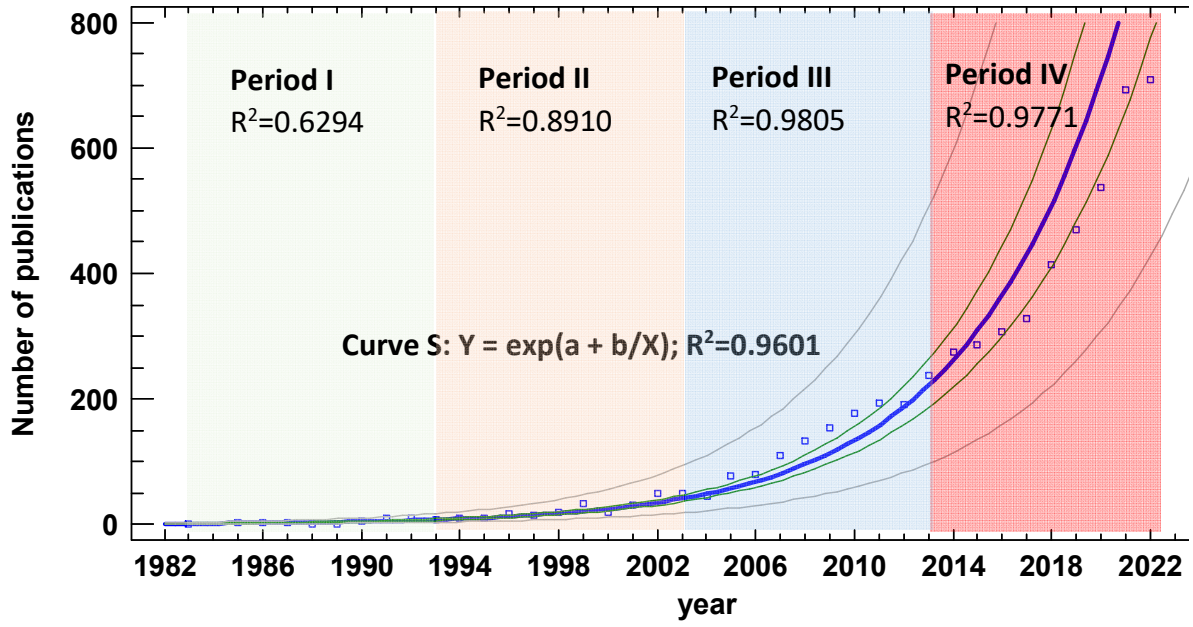

Figure 3. Evolution of the number of publications in silvopastoral system per year (1983–2022). The model fit and the adjusted coefficient of determination used in each stage are shown. R^2, Coefficient of determination.

Because the *p*-value is <0.05, a statistically significant relationship exists between the number of publications and the year, with a confidence level of 95.0%. The R-Squared statistic indicates that the fitted model explains 96.057% of the variability of the number of documents. The correlation coefficient is −0.9801, indicating a relatively strong relationship between the variables. The standard error of the estimate indicates that the standard deviation of the residuals is 0.3977. The mean absolute error (MAE), 0.2811, is the average value of the residuals.

Period I (1983–1993)—Silvopasture Characterization.

For this period, we found 43 scientific publications on silvopastoral systems, equivalent to 0.8% of the total number of analyzed articles. Within this decade, 1991 and 1992 were the years with the highest production, with nine scientific articles published each year. The study subjects focused on the contribution of silvopastoral systems in arid and semi-arid zones [20], as well as on the evaluation of the physical factors of soil affecting tree growth in pastures [21]. Another study stressed the importance of multiple land uses through the application of initiatives based on silvopastoral systems [22]. Likewise, studies focused on the economic and ecological viability of pine plantations in the Central Highlands of Ecuador were also reported [23]. In addition, a review study focused on analyzing the obtained experiences with the implementation of silvopastoral systems in New Zealand [24].

Period II (1994–2003)—Best Practices

During this period, the number of publications on silvopasture increased, with a total of 251 articles, representing 4.4% of the total production in the analyzed periods. In this period, researchers began to quantify carbon storage and analyze the nitrogen cycle [25]. The relationship between microclimate and nutrient dynamics was also analyzed [26], highlighting the importance of silvopastoral systems for soil bioimprovement [27]. Frequent studies investigated the economic benefits of implementing silvopastoral systems [28,29] and the adoption of silvopastoral practices [30]. Moreover, a novelty in this period was the incorporation of ancestral knowledge focused on the use of fodder trees in silvopastoral systems [31].

Period III (2004–2013)—Ecosystem Services

In this period, we found 1396 articles, representing 24.5% of the total number of documents analyzed, with an average annual production of 139.6 articles and a maximum of 237 articles reported in 2013. During this decade, likely driven by the Millennium Declaration through the Millennium Development Goals (MDGs) [32] and the Millennium Ecosystem Assessment [33], researchers focused on environmental valuation and payments for environmental services associated with silvopastoral systems [34–38]. Some researchers focused on enhancing carbon storage provided by silvopastoral systems [39–42]. Moreover, at the soil level, reductions in nutrient loss [43,44], the improvement of the environmental quality of agricultural lands [45], and the influence of trees as nutrient reserves [46] were addressed. Most of these studies proposed actions to mitigate the effects of climate change [47] and the recovery of ecological processes [48].

Period IV (2014–2022)—Landscape Restoration

Finally, the last period was the most relevant in relation to the increase in scientific productions focused on silvopastoral systems. In this period, 4255 scientific papers were published, representing 74.5% of the total number of articles considered in this analysis. For this decade, we observed annual growth, with a peak number of publications in the year 2022 with 708 articles, suggesting that silvopastoral systems are a topic of great interest at a global level. The conversion of extensive pastures to silvopasture with timber trees as a measure to improve soil health [49] and the restoration of degraded lands [50] were addressed. Other studies focused on the combination of silvopastoral systems and remaining forests under livestock strategies [51], the benefits of thermal cooling in tropical silvopastoral systems [52], and how these can enhance the mitigation of climate change

effects related to greenhouse gas emissions generated by cattle ranching activities [53]. The focus of this research was also related to the launch of the Millennium Development Goals (MDGs) by the United Nations [54]. Finally, during this period, drones and remote sensors were used for the characterization of woody trees dispersed within silvopastoral systems [55].

3.2. Country Classification by Publications

For our analysis, regarding the affiliation of the authors of the articles at the country level, we considered the total contributions by nation in relation to the subject of study [56,57]. For this purpose, we produced a map using ArcMap 10.5 software to geographically visualize the contributions detected in 138 countries. Figure 4 shows a map of the world's scientific contributions in the last 39 years on topics related to silvopastoral systems. The range of colors used in the map differentiates the number of scientific papers for each country, in which countries in white reported zero publications. The top 10 countries include five countries in the Americas (United States, Brazil, Mexico, Colombia, and Argentina), two Asian countries (China and India), and three European countries (Spain, Germany, and UK). The country with the highest number of publications was the United States with 1090 documents, and Brazil and Spain were in second and third place with 954 and 601 documents, respectively. Finally, most of the reported research was carried out in developed countries and in countries that have presented significant increases in activities focused on silvopasture [51,52,58,59].

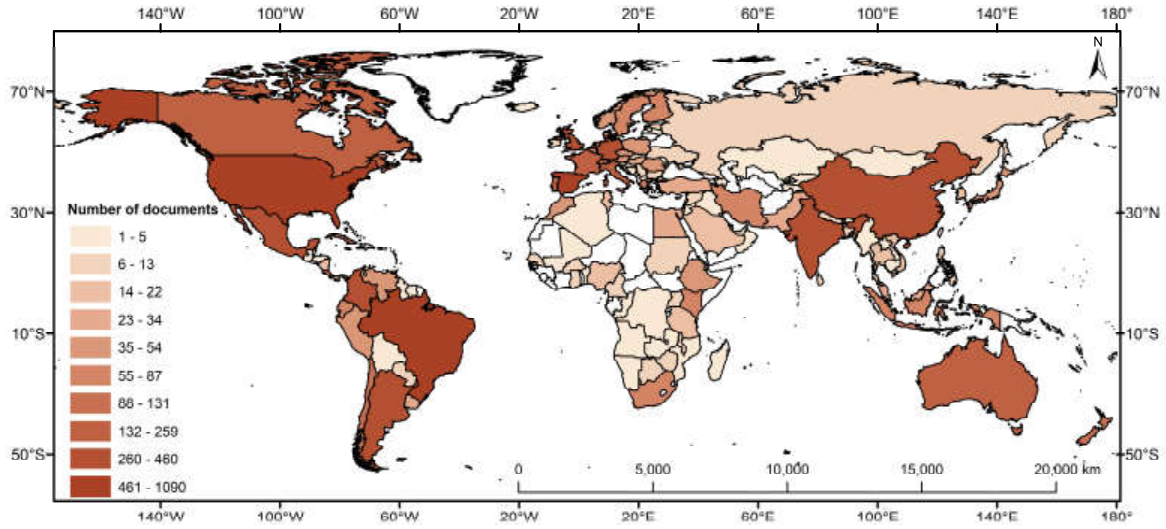

Figure 4. Number of publications on silvopastoral systems by country.

Regarding the Americas, in the United States, open grassland conservation benefits silvopastoralism by improving soil health [49]. Likewise, researchers reported that silvopastoral systems can contribute to −0.32 °C to −2.4 °C of cooling for every 10 metric tons of woody carbon per hectare [52]. We also found studies focused on analyzing silvopastoral systems as an alternative for the improvement of animal welfare and production performance [60]. Innovation was found with the use of high spatial resolution satellite images to estimate leaf indices and area biomass in spatial pastures [61], and silvopastoral systems were compared between countries [62]. Regarding economics, we observed studies focused on analyzing the profitability of silvopastoral systems [28]. In the United States, we also observed the use of timber species such as *Pinus taeda*, *Ceanothus integerrimus*, and *Acacia koa* [63–65].

The second leader was Brazil, with publications focused on relating silvopastoral systems to animal welfare by estimating thermal comfort indices [66,67], the influence of grazing, agriculture, and crop–livestock systems on C stocks [68], and the integration

of legumes in silvopastoral systems to boost soil C and N stocks [69]. Publications were also focused on changes in soil organic carbon over 22 years of grazing in integrated crop–livestock systems [70]. However, we also found that one of the species of greatest consideration for silvopastoral and climate change mitigation strategies in Brazil belonged to the genus Eucalyptus, specifically *Eucalyptus grandis*, *Eucalyptus urophylla*, *Eucalyptus astringens*, *Eucalyptus leucoxylon*, *Eucalyptus sideroxylon*, *Eucalyptus lehmannii*, and *Eucalyptus camaldulensis* [71–74].

In Europe, Spain leads scientific production in this field, contributing publications focused on the promotion of silvopastoral policies in European Mediterranean areas [75]. The potential of trees and the climate to regulate soil carbon balance was also evaluated [76]. The proper management of high-quality wood plantations in silvopastoral systems [77] and the establishment of silvopastoral systems in abandoned agricultural lands in northwest Spain [78] were also among the themes of interest. In relation to economics, we observed a study focused on analyzing the environmental and economic profitability of livestock grazing on farms under a silvopastoral system [79]. Finally, the most relevant species were *Quercus ilex*, *Quercus rubra*, *Pinus radiata*, *Fraxinus excelsior*, *Prunus avium*, *Pinus pinea*, *Eucalyptus nitens*, and *Betula pubescens* [79–85].

3.3. Journals with the Largest Number of Documents

Table 2 shows the performance and quality indexes of the ten leading journals with the highest number of papers that collaborated to generate knowledge related to silvopastoral systems. These journals contain 1275 of the 5708 publications analyzed, which representing 22.3% of the scientific production. The table shows the performance indicators of journals such as SJR and their quartile for 2021.

Table 2. Ranking of journals by number of publications in silvopastoral systems.

Journal	Country	Editorial	Number of Documents	SJR 2021	Quartile
Agroforestry Systems	The Netherlands	Springer	533	0.59	Q1
Forest Ecology and Management	The Netherlands	Elsevier	161	1.11	Q1
Agriculture Ecosystems and Environment	The Netherlands	Elsevier	99	1.66	Q1
Sustainability	Switzerland	MDPI	92	0.66	Q1
Livestock Research for Rural Development	Colombia	CIPAV	84	0.25	Q3
Forests	Switzerland	MDPI	71	0.62	Q1
Plant and Soil	The Netherlands	Springer	62	1.12	Q1
Science of the Total Environment	The Netherlands	Elsevier	61	1.81	Q1
Tropical and Subtropical Agroecosystems	Mexico	UADY	58	0.2	Q3
Land Use Policy	UK	Elsevier	54	1.64	Q1

Agroforestry Systems is the leading journal in these particular scientific contributions with 533 articles, representing 9.3% of the total number of published papers. This journal has an SJR index of 0.59 and is in Q1 according to the latest evaluation for 2021. The most relevant paper in this journal was published by Cubbage et al. [62] and has been cited 78 times in the scientific literature. They focused on comparing silvopastoral systems in eight regions of the world, considering their research methods and experience in those regions. Second place is occupied by Forest Ecology and Management with 161 papers and an SJR index of 1.11, and it is currently in the first quartile (Q1). Its most cited paper (72 citations) was published by Mohan et al. [86], which focused on evaluating the biomass production potential of nine fast-growing multipurpose tropical taxa, four of which were grown under two land management systems (forest and silvopasture). Finally, the journal with the third highest scientific production in this field was Agriculture Ecosystems and Environment, which has published 99 articles. It has an SJR index of 1.66 and is in the first quartile (Q1). One of the most relevant scientific contributions in this journal analyzed the role of positive incentives and information exchange on stimulating the adoption of silvopastoral conservation practices [36].

3.4. The 10 Most Frequently Cited Documents

We identified the most cited publications to highlight the topics of greatest interest. In this context, scientific production focused on silvopastoral systems at the global level (5708 documents) comprises 95,355 citations. Table 3 presents the top 10 most cited papers with 1023 citations, representing 1.07% of the total.

Within this group, publications focused on South American countries (Nicaragua, Colombia, Argentina, Chile, Brazil, Paraguay, and Uruguay), North America (United States, particularly Florida), Asia (India), Europe (Greece), and Oceania (New Zealand). Among the analyzed documents, the oldest documents were published by Kumar et al. [86] in 1998 and Wedderburn et al. [87] in 1999. The paper published by Kumar et al. [86] evaluated biomass and nutrient accumulation rates in multipurpose trees in woodlot and silvopasture experiments. Wedderburn et al. [87] quantified the fall, chemical characteristics, and litter decomposition rate of functional trees for use in silvopastoral systems. We noted that the most recent paper was published in 2012, in which Cubbage et al. [62] focused on describing and comparing the actual agricultural practices and research trials of silvopastoral systems in eight regions within seven countries of the world.

Table 3. Top 10 most cited papers on silvopastoral systems from 1983 to 2022 with 1023 citations, representing 1.07% of the total citations.

Ranking	Authors	Article	Journal	Citations
1	Shrestha et al. [88]	Exploring the potential for silvopasture adoption in south-central Florida: An application of SWOT-AHP method	Agricultural Systems	197
2	Pagiola et al. [34]	Paying for the environmental services of silvopastoral practices in Nicaragua	Ecological Economics	171
3	Haile et al. [39]	Carbon storage of different soil-size fractions in Florida silvopastoral systems	Journal of Environmental Quality	118
4	Pagiola et al. [35]	Can the poor participate in payments for environmental services? Lessons from the Silvopastoral Project in Nicaragua	Environment and Development Economics	89
5	Cubbage et al. [62]	Comparing silvopastoral systems and prospects in eight regions of the world	Agroforestry Systems	78
6	Giraldo et al. [48]	The adoption of silvopastoral systems promotes the recovery of ecological processes regulated by dung beetles in the Colombian Andes	Insect Conservation and Diversity	77
7	Haile et al. [40]	Contribution of trees to carbon storage in soils of silvopastoral systems in Florida, United States	Global Change Biology	77
8	Plieninger et al. [89]	Land-use legacies in the forest structure of silvopastoral oak woodlands in the Eastern Mediterranean	Regional Environmental Change	76
9	Wedderburn et al. [87]	Litter decomposition by four functional tree types for use in silvopastoral systems	Soil Biology and Biochemistry	72
10	Kumar et al. [86]	Comparison of biomass production, tree allometry and nutrient use efficiency of multipurpose trees grown in woodlot and silvopastoral experiments in Kerala, India	Forest Ecology and Management	72

Shrestha et al. [88] listed 197 citations. The authors evaluated the sustainability of silvopastoral adoption decisions by implementing a strengths, weaknesses, opportunities, and threats (SWOT) approach and an analytical hierarchy process (AHP). Among the main findings of this research, we found land stewardship, income diversification, environmental benefits, and government support programs to be the main prospects for silvopastoral adoption [88]. Second place was occupied by Pagiola et al. [34], who described the results achieved by the Regional Integrated Project for the Management of Silvopastoral Ecosystems (PRIMES), which aimed to fund payment for environmental services to farmers for their contribution to biodiversity conservation and carbon sequestration provided by the implementation of silvopastoral strategies. This article indicated that the implementation of PRIMES allowed for the adoption of silvopastoral systems that, in turn, generated the expected ecosystem services. However, much uncertainty exists regarding the financial

sustainability of payment for environmental services [33]. Finally, the third most cited paper on silvopastoral systems was published by Haile et al. [38], who focused on determining the total soil carbon contents at six soil depths (0–5, 5–15, 15–30, 30–50, 50–75, and 75–125 cm) in silvopastoral systems to evaluate the carbon storage potential. Among the main results, the authors concluded that the integration of trees in open pastures generates even more soil organic carbon, particularly at shallower depths [39].

3.5. Collaboration Networks

Scientific collaboration allows for the transfer of knowledge and enhances technological innovation through the multidisciplinary contribution of papers published by the authors from different countries on a global scale. In research focused on silvopastoral systems, 119 countries have collaborated in the development of scientific papers. Of this total, at least 77 countries have three articles in collaboration with authors from other countries. Figure 5 shows a map of the global network of scientific collaborations between countries in different regions of the world.

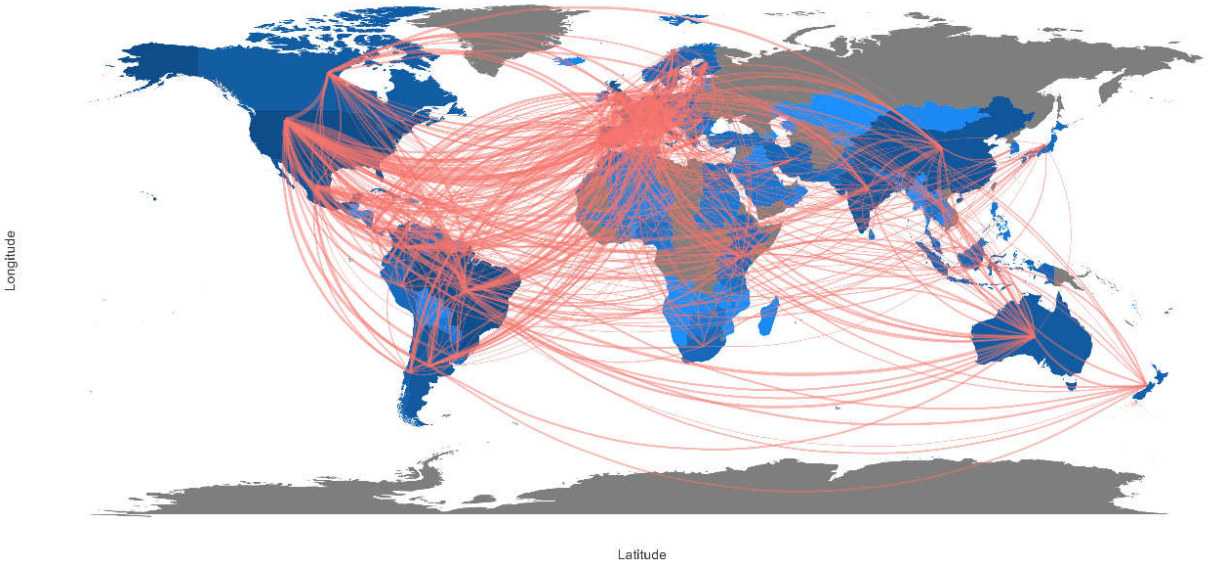

Figure 5. Collaborative networks in silvopastoral systems studies around the world from 1983 to 2022.

In general, the country with the highest number of contributions among nations is the United States with 80 collaborations, followed by Germany and the UK with 64 individual collaborations. In relation to the United States, its collaborations have focused on the evaluation of sustainability [88], the analysis of payment for environmental services [34–38], soil carbon storage potential [39–42,90,91], nitrogen transfer [92], and reductions in nutrient loss on farms [43]. In addition, these collaborations have also focused on evaluating microclimate and nutrient dynamics [26], as well as ecological considerations in the design and sustainable management of silvopasture [93]. Germany has collaborated on papers focused on assessing deforestation reduction and the mitigation potential of greenhouse gas effects [94], the effect of herbivory on trees in a reforestation system [95], land use and land cover change [96], phosphorus dynamics [97], meat production, and food webs [98,99]. Finally, the UK has collaborated in research focused on determining the growth, production, and carbon sequestration of native timber species [100], the evaluation of milk production in dual-purpose cattle farms [101], the analysis of the environmental rent of cattle grazing [79], the determination of the carbon sequestration potential of tree biomass and soil [102], the quantification of land use change and soil carbon deposition [103], and the understanding of sustainable practices [104].

3.6. Analysis of Ecuador

3.6.1. Scientific Production and Distribution by Province

Scientific production focused on silvopastoral systems in Ecuador comprises 17 articles published during the last three decades (1992–2022). The first article concerning Ecuador was published in 1992 by Garrison et al. [23]. In this paper, the authors evaluated ten pine plantations in the provinces of Tungurahua and Chimborazo for their potential as silvopastoral systems, and they discussed the possibilities of integrating local farmers in their management and appropriate use. Between 1993 and 2014, no scientific publications were reported for Ecuador in relation to the topic addressed. We obtained the highest number of contributions in 2021. However, in relation to the current year (2022), we observed a total of three articles. Among these articles, the most recent paper was published by Torres et al. [105]; in this study, the researchers evaluated carbon stocks in silvopastoral systems in the Ecuadorian Amazon. Among the main findings reported in this study, the authors indicated the high potential of traditional grazing systems with dispersed trees for carbon sequestration in the Ecuadorian Amazon. For this reason, silvopastoral systems allow for the implementation of strategies focused on mitigating and adapting to climate change in tropical countries. Finally, the authors recommended that these systems should be managed by applying the best livestock management practices (BMPs) to mitigate the expansion of the agricultural frontier in the Ecuadorian Amazon. In addition, these silvopastoral systems can be associated with REDD+-focused initiatives in Ecuador, thus contributing to the Nationally Determined Contributions (NDCs), which were set as a goal of the Paris Agreement to stabilize the global average temperature at less than 2 °C.

3.6.2. Most Relevant Documents

Table 4 shows the 10 most cited papers that have been reported for Ecuador concerning silvopastoral systems. Among the analyzed papers, the study by Lerner et al. [106] is the most cited paper with 28 citations. In this research, the authors focused on determining the socio-ecological factors associated with the apparently spontaneous emergence of silvopastoral landscapes and possible explanations for the variation in tree density found in pastures. Second place is occupied by Raes et al. [107], who investigated farmers' preferences toward participating in payment contracts to adopt silvopastoral systems in Ecuador. Finally, the third most cited paper was published by McGroddy et al. [108]; in this study, the authors' main objective was to quantify the biomass carbon stored in spontaneous silvopastoral systems in the province of Morona Santiago in the Ecuadorian Amazon.

Table 4. Most cited documents on silvopastoral systems in Ecuador.

Ranking	Authors	Article	Journal	Citations
1	Lerner et al. [106]	The spontaneous emergence of silvo-pastoral landscapes in the Ecuadorian Amazon: Patterns and processes	Regional Environmental Change	28
2	Raes et al. [107]	Farmers' Preferences for PES Contracts to Adopt Silvopastoral Systems in Southern Ecuador, Revealed Through a Choice Experiment	Environmental Management	19
3	McGroddy et al. [108]	Carbon Stocks in Silvopastoral Systems: A Study from Four Communities in Southeastern Ecuador	Biotropica	19
4	Torres et al. [109]	Determinants of agricultural diversification in a hotspot area: Evidence from colonist and indigenous communities in the Sumaco Biosphere Reserve, Ecuadorian Amazon	Sustainability	18
5	Hayes et al. [110]	Can Conservation Contracts Co-exist with Change? Payment for Ecosystem Services in the Context of Adaptive Decision-Making and Sustainability	Environmental Management	15

Table 4. *Cont.*

Ranking	Authors	Article	Journal	Citations
6	Cañadas-L et al. [111]	Growth and yield models for teak planted as living fences in coastal Ecuador	Forests	14
7	González Marcillo et al. [112]	Assessment of guinea grass panicum maximum under silvopastoral systems in combination with two management systems in Orellana province, Ecuador	Agriculture	5
8	Vargas-Tierras et al. [113]	Characterization and role of Amazonian fruit crops in family farms in the provinces of Sucumbíos and Orellana (Ecuador)	Ciencia y Tecnología Agropecuaria	4
9	Diana Rade et al. [114]	Silvopastoral System Economical and Financial Feasibility with Jatropha Curcas L. in Manabí, Ecuador	Revista MVZ Córdoba	4
10	Torres et al. [2]	Identification and assessment of livestock best management practices (BMPs) using the REDD+ approach in the Ecuadorian amazon	Agronomy	3

4. Conclusions

The evolution of the number of scientific publications in the field of silvopastoral systems has shown sustained growth over the last 39 years with exponential growth in the last 20 years, which we adjusted to an S-Curve function. However, with respect to the number of citations, we significantly differentiated two periods: the intervals of 1983–2003 and 2004–2022. Researchers' interest in the knowledge of silvopastoral systems has also evolved. They initially focused on the characterization of silvopastures and soil physical factors, whereas in the last decade, research has been directed toward the search for strategies to improve the sustainable use of these systems, such as ecosystem restoration and the implementation of better practices. Most of the scientific production has originated from a few countries, mainly those using mixed silvopastoral systems. The following countries stand out regarding scientific production on such systems: United States, Brazil, Mexico, Colombia, and Argentina in the Americas; China and India in Asia; and Spain, Germany, and UK in Europe. These publications are distributed among different journals, but in terms of the number of documents published, the publishers that accounted for the most publications were Springer, Elsevier, and MDPI.

In the case of Ecuador, we showed the 10 most cited documents referring to this country's silvopasture, facilitating the visibility of a group of prestigious experts according to bibliometric indexes so that they can collaborate in the design of public policies and help develop the country's guidelines for ecosystem conservation. In this group, four of the most cited publications were in MDPI journals (Sustainability, Forest, Agronomy, and Agriculture) in the open-access system.

Future studies should consider the moderating role of the "h-index" in the results and the disruptive contribution of open-access systems in the global dissemination of knowledge, breaking through the economic constraints of countries, universities, and researchers.

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References

1. FAO. *Buena Gobernanza En La Tenencia y La Administracion de Tierras/Good Governance in Land Tenure and Administration*; Food & Agriculture Organization: Rome, Italy, 2007; Volume 9, ISBN 925305753X.
2. Torres, B.; Eche, D.; Torres, Y.; Bravo, C.; Velasco, C.; García, A. Identification and Assessment of Livestock Best Management Practices (BMPs) Using the REDD+ Approach in the Ecuadorian Amazon. *Agronomy* **2021**, *11*, 1336. [CrossRef]
3. Rangel, J.; Perea, J.; De-Pablos-heredero, C.; Espinosa-García, J.A.; Mujica, P.T.; Feijoo, M.; Barba, C.; García, A. Structural and Technological Characterization of Tropical Smallholder Farms of Dual-Purpose Cattle in Mexico. *Animals* **2020**, *10*, 86. [CrossRef] [PubMed]
4. Mancilla-Leytón, J.M.; Gribis, D.; Pozo-Campos, C.; Morales-Jerrett, E.; Mena, Y.; Cambrollé, J.; Vicente, Á.M. Ecosystem Services Provided by Pastoral Husbandry: A Bibliometric Analysis. *Land* **2022**, *11*, 2083. [CrossRef]
5. Villarroel-Molina, O.; Barba Capote, C.; García Martínez, A.R.; Rangel, J. Use of Social Networks to Explore Smallholder's Adoption of Technologies in Dual Purpose Farms. *Esic Mark. Econ. Bus. J.* **2019**, *50*, 233–257.
6. Bastanchury-López, M.T.; De-Pablos-Heredero, C. A Bibliometric Analysis on Smart Cities Related to Land Use. *Land* **2022**, *11*, 2132. [CrossRef]
7. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to Conduct a Bibliometric Analysis: An Overview and Guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]
8. Ellegaard, O.; Wallin, J.A. The Bibliometric Analysis of Scholarly Production: How Great Is the Impact? *Scientometrics* **2015**, *105*, 1809–1831. [CrossRef]
9. Chen, C. Science Mapping: A Systematic Review of the Literature. *J. Data Inf. Sci.* **2017**, *2*, 1–40. [CrossRef]
10. Velastegui-Montoya, A.; Montalván-Burbano, N.; Peña-Villacreses, G.; de Lima, A.; Herrera-Franco, G. Land Use and Land Cover in Tropical Forest: Global Research. *Forests* **2022**, *13*, 1709. [CrossRef]
11. Huang, L.; Zhou, M.; Lv, J.; Chen, K. Trends in Global Research in Forest Carbon Sequestration: A Bibliometric Analysis. *J. Clean. Prod.* **2020**, *252*, 119908. [CrossRef]
12. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Moher, D. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *Syst. Rev.* **2021**, *10*, 89. [CrossRef]
13. Saltelli, A.; Ratto, M.; Andres, T.; Campolongo, F.; Cariboni, J.; Gatelli, D.; Saisana, M.; Tarantola, S. Introduction to Sensitivity Analysis. *Glob. Sensit. Anal. Prim.* **2008**, *50*, 1–51.
14. Pranckutė, R. Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World. *Publications* **2021**, *9*, 12. [CrossRef]
15. Zhu, J.; Liu, W. A Tale of Two Databases: The Use of Web of Science and Scopus in Academic Papers. *Scientometrics* **2020**, *123*, 321–335. [CrossRef]
16. Singh, V.K.; Singh, P.; Karmakar, M.; Leta, J.; Mayr, P. The Journal Coverage of Web of Science, Scopus and Dimensions: A Comparative Analysis. *Scientometrics* **2021**, *126*, 5113–5142. [CrossRef]
17. Baas, J.; Schotten, M.; Plume, A.; Côté, G.; Karimi, R. Scopus as a Curated, High-Quality Bibliometric Data Source for Academic Research in Quantitative Science Studies. *Quant. Sci. Stud.* **2020**, *1*, 377–386. [CrossRef]
18. Thelwall, M. Dimensions: A Competitor to Scopus and the Web of Science? *J. Informetr.* **2018**, *12*, 430–435. [CrossRef]
19. Aria, M.; Cuccurullo, C. Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
20. Ormazábal, C.S. Silvopastoral Systems in Arid and Semiarid Zones of Northern Chile. *Agrofor. Syst.* **1991**, *14*, 207–217. [CrossRef]
21. Wairiu, M.; Mullins, C.E.; Campbell, C.D. Soil Physical Factors Affecting the Growth of Sycamore (Acer pseudoplatanus L.) in a Silvopastoral System on a Stony Upland Soil in North-East Scotland. *Agrofor. Syst.* **1993**, *24*, 295–306. [CrossRef]
22. Peñaloza, R.; Hervé, M.; Sobarzo, L. Applied Research on Multiple Land Use through Silvopastoral System in Southern Chile. *Agrofor. Syst.* **1985**, *3*, 59–77. [CrossRef]
23. Garrison, M.; Pita, M. An Evaluation of Silvopastoral Systems in Pine Plantations in the Central Highlands of Ecuador. *Agrofor. Syst.* **1992**, *18*, 1–16. [CrossRef]
24. Knowles, R.L. New Zealand Experience with Silvopastoral Systems: A Review. *For. Ecol. Manag.* **1991**, *45*, 251–267. [CrossRef]
25. Kaur, B.; Gupta, S.R.; Singh, G. Carbon Storage and Nitrogen Cycling in Silvopastoral Systems on a Sodic Soil in Northwestern India. *Agrofor. Syst.* **2002**, *54*, 21–29. [CrossRef]

26. Menezes, R.S.C.; Salcedo, I.H.; Elliott, E.T. Microclimate and Nutrient Dynamics in a Silvopastoral System of Semiarid Northeastern Brazil. *Agrofor. Syst.* **2002**, *56*, 27–38. [CrossRef]
27. Cardinael, R.; Chevallier, T.; Cambou, A.; Béral, C.; Barthès, B.G.; Dupraz, C.; Durand, C.; Kouakoua, E.; Chenu, C. Increased Soil Organic Carbon Stocks under Agroforestry: A Survey of Six Different Sites in France. *Agric. Ecosyst. Environ.* **2017**, *236*, 243–255. [CrossRef]
28. Husak, A.L.; Grado, S.C. Monetary Benefits in a Southern Silvopastoral System. *South J. Appl. For.* **2002**, *26*, 159–164. [CrossRef]
29. Grado, S.C.; Hovermale, C.H.; St. Louis, D.G. A Financial Analysis of a Silvopasture System in Southern Mississippi. *Agrofor. Syst.* **2001**, *53*, 313–322. [CrossRef]
30. Rapey, H.; Lifran, R.; Valadier, A. Identifying Social, Economic and Technical Determinants of Silvopastoral Practices in Temperate Uplands: Results of a Survey in the Massif Central Region of France. *Agric. Syst.* **2001**, *69*, 119–135. [CrossRef]
31. Morrison, B.J.; Gold, M.A.; Lantagne, D.O. Incorporating Indigenous Knowledge of Fodder Trees into Small-Scale Silvopastoral Systems in Jamaica. *Agrofor. Syst.* **1996**, *34*, 101–117. [CrossRef]
32. ONU. *United Nations Millennium Declaration*; United Nations: Washington, DC, USA, 2000.
33. Millennium Ecosystem Assessment. *Ecosystems and Human Well-Being*; Island Press: Washington, DC, USA, 2005; Volume 5.
34. Pagiola, S.; Ramírez, E.; Gobbi, J.; de Haan, C.; Ibrahim, M.; Murgueitio, E.; Ruíz, J.P. Paying for the Environmental Services of Silvopastoral Practices in Nicaragua. *Ecol. Econ.* **2007**, *64*, 374–385. [CrossRef]
35. Pagiola, S.; Rios, A.R.; Arcenas, A. Can the Poor Participate in Payments for Environmental Services? Lessons from the Silvopastoral Project in Nicaragua. *Environ. Dev. Econ.* **2008**, *13*, 299–325.
36. Garbach, K.; Lubell, M.; DeClerck, F.A.J. Payment for Ecosystem Services: The Roles of Positive Incentives and Information Sharing in Stimulating Adoption of Silvopastoral Conservation Practices. *Agric. Ecosyst. Environ.* **2012**, *156*, 27–36. [CrossRef]
37. Shrestha, R.K.; Alavalapati, J.R.R. Valuing Environmental Benefits of Silvopasture Practice: A Case Study of the Lake Okeechobee Watershed in Florida. *Ecol. Econ.* **2004**, *49*, 349–359. [CrossRef]
38. Pagiola, S.; Rios, A.R.; Arcenas, A. Poor Household Participation in Payments for Environmental Services: Lessons from the Silvopastoral Project in Quindío, Colombia. *Environ. Resour. Econ.* **2010**, *47*, 371–394. [CrossRef]
39. Haile, S.G.; Ramachandran Nair, P.K.; Nair, V.D. Carbon Storage of Different Soil-Size Fractions in Florida Silvopastoral Systems. *J. Environ. Qual.* **2008**, *37*, 1789–1797. [CrossRef]
40. Haile, S.G.; Nair, V.D.; Nair, P.K.R. Contribution of Trees to Carbon Storage in Soils of Silvopastoral Systems in Florida, United States. *Glob. Chang. Biol.* **2010**, *16*, 427–438. [CrossRef]
41. Howlett, D.S.; Moreno, G.; Mosquera Losada, M.R.; Nair, P.K.R.; Nair, V.D. Soil Carbon Storage as Influenced by Tree Cover in the Dehesa Cork Oak Silvopasture of Central-Western Spain. *J. Environ. Monit.* **2011**, *13*, 1897–1904. [CrossRef]
42. Tonucci, R.G.; Nair, P.K.R.; Nair, V.D.; Garcia, R.; Bernardino, F.S. Soil Carbon Storage in Silvopasture and Related Land-Use Systems in the Brazilian Cerrado. *J. Environ. Qual.* **2011**, *40*, 833–841. [CrossRef]
43. Nair, V.D.; Nair, P.K.R.; Kalmbacher, R.S.; Ezenwa, I. V Reducing Nutrient Loss from Farms through Silvopastoral Practices in Coarse-Textured Soils of Florida, USA. *Ecol. Eng.* **2007**, *29*, 192–199. [CrossRef]
44. Michel, G.-A.; Nair, V.D.; Nair, P.K.R. Silvopasture for Reducing Phosphorus Loss from Subtropical Sandy Soils. *Plant Soil* **2007**, *297*, 267–276. [CrossRef]
45. Reis, G.L.; Lana, Â.M.Q.; Maurício, R.M.; Lana, R.M.Q.; Machado, R.M.; Borges, I.; Neto, T.Q. Influence of Trees on Soil Nutrient Pools in a Silvopastoral System in the Brazilian Savannah. *Plant Soil* **2010**, *329*, 185–193. [CrossRef]
46. Nair, V.D.; Haile, S.G.; Michel, G.-A.; Nair, P.K.R. Environmental Quality Improvement of Agricultural Lands through Silvopasture in Southeastern United States. *Sci. Agric.* **2007**, *64*, 513–519. [CrossRef]
47. Montagnini, F.; Ibrahim, M.; Restrepo, E.M. Systèmes Silvopastoraux et Atténuation Du Changement Climatique En Amérique Latine. *Bois Forets Trop.* **2013**, *316*, 3–16. [CrossRef]
48. Giraldo, C.; Escobar, F.; Chará, J.D.; Calle, Z. The Adoption of Silvopastoral Systems Promotes the Recovery of Ecological Processes Regulated by Dung Beetles in the Colombian Andes. *Insect Conserv. Divers.* **2011**, *4*, 115–122. [CrossRef]
49. Poudel, S.; Bansal, S.; Podder, S.; Paneru, B.; Karki, S.; Fike, J.; Kumar, S. Conversion of Open Pasture to Hardwood Silvopasture Enhanced Soil Health of an Ultisol. *Agrofor. Syst.* **2022**, *96*, 1237–1247. [CrossRef]
50. Kumar, R.V.; Roy, A.K.; Kumar, S.; Gautam, K.; Singh, A.K.; Ghosh, A.; Singh, H.V.; Koli, P. Silvopasture Systems for Restoration of Degraded Lands in a Semiarid Region of India. *Land Degrad. Dev.* **2022**, *33*, 2843–2854. [CrossRef]
51. Aryal, D.R.; Morales-Ruiz, D.E.; López-Cruz, S.; Tondopó-Marroquín, C.N.; Lara-Nucamendi, A.; Jiménez-Trujillo, J.A.; Pérez-Sánchez, E.; Betanzos-Simon, J.E.; Casasola-Coto, F.; Martínez-Salinas, A. Silvopastoral Systems and Remnant Forests Enhance Carbon Storage in Livestock-Dominated Landscapes in Mexico. *Sci. Rep.* **2022**, *12*, 16769. [CrossRef]
52. Zeppetello, L.R.V.; Cook-Patton, S.C.; Parsons, L.A.; Wolff, N.H.; Kroeger, T.; Battisti, D.S.; Bettles, J.; Spector, J.T.; Balakumar, A.; Masuda, Y.J. Consistent Cooling Benefits of Silvopasture in the Tropics. *Nat. Commun.* **2022**, *13*, 708. [CrossRef]
53. Brook, R.; Forster, E.; Styles, D.; Mazzetto, A.M.; Arndt, C.; Esquivel, M.J.; Chadwick, D. Silvopastoral Systems for Offsetting Livestock Emissions in the Tropics: A Case Study of a Dairy Farm in Costa Rica. *Agron. Sustain. Dev.* **2022**, *42*, 101. [CrossRef]
54. UN Sustainable Development Goals. Available online: https://sustainabledevelopment.un.org/content/documents/4538pressowg13.pdf (accessed on 30 December 2022).
55. Iñamagua-Uyaguari, J.P.; Green, D.R.; Fitton, N.; Sangoluisa, P.; Torres, J.; Smith, P. Use of Unoccupied Aerial Systems to Characterize Woody Vegetation across Silvopastoral Systems in Ecuador. *Remote Sens.* **2022**, *14*, 3386. [CrossRef]

56. Centobelli, P.; Cerchione, R.; Merigo, J.M. Mapping Knowledge Management Research: A Bibliometric Overview. *Technol. Econ. Dev. Econ.* **2022**, *28*, 239–267.
57. McAllister, J.T.; Lennertz, L.; Atencio Mojica, Z. Mapping a Discipline: A Guide to Using VOSviewer for Bibliometric and Visual Analysis. *Sci. Technol. Libr.* **2022**, *41*, 319–348. [CrossRef]
58. Jaureguiberry, P.; Titeux, N.; Wiemers, M.; Bowler, D.E.; Coscieme, L.; Golden, A.S.; Guerra, C.A.; Jacob, U.; Takahashi, Y.; Settele, J. The Direct Drivers of Recent Global Anthropogenic Biodiversity Loss. *Sci. Adv.* **2022**, *8*, eabm9982. [CrossRef]
59. Winkler, K.; Fuchs, R.; Rounsevell, M.; Herold, M. Global Land Use Changes Are Four Times Greater than Previously Estimated. *Nat. Commun.* **2021**, *12*, 2501. [CrossRef]
60. Lemes, A.P.; Garcia, A.R.; Pezzopane, J.R.M.; Brandão, F.Z.; Watanabe, Y.F.; Cooke, R.F.; Sponchiado, M.; de Paz, C.C.P.; Camplesi, A.C.; Binelli, M.; et al. Silvopastoral System Is an Alternative to Improve Animal Welfare and Productive Performance in Meat Production Systems. *Sci. Rep.* **2021**, *11*, 14092. [CrossRef]
61. Wang, J.; Xiao, X.; Bajgain, R.; Starks, P.; Steiner, J.; Doughty, R.B.; Chang, Q. Estimating Leaf Area Index and Aboveground Biomass of Grazing Pastures Using Sentinel-1, Sentinel-2 and Landsat Images. *ISPRS J. Photogramm. Remote Sens.* **2019**, *154*, 189–201. [CrossRef]
62. Cubbage, F.; Balmelli, G.; Bussoni, A.; Noellemeyer, E.; Pachas, A.N.; Fassola, H.; Colcombet, L.; Rossner, B.; Frey, G.; Dube, F. Comparing Silvopastoral Systems and Prospects in Eight Regions of the World. *Agrofor. Syst.* **2012**, *86*, 303–314. [CrossRef]
63. Nyakatawa, E.Z.; Mays, D.A.; Naka, K.; Bukenya, J.O. Carbon, Nitrogen, and Phosphorus Dynamics in a Loblolly Pine-Goat Silvopasture System in the Southeast USA. *Agrofor. Syst.* **2012**, *86*, 129–140. [CrossRef]
64. Huntsinger, L. Grazing in a California Silvopastoral System: Effects of Defoliation Season, Intensity, and Frequency on Deerbrush, Ceanothus Integerrimus Hook. & Arn. *Agrofor. Syst.* **1996**, *34*, 67–82. [CrossRef]
65. Akau, G.; Detlefsen, G.; Imbach, A.; Jenkins, T.; Villanueva, C. Agronomic Qualities of Pennisetum Clandestinum in Association with Acacia Koa for the Mitigation of the Effects of Ranching and Promotion of Conservation in a Silvopastoral Context on the Island of Maui, Hawaii. *Agroecol. Sustain. Food Syst.* **2022**, *46*, 1047–1074. [CrossRef]
66. Pezzopane, J.R.M.; Nicodemo, M.L.F.; Bosi, C.; Garcia, A.R.; Lulu, J. Animal Thermal Comfort Indexes in Silvopastoral Systems with Different Tree Arrangements. *J. Therm. Biol.* **2019**, *79*, 103–111. [CrossRef] [PubMed]
67. Deniz, M.; Schmitt Filho, A.L.; Farley, J.; de Quadros, S.F.; Hötzel, M.J. High Biodiversity Silvopastoral System as an Alternative to Improve the Thermal Environment in the Dairy Farms. *Int. J. Biometeorol.* **2019**, *63*, 83–92. [CrossRef]
68. Carvalho, J.L.N.; Raucci, G.S.; Cerri, C.E.P.; Bernoux, M.; Feigl, B.J.; Wruck, F.J.; Cerri, C.C. Impact of Pasture, Agriculture and Crop-Livestock Systems on Soil C Stocks in Brazil. *Soil Tillage Res.* **2010**, *110*, 175–186. [CrossRef]
69. Lira Junior, M.A.; Fracetto, F.J.C.; Ferreira, J.D.S.; Silva, M.B.; Fracetto, G.G.M. Legume-Based Silvopastoral Systems Drive C and N Soil Stocks in a Subhumid Tropical Environment. *Catena* **2020**, *189*, 104508. [CrossRef]
70. Cá, J.; Lustosa Filho, J.F.; da Silva, N.R.; de Castro, C.R.T.; de Oliveira, T.S. C and N Stocks in Silvopastoral Systems with High and Low Tree Diversity: Evidence from a Twenty-Two Year Old Field Study. *Sci. Total Environ.* **2022**, *833*, 155298. [CrossRef]
71. Bosi, C.; Pezzopane, J.R.M.; Sentelhas, P.C. Silvopastoral System with Eucalyptus as a Strategy for Mitigating the Effects of Climate Change on Brazilian Pasturelands. *An. Acad. Bras. Cienc.* **2020**, 92. [CrossRef]
72. Horst, E.H.; Ammar, H.; Ben Rhouma, R.; Khouja, M.; Khouja, M.L.; Giráldez, F.J.; López, S. Seasonal and Species Variations in the Nutritive Value of Eucalyptus Foliage as a Potential Feed Resource for Ruminants in Silvopastoral Systems. *Agrofor. Syst.* **2022**, *96*, 1189–1198. [CrossRef]
73. De Oliveira, A.F.; Menezes, G.L.; Gonçalves, L.C.; de Araújo, V.E.; Ramirez, M.A.; Guimarães Júnior, R.; Jayme, D.G.; Lana, Â.M.Q. Pasture Traits and Cattle Performance in Silvopastoral Systems with Eucalyptus and Urochloa: Systematic Review and Meta-Analysis. *Livest. Sci.* **2022**, *262*, 104973. [CrossRef]
74. de Macêdo Carvalho, C.B.; de Mello, A.C.L.; da Cunha, M.V.; de Oliveira Apolinário, V.X.; da Silva, V.J.; de Miranda Costa, S.B.; de Carvalho, R.O.; dos Santos, M.V.F. Initial Growth and Survival of Eucalyptus Spp. and Mimosa Caesalpiniifolia Benth. in Silvopastoral Systems and Their Impact on Herbage Accumulation of Urochloa Decumbens Stapf RD Webster. *Agrofor. Syst.* **2022**, *96*, 1053–1064.
75. Rodriguez-Rigueiro, F.R.; Santiago-Freijanes, J.J.; Mosquera-Losada, M.R.; Castro, M.; Silva-Losada, P.; Pisanelli, A.; Pantera, A.; Rigueiro-Rodriguez, A.; Ferreiro-Dominguez, N. Silvopasture Policy Promotion in European Mediterranean Areas. *PLoS ONE* **2021**, *16*, e0245846. [CrossRef]
76. Ferreiro-Domínguez, N.; Rodríguez-Rigueiro, F.J.; Rigueiro-Rodríguez, A.; González-Hernández, M.P.; Mosquera-Losada, M.R. Climate Change and Silvopasture: The Potential of the Tree and Weather to Modify Soil Carbon Balance. *Sustainability* **2022**, *14*, 4270. [CrossRef]
77. López-Díaz, M.L.; Benítez, R.; Rolo, V.; Moreno, G. Managing High Quality Timber Plantations as Silvopastoral Systems: Tree Growth, Soil Water Dynamics and Nitrate Leaching Risk. *New For.* **2020**, *51*, 985–1002. [CrossRef]
78. Pasalodos-Tato, M.; Pukkala, T.; Rigueiro-Rodríguez, A.; Fernández-Núñez, E.; Mosquera-Losada, M.R. Optimal Management of Pinus Radiata Silvopastoral Systems Established on Abandoned Agricultural Land in Galicia (North-Western Spain). *Silva Fenn* **2009**, *43*, 831–845. [CrossRef]
79. Campos, P.; Ovando, P.; Mesa, B.; Oviedo, J.L. Environmental Income of Livestock Grazing on Privately-Owned Silvopastoral Farms in Andalusia, Spain. *L. Degrad. Dev.* **2018**, *29*, 250–261. [CrossRef]

80. Rivest, D.; Rolo, V.; Lopez-Diaz, L.; Moreno, G. Shrub Encroachment in Mediterranean Silvopastoral Systems: Retama Sphaerocarpa and Cistus Ladanifer Induce Contrasting Effects on Pasture and Quercus Ilex Production. *Agric. Ecosyst. Environ.* **2011**, *141*, 447–454. [CrossRef]
81. Mosquera-Losada, M.R.; Rigueiro-Rodríguez, A.; Ferreiro-Domínguez, N. Effect of Liming and Organic and Inorganic Fertilization on Soil Carbon Sequestered in Macro-and Microaggregates in a 17-Year Old Pinus Radiata Silvopastoral System. *J. Environ. Manag.* **2015**, *150*, 28–38. [CrossRef]
82. Ferreiro-Domínguez, N.; Rigueiro-Rodríguez, A.; Rial-Lovera, K.E.; Romero-Franco, R.; Mosquera-Losada, M.R. Effect of Grazing on Carbon Sequestration and Tree Growth That Is Developed in a Silvopastoral System under Wild Cherry (Prunus avium L.). *Catena* **2016**, *142*, 11–20. [CrossRef]
83. Mancilla-Leyton, J.M.; Sánchez-Lineros, V.; Martín Vicente, A. Influence of Grazing on the Decomposition of Pinus pinea L. Needles in a Silvopastoral System in Doñana, Spain. *Plant Soil* **2013**, *373*, 173–181.
84. Mosquera-Losada, M.R.; Ferreiro-Domínguez, N.; Daboussi, S.; Rigueiro-Rodríguez, A. Sewage Sludge Stabilisation and Fertiliser Value in a Silvopastoral System Developed with Eucalyptus Nitens Maiden in Lugo (Spain). *Sci. Total Environ.* **2016**, *566*, 806–815. [CrossRef]
85. Fernández-Núñez, E.; Rigueiro-Rodríguez, A.; Mosquera-Losada, M.R. Silvopastoral Systems Established with Pinus Radiata D. Don and Betula Pubescens Ehrh.: Tree Growth, Understorey Biomass and Vascular Plant Biodiversity. *For. Int. J. For. Res.* **2014**, *87*, 512–524. [CrossRef]
86. Mohan Kumar, B.; Jacob George, S.; Jamaludheen, V.; Suresh, T.K. Comparison of Biomass Production, Tree Allometry and Nutrient Use Efficiency of Multipurpose Trees Grown in Woodlot and Silvopastoral Experiments in Kerala, India. *For. Ecol. Manag.* **1998**, *112*, 145–163. [CrossRef]
87. Wedderburn, M.E.; Carter, J. Litter Decomposition by Four Functional Tree Types for Use in Silvopastoral Systems. *Soil Biol. Biochem.* **1999**, *31*, 455–461. [CrossRef]
88. Shrestha, R.K.; Alavalapati, J.R.R.; Kalmbacher, R.S. Exploring the Potential for Silvopasture Adoption in South-Central Florida: An Application of SWOT-AHP Method. *Agric. Syst.* **2004**, *81*, 185–199. [CrossRef]
89. Plieninger, T.; Schaich, H.; Kizos, T. Land-Use Legacies in the Forest Structure of Silvopastoral Oak Woodlands in the Eastern Mediterranean. *Reg. Environ. Chang.* **2011**, *11*, 603–615. [CrossRef]
90. Vallejo, V.E.; Arbeli, Z.; Terán, W.; Lorenz, N.; Dick, R.P.; Roldan, F. Effect of Land Management and Prosopis Juliflora (Sw.) DC Trees on Soil Microbial Community and Enzymatic Activities in Intensive Silvopastoral Systems of Colombia. *Agric. Ecosyst. Environ.* **2012**, *150*, 139–148. [CrossRef]
91. Howlett, D.S.; Mosquera-Losada, M.R.; Nair, P.R.R.; Nair, V.D.; Rigueiro-Rodríguez, A. Soil Carbon Storage in Silvopastoral Systems and a Treeless Pasture in Northwestern Spain. *J. Environ. Qual.* **2011**, *40*, 825–832. [CrossRef]
92. Sierra, J.; Nygren, P. Transfer of N Fixed by a Legume Tree to the Associated Grass in a Tropical Silvopastoral System. *Soil Biol. Biochem.* **2006**, *38*, 1893–1903. [CrossRef]
93. Jose, S.; Walter, D.; Mohan Kumar, B. Ecological Considerations in Sustainable Silvopasture Design and Management. *Agrofor. Syst.* **2019**, *93*, 317–331. [CrossRef]
94. Landholm, D.M.; Pradhan, P.; Wegmann, P.; Sánchez, M.A.R.; Salazar, J.C.S.; Kropp, J.P. Reducing Deforestation and Improving Livestock Productivity: Greenhouse Gas Mitigation Potential of Silvopastoral Systems in Caquetá. *Environ. Res. Lett.* **2019**, *14*, 114007. [CrossRef]
95. Riedel, J.; Dorn, S.; Plath, M.; Mody, K. Growth, Herbivore Distribution, and Herbivore Damage of Timber Trees in a Tropical Silvopastoral Reforestation System. *Ann. For. Sci.* **2013**, *70*, 75–86. [CrossRef]
96. Cárdenas, A.; Moliner, A.; Hontoria, C.; Schernthanner, H. Analysis of Land-Use/Land-Cover Changes in a Livestock Landscape Dominated by Traditional Silvopastoral Systems: A Methodological Approach. *Int. J. Remote Sens.* **2018**, *39*, 4684–4698. [CrossRef]
97. Ferreiro-Domínguez, N.; Nair, V.D.; Freese, D. Phosphorous Dynamics in Poplar Silvopastoral Systems Fertilised with Sewage Sludge. *Agric. Ecosyst. Environ.* **2016**, *223*, 87–98. [CrossRef]
98. Röhrig, N.; Hassler, M.; Roesler, T. Silvopastoral Production as Part of Alternative Food Networks: Agroforestry Systems in Umbria and Lazio, Italy. *Agroecol. Sustain. Food Syst.* **2021**, *45*, 654–672. [CrossRef]
99. Pereira, M.; Morais, M.D.G.; Fernandes, P.B.; Santos, V.A.C.D.; Glatzle, S.; Almeida, R.G.D. Beef Cattle Production on Piatã Grass Pastures in Silvopastoral Systems: Producción de Ganado de Carne En Pasturas de Urochloa Brizantha Cv. BRS Piatã En Sistemas Silvopastoriles. *Trop. Grassl. Trop.* **2021**, *9*, 1–12. [CrossRef]
100. Andrade, H.J.; Brook, R.; Ibrahim, M. Growth, Production and Carbon Sequestration of Silvopastoral Systems with Native Timber Species in the Dry Lowlands of Costa Rica. *Plant Soil* **2008**, *308*, 11–22. [CrossRef]
101. Yamamoto, W.; Dewi, I.A.; Ibrahim, M. Effects of Silvopastoral Areas on Milk Production at Dual-Purpose Cattle Farms at the Semi-Humid Old Agricultural Frontier in Central Nicaragua. *Agric. Syst.* **2007**, *94*, 368–375. [CrossRef]
102. Beckert, M.R.; Smith, P.; Lilly, A.; Chapman, S.J. Soil and Tree Biomass Carbon Sequestration Potential of Silvopastoral and Woodland-Pasture Systems in North East Scotland. *Agrofor. Syst.* **2016**, *90*, 371–383. [CrossRef]
103. Fornara, D.A.; Olave, R.; Burgess, P.; Delmer, A.; Upson, M.; McAdam, J. Land Use Change and Soil Carbon Pools: Evidence from a Long-Term Silvopastoral Experiment. *Agrofor. Syst.* **2018**, *92*, 1035–1046. [CrossRef]
104. Tschopp, M.; Ceddia, M.G.; Inguaggiato, C.; Bardsley, N.O.; Hernández, H. Understanding the Adoption of Sustainable Silvopastoral Practices in Northern Argentina: What Is the Role of Land Tenure? *Land Use Policy* **2020**, *99*, 105092. [CrossRef]

105. Torres, B.; Bravo, C.; Torres, A.; Tipán-Torres, C.; Vargas, J.C.; Herrera-Feijoo, R.J.; Heredia, R.M.; Barba, C.; García, A. Carbon Stock Assessment in Silvopastoral Systems along an Elevational Gradient: A Study from Cattle Producers in the Sumaco Biosphere Reserve, Ecuadorian Amazon. *Sustainability* **2023**, *15*, 449. [CrossRef]
106. Lerner, A.M.; Rudel, T.K.; Schneider, L.C.; McGroddy, M.; Burbano, D.V.; Mena, C.F. The Spontaneous Emergence of Silvo-Pastoral Landscapes in the Ecuadorian Amazon: Patterns and Processes. *Reg. Environ. Chang.* **2015**, *15*, 1421–1431. [CrossRef]
107. Raes, L.; Speelman, S.; Aguirre, N. Farmers' Preferences for PES Contracts to Adopt Silvopastoral Systems in Southern Ecuador, Revealed Through a Choice Experiment. *Environ. Manag.* **2017**, *60*, 200–215. [CrossRef] [PubMed]
108. McGroddy, M.E.; Lerner, A.M.; Burbano, D.V.; Schneider, L.C.; Rudel, T.K. Carbon Stocks in Silvopastoral Systems: A Study from Four Communities in Southeastern Ecuador. *Biotropica* **2015**, *47*, 407–415. [CrossRef]
109. Torres, B.; Vasco, C.; Günter, S.; Knoke, T. Determinants of Agricultural Diversification in a Hotspot Area: Evidence from Colonist and Indigenous Communities in the Sumaco Biosphere Reserve, Ecuadorian Amazon. *Sustainability* **2018**, *10*, 1432. [CrossRef]
110. Hayes, T.; Murtinho, F.; Cárdenas Camacho, L.M.; Crespo, P.; McHugh, S.; Salmerón, D. Can Conservation Contracts Co-Exist with Change? Payment for Ecosystem Services in the Context of Adaptive Decision-Making and Sustainability. *Environ. Manag.* **2015**, *55*, 69–85.
111. Cañadas, L.Á.; Andrade-Candell, J.; Domínguez, A.J.M.; Molina, H.C.; Schnabel, D.O.; Vargas-Hernández, J.J.; Wehenkel, C. Growth and Yield Models for Teak Planted as Living Fences in Coastal Ecuador. *Forests* **2018**, *9*, 55. [CrossRef]
112. González Marcillo, R.L.; Castro Guamàn, W.E.; Guerrero Pincay, A.E.; Vera Zambrano, P.A.; Ortiz Naveda, N.R.; Guamàn Rivera, S.A. Assessment of Guinea Grass Panicum Maximum under Silvopastoral Systems in Combination with Two Management Systems in Orellana Province, Ecuador. *Agriculture* **2021**, *11*, 117. [CrossRef]
113. Vargas-Tierras, Y.B.; Prado-Beltrán, J.K.; Nicolalde-Cruz, J.R.; Casanoves, F.; de Virginio-Filho, E.M.; Viera-Arroyo, W.F. Characterization and Role of Amazonian Fruit Crops in Family Farms in the Provinces of Sucumbíos and Orellana (Ecuador). *Cienc. Tecnol. Agropec.* **2018**, *19*, 501–515.
114. Diana Rade, L.; Álvaro Cañadas, L.; Carlos Zambrano, Z.; Carlos Molina, H.; Alexandra Ormaza, M.; Wehenkel, C. Silvopastoral System Economical and Financial Feasibility with Jatropha Curcas L. in Manabí, Ecuador. *Rev. MVZ Cordoba* **2017**, *22*, 6241–6255. [CrossRef]