Revue Ecosystèmes et Paysages, 2024, 4 (2) : 1-20
https://lbev-univlome.com/revue-ecosysteme-et-paysage/
ISSN Online: 2790-3230

Trends and research features on ecosystem services of agroforestry system: bibliometric review

Tendances et caractéristiques de la recherche sur les services écosystémiques des systèmes agroforestiers : revue bibliométrique

Yabi Chaffra Charles [1], Biaou Séverin[1*], Ahouandjinou Enagnon Benoit Olivier [2], Gouwakinnou Nounagnon Gérard [1]

[1]Research Unit Biodiversity Conservation at the Interface People, Land use and Climate Changes (BIPLaC), Laboratoire d'Ecologie, de Botanique et de Biologie végétale (LEB), University of Parakou, 03 BP 125, Parakou, Benin
[2]West African Centre for Climate Change and Adapted Land Use (WASCAL), Department of Climate Change & Human Habitat, Federal University of Technology, Minna, Niger State, Nigeria

(*) Corresponding author: sbbiaou@gmail.com

Authors' ORCDI
Yabi Chaffra Charles : https://orcid.org/0009-0003-3913-6896 , Biaou Séverin : https://orcid.org/0000-0002-7052-5465 , Ahouandjinou Enagnon Benoit Olivier : https://orcid.org/0000-0001-8717-2005 , Gouwakinnou Nounagnon Gérard : https://orcid.org/0000-0002-3595-9831

Comment citer l'article : Yabi Chaffra Charles, Biaou Séverin, Ahouandjinou Enagnon Benoit Olivier, Gouwakinnou Nou-nagnon Gérard (2024). Trends and research features on ecosystem services of agroforestry system: bibliometric review. *Revue Écosystèmes et Paysages*, 4(2) : 1-20, e-ISSN (Online) : 2790-3230

Doi: https://doi.org/10.59384/recopays.tg4227

Reçu : 30 septembre 2024
Accepté : 15 décembre 2024
Publié : 30 décembre 2024

Abstract

Tropical agroforestry systems make an important contribution to mitigating the effects of climate change and conserving biodiversity. Despite the scientific gaps regarding the ecosystem services of these particular ecosystems, understanding how tropical agroforestry systems work is essential if we are to take full advantage of the ecosystem services they provide. Although there has been a boom in the study of the ecosystem services provided by agroforestry systems, few syntheses are structuring this knowledge in the context of the challenges posed by climate change. This study aims to analyse global trends in agroforestry-related ecosystem services and their implications for climate change mitigation based on a bibliometric analysis of 1965 articles published between 1992 and 2022 and extracted from the Scopus database. These extracted data were analysed using the Biobliometrix R tool to examine sources, authors and documents. The results reveal a notable increase in interest in agroforestry's ecosystem services, coupled with a rise in international collaborations, especially among African countries, Germany, and France. These partnerships reflect a shared commitment to understanding agroforestry systems and developing sustainable solutions. Furthermore, our analysis identifies key research themes, guiding future studies. Ecosystem services, climate dynamics, and biodiversity emerge as central aspects of agroforestry research. The findings highlight agroforestry's multiple benefits, particularly its role in adapting to and mitigating climate change while significantly contributing to biodiversity conservation. A thorough evaluation of agroforestry systems is, therefore, crucial to developing innovative, integrated strategies that address current environmental and climate challenges.

Keywords: Parkland; Biodiversity Conservation; Carbon Storage; Scientific Mapping

Résumé

Les systèmes agroforestiers tropicaux contribuent essentiellement à l'atténuation des effets du changement climatique et à la préservation de la biodiversité. Malgré les lacunes scientifiques concernant les services écosystémiques de ces écosystèmes particuliers, la compréhension du fonctionnement des systèmes agroforestiers tropicaux est essentielle pour tirer pleinement parti des services écosystémiques qu'ils offrent. Bien que l'étude des services écosystémiques fournis par les systèmes agroforestiers ait connu un essor, les synthèses permettant de structurer ces connaissances restent rares, dans le contexte des enjeux du changement climatique. Cette étude vise à analyser les tendances mondiales des services écosystémiques liés à l'agroforesterie et leur impact sur l'atténuation climatique à travers une analyse bibliométrique de 1965 articles publiés entre 1992 et 2022 et extraits de la base de données Scopus. Ces données extraites ont été analysées à l'aide de l'outil Bibliometrix R pour examiner les sources, les auteurs et les documents. Les résultats montrent une augmentation remarquable des études sur les services écosystémiques fournis par l'agroforesterie. Une tendance remarquable est l'intensification des collaborations internationales, en particulier entre les pays africains, l'Allemagne et la France. Cette coopération reflète un intérêt commun pour la compréhension des systèmes agroforestiers et la recherche de solutions durables. En outre, l'étude identifie des thèmes de recherche importants, fournissant des orientations pour les futures études. Les services écosystémiques, la dynamique du changement climatique et la biodiversité sont des aspects clés de la recherche sur les systèmes agroforestiers. L'étude met en évidence les avantages multiples de l'agroforesterie, notamment son rôle dans l'adaptation et l'atténuation du changement climatique. De plus, l'agroforesterie contribue de manière significative à la préservation de la biodiversité, ce qui renforce l'importance de son intégration dans les efforts de conservation. L'exploration continue des systèmes agroforestiers est donc essentielle pour développer des approches innovantes en réponse aux défis climatiques et environnementaux. De ce fait, la contribution cruciale de l'agroforesterie à la préservation de la biodiversité souligne la nécessité d'une évaluation rigoureuse et d'une intégration stratégique dans les efforts de conservation.

Mots clés : Systèmes Agroforestiers ; Services Ecosystémiques ; Stockage du Carbone ; Cartographie

1. Introduction

Understanding agroforestry's potential is essential for addressing the twin challenges of climate change and food insecurity, especially in tropical regions. Climate change, one of this decade's most pressing global threats, is largely driven by human activities like fossil fuel combustion, deforestation, and unsustainable agricultural practices (IPCC, 2021). Among these, agriculture is particularly vulnerable, with smallholder farmers often lacking the resources to adapt effectively (Amadu et al., 2020). Tropical agriculture, especially subsistence farming, faces elevated risks due to limited adaptive capacity (Tschora & Cherubini, 2020; Verchot et al., 2007). Agroforestry parklands, however, are emerging as valuable systems with the dual potential to mitigate climate change and enhance ecosystem services (Middendorp et al., 2018; Ntawuruhunga et al., 2023).

Agroforestry parkland is a land-use system that combines trees, crops, and livestock in a spatial arrangement that mimics natural ecosystems. This system has been practiced for centuries in various parts of the world (Norgrove & Beck, 2016; Reith et al., 2020), particularly in sub-Saharan Africa, where it has been used to provide food, fuel, and timber, as well as to maintain soil fertility and biodiversity (Middendorp et al., 2018; Reith et al., 2020; Tschora & Cherubini, 2020; Fousseni et al. 2023; Folega et al. 2023). Evidence is accumulating that, if trees are wisely maintained with crops and/or animals on agricultural grounds, they are thought to represent a significant potential sink that might absorb significant amounts of carbon. As a result, agroforestry's significance as a system of land use is becoming more widely acknowledged, both in terms of concerns relating to the sustainability of biodiversity conservation and those relating to climate change. For example, Albrecht & Kandji, (2003) emphasized that Agroforests, home gardens, and boundary plantings are examples of long rotation systems that can store significant amounts of carbon in plant biomass and durable wood products. Another feasible approach that can be achieved in many agroforestry systems is soil Carbon sequestration (Middendorp et al., 2018).

Agroforestry has the potential to be an agriculturally sustainable practice since it replicates the structure and functionality of natural woody perennial ecosystems. These systems have been acknowledged for their capacity to offer a variety of ecological services, including improving soil fertility, sequestering carbon, conserving biodiversity, and regulating water. Garrity *et al.* (2010) found that the presence of trees in agroforestry parklands increased soil organic matter content, nutrient availability, and water-holding capacity, resulting in increased crop productivity. Carbon sequestration is another ecosystem service provided by agroforestry parklands. Research has shown that agroforestry parklands can sequester large amounts of carbon, particularly when compared to conventional agriculture (Ramachandran Nair et al., 2009; Sheppard et al., 2020). Furthermore, the presence of trees in agroforestry parklands can contribute to water regulation by reducing runoff and increasing water infiltration (Reith et al., 2020). Livestock grazing in agroforestry parklands can also provide ecosystem services. For example, a study in Kenya found that integrated crop-livestock systems had higher soil organic carbon and nitrogen contents than conventional agricultural systems (Githongo et al., 2023). Another study found that integrating livestock into agroforestry systems increased soil fertility, leading to improved crop yields (Fahad et al., 2022). In addition to providing ecosystem services, agroforestry parklands can also contribute to food security and income generation. One study in Ethiopia found that households with access to agroforestry parklands had higher food security and income levels than those without (Garrity et al., 2010; Rahman et al., 2017).

In recent years, the potential of agroforestry parkland to mitigate climate change and provide ecosystem services has been increasingly recognized by researchers and policymakers (Abdulai et al., 2018; Middendorp et al., 2018; Ramachandran Nair et al., 2009). This has led to a growing body of literature on the subject, with a focus on understanding the key trends and research features of ecosystem services provided by agroforestry parkland (Rahman et al., 2017). To provide a comprehensive overview of this literature, a bibliometric analysis was conducted. The analysis focused on the key trends and research features of ecosystem services provided by agroforestry parkland, including the types of services provided, the spatial and temporal scales of the research, the geographical locations of the research, and the types of publications (Mbow, Smith, et al., 2014).

This paper undertakes a bibliometric analysis to review the performance of agroforestry-related publications published between 1990 and 2022 to address the knowledge gap and contribute to the advancement of research. We aim to (1) identify publication characteristics, such as quantity of publications, representative nations, and research topics; (2) recognize the body of knowledge based on frequently cited sources; (3) identify changing trends in research topics over time and by region; and (4) identify knowledge gaps for future exploration. Through this analysis, we seek to advance our understanding of agroforestry's role in sustainable development and climate adaptation, fostering pathways for research and practical application.

2. Materiel and Method

2.1.Data Acquisition

Bibliometric analysis is a well-liked and exacting technique for investigating and analyzing vast amounts of scientific data (Donthu et al., 2021; Pritchard, 1969). It allows us to explore the subtleties of a particular field's evolutionary history while illuminating its frontiers (Guler et al., 2016). However, its use in agroforestry research is still relatively new and often underdeveloped. The study gathered information on different ecosystem services of agroforestry parkland and how climate change affects these services by searching for relevant articles in the Scopus scientific database. Scopus is a well-known and widely used database to create datasets for systematic review of research academic research (Sossa et al., 2022). It contains many peer-reviewed articles on various subjects (Baas et al., 2020; Falagas et al., 2008). Compared to other scientific databases such as Web of Science, Scopus has a broader coverage and presents a better research option. Numerous reviews have also been used for bibliometric analysis (Baas et al., 2020; Sossa et al., 2022). The study used advanced search strategies to identify articles that contained specific keywords related to climate change's impact on ecosystem services provided by agroforestry parkland.

The following search strategy was applied: TITLE-ABS-KEY (agroforest* OR parkland OR vitellaria OR karité OR parkia OR nere) AND TITLE-ABS-KEY ("Carbon storage" OR "Climate change" OR "Ecosystem service" OR "Ecosystem function" OR " Economic value of ecosystem services"). These keywords were selected to appear in the title, abstract, or keywords to ensure comprehensive coverage of relevant literature. An initial list of 2,771 articles was retrieved from the Scopus database, limited to publication in “English” and «French” to accommodate widely understood language within the research community. The search further refined to articles published between January 1, 1990, and December 31, 2022, focussing on subject areas including Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Environmental Science, and Multidisciplinary. From this refined list, 1965 articles met the inclusion criteria in the analysis. Data extracted from these articles included authorship, article titles, abstracts, keywords, and citation metrics. A diagram of the data retrieval process is provided in Figure 1.

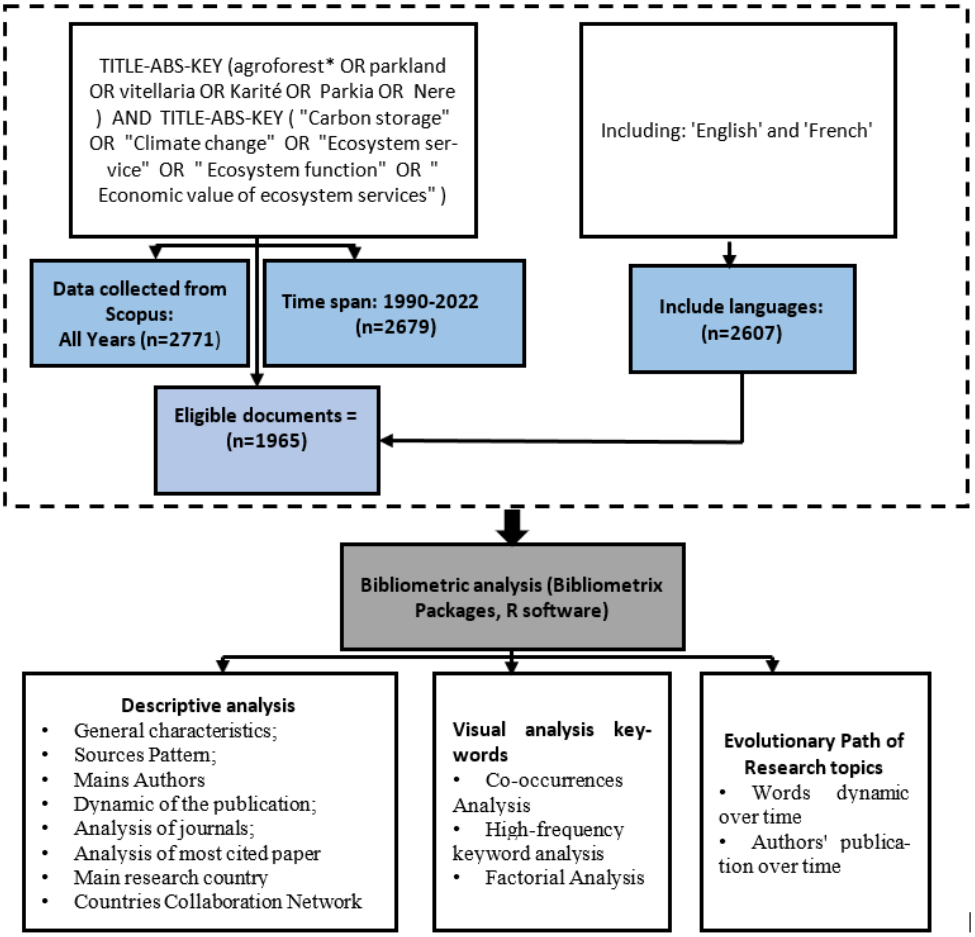

Figure 1: Flow chart for refining, retrieving, and analyzing literature data from Scopus collection.

2.2. Analysis and synthesis

To gain insight into the trends and research features related to ecosystem services of agroforestry parkland, a bibliometric analysis was conducted using the Bibliometrix package in the R language environment (Aria & Cuccurullo, 2017; Derviş, 2019). The analysis utilized data from Scopus datasets and was used to characterize the descriptive and visual analysis, as well as the evolutionary path of research topics during the study period. The data retrieved included the number of articles associated with the related global citation dynamics, the top 10 authors over time, the most prominent authors and their contributions to the study field, and the number of articles by country. The analysis was performed using R software (R Core Team, 2017) and Bibliometric packages (Derviş, 2019) with data imported in BibTeX formats. This analysis also included a mapping of the country collaboration network to ascertain research hotspots and the annual number of articles on the main research topics (Guler et al., 2016).
Furthermore, relevant keywords from the literature used by authors in the field were extracted and analysed to explore research hotspots. The authors extracted 50 keywords with the highest citation frequency from the Scopus database and used them to generate the "Word map" of the authors' keywords. Referring to the h-index shows the number of published articles that were cited at least h times (Bertoli-Barsotti & Lando, 2017). The five main “keywords plus” were also extracted and analysed to evaluate word growth, which showed the changing rules, evolutionary relationships, paths, and trends in the field. In addition, cluster analysis was conducted based on the occurrence of the most used author's keywords in the literature. The analysis utilized the Multiple Correspondence Analysis (MCA) method and was used to draw a conceptual structure of the field and clustering of K-means. Overall, the bibliometric analysis provided valuable insights into the trends and research features related to ecosystem services of agroforestry parkland, which could help guide future research in this field.

3. Results

3.1. General characterisation of the selected articles

A search using specific keywords related to agroforestry, climate, and ecosystem services on the Scopus platform yielded a total of 1,965 documents published between 1992 and 2022 (Table 1). These publications involved contributions from 6,934 authors across 522 journals, with an average publication rate of 6.27 per year. Table 1 provides an overview of the dataset used for this research.

Table 1. Document use characteristic

Description	Results	Unit
Main information about data		
Annual Growth Rate	18.28	%
Document Average Age	6.27	Years
Average Citations per Document	24.98	Citations
References	117,027	Total References
Document contents		
Keywords Plus (ID)	6,463	Keywords
Authors Keywords (DE)	5,324	Keywords
Authors		
Authors	6,934	Total Authors
Authors of Single-Authored Docs	94	Authors
Authors collaboration		
Single-Authored Docs	111	Documents
Co-Authors per Document	4.97	Authors
International Co-Authorships	45.29	%

3.2. Evolution of the number of publications on Ecosystem services of Agroforestry parkland

Dynamic trends of the studies on agroforestry systems in worldwide exhibited a general increasing trend over the years (Figure 2). Global overview, this trend in the field over time can be subdivided into three major periods. An initial development stage occurred from 1992 to 2006. The worldwide publication on agroforestry during this period

was extremely limited with fewer than 100 publications and up to 375 total global citations. The second stage between 2007 and 2011 of slow development of the research on the topic exhibits an overall upward trend of the influence of publication on agroforestry system. However, we observed that the scholars' publications were still higher than 90 publications per year. The last stage showed a rapid increase in the publication, extending from 2012 to 2022. There is a substantial increase in the number of publications by the international community on agroforestry systems, as well as an increasing influence yearly. The number of new publications each year reached 75.

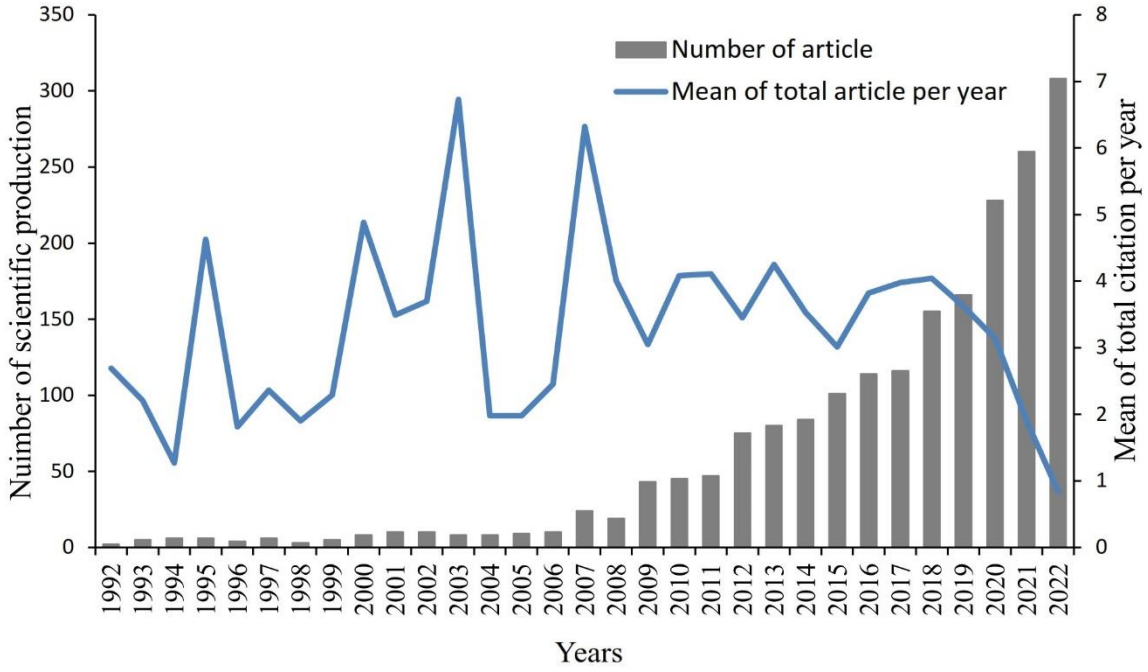

Figure 2: Annual evolution and the cumulative distribution of the number of publications over the study period

3.3. Main journal analysis

A total of 1965 scientific papers have been published for the period from 1991 to 2020 in 522 sources. From 1992 to September 2022, all articles published on ecosystem services provided by agroforestry parkland generally came from different sources. As displayed in Table 2, "Agriculture, Ecosystems and Environment" (4095 citations and 99 articles, since 1997), "Agroforestry Systems" (4133 citations and 185 articles, since 1994) and "Land Use Policy" (705 citations and 29 articles since 2008) were the most relevant and top-ranked journal with the highest h-index (Table 2).

Table 2: Top 10 journals publishing the most articles on species local adaptation under climate change

Rank	Journal	h-index	g-index	m-index	TC	NP	PY
1	Agriculture. Ecosystems and Environment	38	60	1.41	4095	99	1997
2	Agroforestry Systems	35	54	1.17	4133	185	1994
3	Land Use Policy	16	26	1.00	705	29	2008
4	Sustainability (Switzerland)	15	23	1.36	664	60	2013
5	Agricultural Systems	14	23	0.61	549	23	2001
6	Forest Ecology and Management	14	24	0.58	1779	24	2000
7	Plos One	14	20	1.17	491	20	2012
8	Ecological Indicators	13	19	1.08	637	19	2012
9	Agricultural and Forest Meteorology	12	22	0.71	1044	22	2007
10	Ecological Economics	12	13	0.80	703	13	2009

Abbreviations: NP = Number of scientific publications; TC = Total citation; PY = start year

3.4. Main research country addressing ecosystem services of agroforestry parkland

Given the relevance of agroforestry parkland, one hundred and six (106) countries have invested and influenced research in this field. According to Figure 3, the top ten countries include three Asian countries (China, India and Indonesia), three American countries (the United States, Brazil and Canada) and four European countries (the United Kingdom, Germany, France, and Spain). Of the 10 countries that have contributed heavily in the field, developing countries are represented by only four countries (China, India, Indonesia and Kenya). Considering the top 30 countries, seven (07) African countries led by Kenya (251 articles), Ethiopia (182 articles), Cameroon (139 articles), Ghana (128 articles), Burkina Faso (83 articles), South Africa (76 articles) and Nigeria (60 articles).

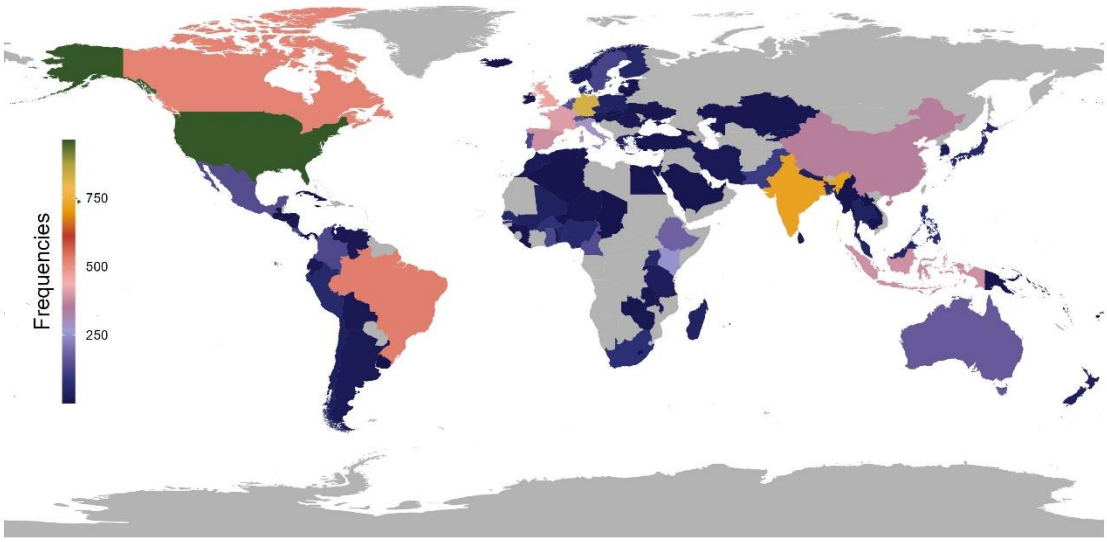

Figure 3: Global Distribution of Research Publications on Agroforestry Parkland Ecosystem Services. Warmer colors indicate higher publication counts, with the color gradient from blue (low frequency) to red (high frequency) representing the volume of contributions across different countries.

3.5. Countries collaboration network analysis

Overall, each country has a different degree of cooperation, and a total of four networks have emerged which are led by Germany (red cluster), the USA (blue cluster), France (green cluster) and the UK (yellow cluster). In the field of ecosystem service from agroforestry parkland, collaboration and exchange among researchers from the United States, Germany, France, and the United Kingdom deepened (Figure 4). Germany has more collaborations than any other country (Figure 3A). The global debate on the urgency of biodiversity conservation and ecosystem services has created an interest among scientists to collaborate around the year 2019. African countries have also developed their collaboration on the issue with the developed countries (Germany and France in the majority) (Figure 3B). The top 20 countries where authors collaborated inside the same country: single-country publications (SCP) and between countries: multiple-country publications (MCP) have been described in Figure 4. The number of total articles is the sum of SCP and MCP. The United States is far ahead of other countries in terms of single-country articles (Figure 4). However, Germany is far ahead of other countries in terms of multi-country articles, which reflects in part the increased attention of German researchers to these issues. Figure 5 illustrates the different clusters in studies related to ecosystem services provided by agroforestry parklands in each country.

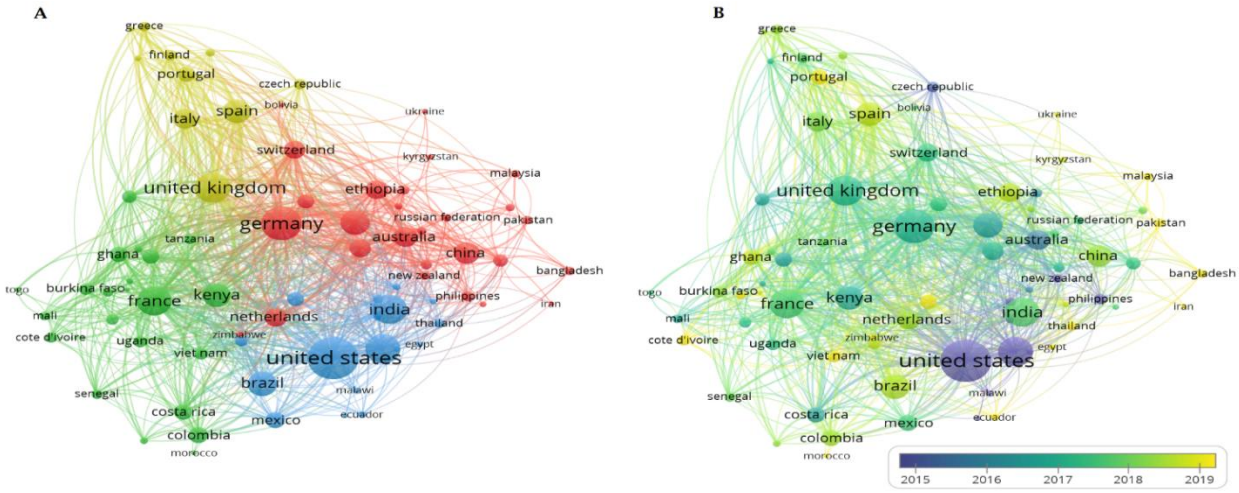

Figure 4: Map of collaboration between the most productive countries in the field of ecosystem services and agroforestry parkland. The size of the circle indicates the number of articles (A). The connection line between the countries indicates the status of collaboration between those countries and the thickness of the line represents the scale of cooperation and the trends of the cooperation (B).

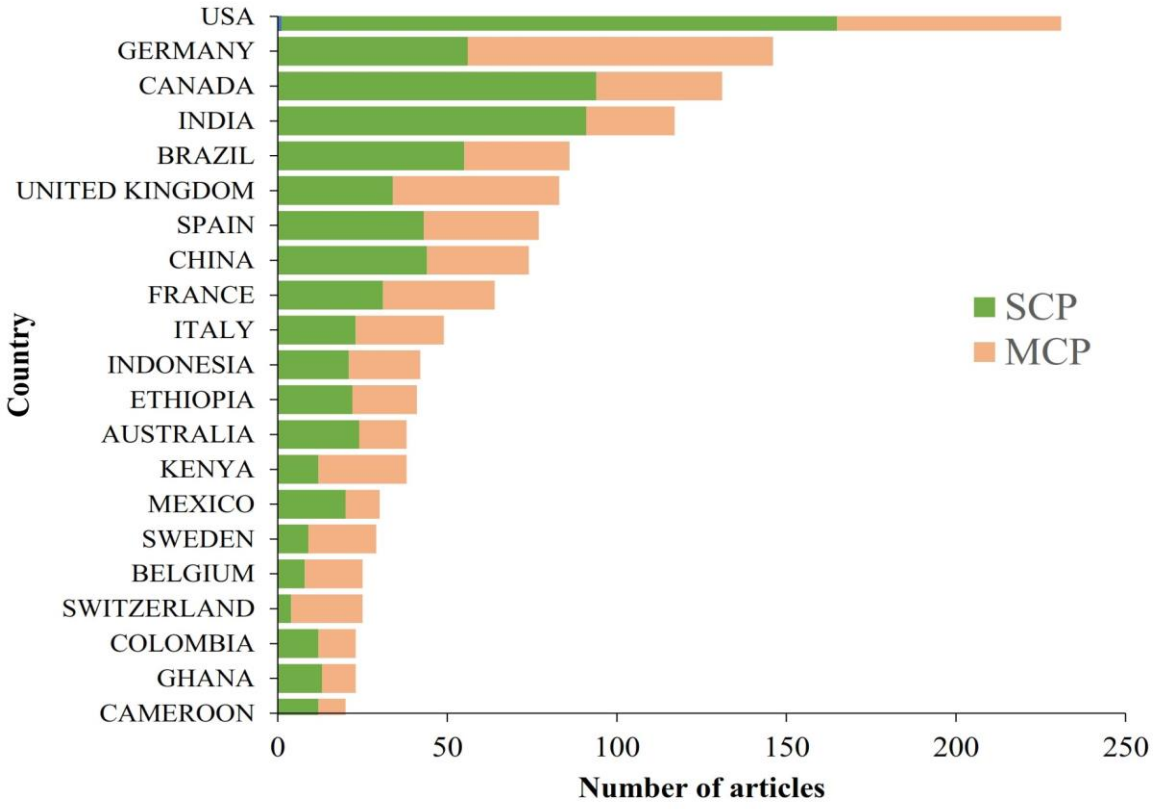

Figure 5: Top 20 countries of study's authors. SCP: Single Country Publications; MCP: Multiple Country Publications

3.6. Main authors' scientific production analysis

The subjects of papers that are highly cited often indicate research hotspots in a field (Liu et al., 2021). The number of times a paper is cited is often used to evaluate its academic quality (Usman & Ho, 2020). Only one of the 10 most highly cited papers was published in 1990–2002, while three were published in 2003–2009, and five were published in 2011–2019. Regarding the number of citations in the Scopus database, the highest TC (Klein et al., 2003) was 548. In addition, one paper (Klein et al., 2003) has been cited more than 500 times, making them high-impact papers in this research field. In this paper, Klein et al. (2002) showed that many non-pests and beneficial insect species can benefit from agricultural land use in contrast to the knowledge of biodiversity loss in intensively used agroforestry systems. Among the papers published in 2003 and 2009, the paper by Hoehn *et al.* (2010) was the most cited, 481 times. In this paper, Hoehn *et al.* (2010) investigated the contribution of primary tropical forests, cocoa-based agroforestry systems with various management practices, and open land to temporal and spatial variation in native bee community diversity in the herbaceous layer. They found that local bee density and diversity were highest in open lands, followed by agroforestry systems, and lowest in primary forests. In contrast, the greatest regional bee richness was observed in agroforestry systems, due to the high community dissimilarity. The paper by Bryan *et al*. (2013) leads the publications between 2011 and 2019 with 435 citations. *Bryan et al.* (2013) investigated farmers' perceptions of adaptive strategies. They have shown that farmers perceive climate change and adopt some adjustments to cope with climate change. However, whether they adopt agroforestry systems and/or irrigation, they do not have enough means to invest in more costly actions. This highlights the necessity for greater investment in rural and agricultural development to support the ability of households to make long-term policy decisions that affect their future livelihoods and the conservation of biodiversity. The most recent paper with the highest citation (338 times in less than 5 years) is (Lewis *et al.* (2019) (Table 3). These authors showed that tropical forests represent the empty spaces where planting and restoring forests will address climate change. Of all conservation practices, agroforestry occupies 21% and is widely used by subsistence farmers, but rarely on a large scale. This practice allows some plants to benefit from the increased nitrogen content of the soil. The trees themselves provide fuel, wood, fruit or nuts.

Table 3. Most cited articles

Rank	Title	Zone or Country	Total Citations	TC per Year	Normalized TC	Reference
1	Effects of land-use intensity in tropical agroforestry systems on coffee flower-visiting and trap-nesting bees and wasps	Indonesia	548	26.1	3.88	Klein et al. (2002)
2	Relative contribution of agroforestry, rainforest and open land to local and regional bee diversity	Indonesia	481	30.06	7.497	Hoehn et al. (2010)
3	Adapting agriculture to climate change in Kenya: Household strategies and determinants	Kenya	435	39.55	9.3	Bryan et al. (2013)
4	Climate change: Linking adaptation and mitigation through agroforestry	Kenya	399	23.47	3.71	Verchot et al. (2007)
5	Trade-offs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification	Germany	345	20.29	3.21	Steffan-Dewenter et al. (2007)
6	Restoring natural forests is the best way to remove atmospheric carbon	Indonesia	338	67.6	18.69	Lewis et al. (2019)
7	Evergreen Agriculture: A robust approach to sustainable food security in Africa	Kenya	331	23.64	5.79	Garrity et al. (2010)
8	Soil management in relation to sustainable agriculture and ecosystem services	United Kingdom	326	25.08	6.1	Powlson et al. (2011)
9	Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project	Panama	259	15.24	2.41	Kirby and Potvin, (2007)
10	Institutional dimensions of Payments for Ecosystem Services: An analysis of Mexico's carbon forestry program	United Kingdom	238	15.87	5.21	Corbera et al. (2009)

3.7. Analysis of the trends of the most influential author

The total number of sample authors was 6934, indicating that many scholars have participated in research on ecosystem services provided by agroforestry parkland underlings to climate change. In order to detect influential authors in the research area, the top 10 most cited authors are show in Table 2. It can be seen that Van Noordwijk M and collaborators rank first, with 1033 citations, The highly cited papers published by Van Noordwijk M. were published between 2002 and 2022 (Figure 6) Van Noordwijk M's main research was more concerned agroforestry system and ecosystem services under the landscape. For example, Van Noordwijk M's team analysed temporal patterns of land use change inside and outside four protected areas in 2013. The author with the most publications is Tscharntke T. from Germany, who published 16 papers with a high h index. Tscharntke T. is an agroecologist who works on interdisciplinary, socio-economic and ecological projects dealing with ecosystem services of biodiversity and agroecological landscape management. In 2022, Tscharntke T with his team reviewed the land-use history of focal agroforestry systems. Researchers such as Palma J.H.N. have published a small number of papers but have been extensively cited. Their works have great influence and are still widely cited (Figure 3). Palma J.H.N.'s article published in Agroforestry Systems in 2018 has been cited 93 times (Figure 6). Moreno et al. (2018) showed that agroforestry in Europe generally enhances biodiversity and regulating ecosystem services relative to conventional agriculture and forestry.

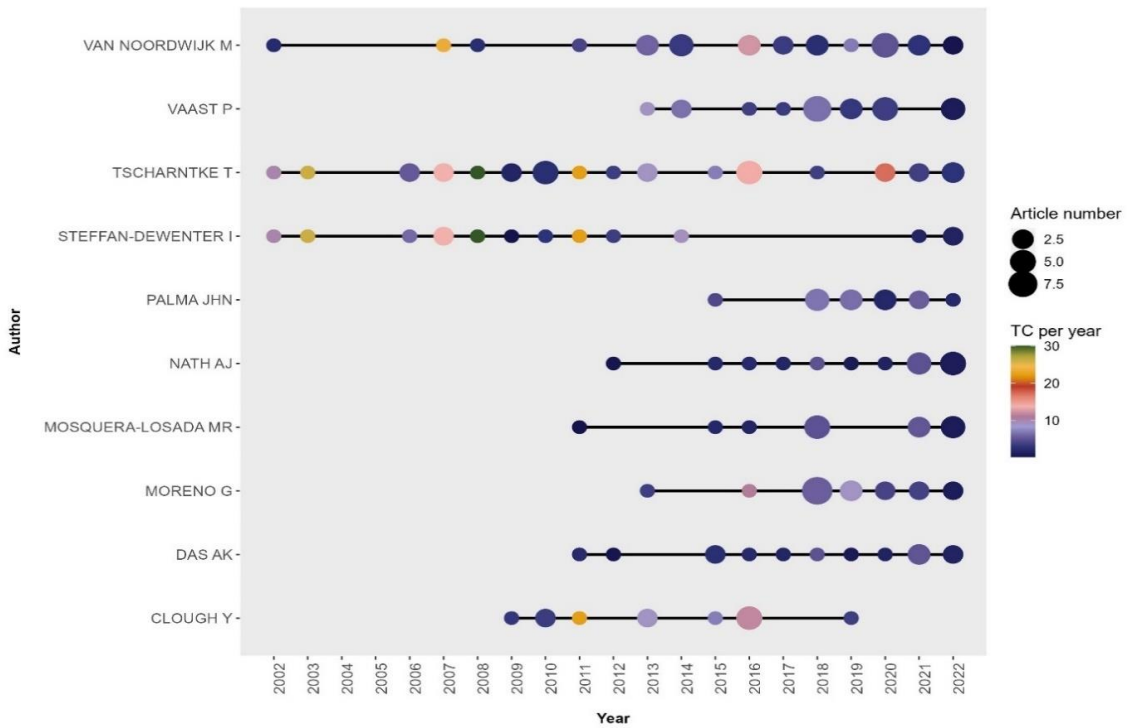

Figure 6: Authors' article over time. The shade of colour in the figure indicates the citation of the authors and the size of the circle indicates the amount of article published.

3.8. Analysis of key research topics and keywords on ecosystem services of agroforestry parkland

Authors' keyword analysis is a crucial tool for investigating the correlation between words and revealing their appearance relationships (Song et al. 2019; Abdallah et al. 2021). This study investigated the author's keyword frequency used to gain further insight into the trends in the ecosystem services provided by agroforestry parkland. The top 05 author keywords in the field are Agroforestry, climate change, ecosystem service, forestry and carbon sequestration.

3.9. Authors keywords trends over time

Words over time for a given subject show the changing rules, evolutionary relationships, paths, and trends of the content (Figure 8). Authors' keywords regarding studies related to ecosystem services from agroforestry parkland have noticeably increased over the years. Two main periods were identified. The first period was from 1992 to 2008, when the evolution trend was very low, and the second period was from 2009 to 2022, when the evolution trend was very fast. This showed that, during this second period, many studies were focused on ecosystem services provided by agroforestry parkland under climate change and its importance on biodiversity decrease.

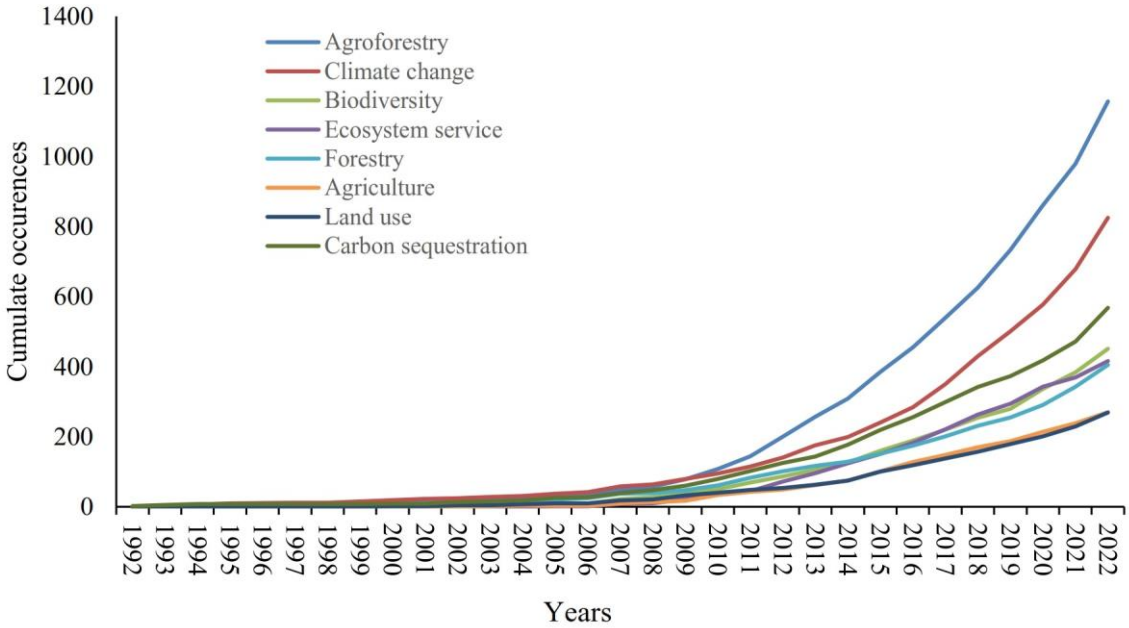

Figure 7: Change and evolution of keyword annual occurrence over time.

3.10. Analysis of key research topics

The multi-correspondence analysis of keywords confirms what was presented in the keyword co-occurrence. However, studies on ecosystem services provided by agroforestry parkland can be summarised into the following four major categories (depending on the clusters' colours). The first category (the red group) mainly highlights the relationship between agroforestry management the ecosystem services, particularly soil carbon stock, biomass production, biodiversity conservation, climate regulation and food security (Figure 9). The second category (the blue group) mainly focuses on the interaction between agroforestry (e.g., smart agriculture) to develop an adaptative or resilience strategy to mitigate climate change effects. The third group (cluster green) includes studies that have addressed intercropping, alley cropping, and silvopastoralism to develop actions to mitigate the effects of climate change and conserve ecosystem services sustainably (Figure 9). The last group (the purple group) mainly concerns studies on pollination services provided by the diversity of insects that agroforestry parks allow to conserve. This

service is very important for the gene flow between species populations, agroforestry systems constitute a means of biodiversity conservation and human well-being.

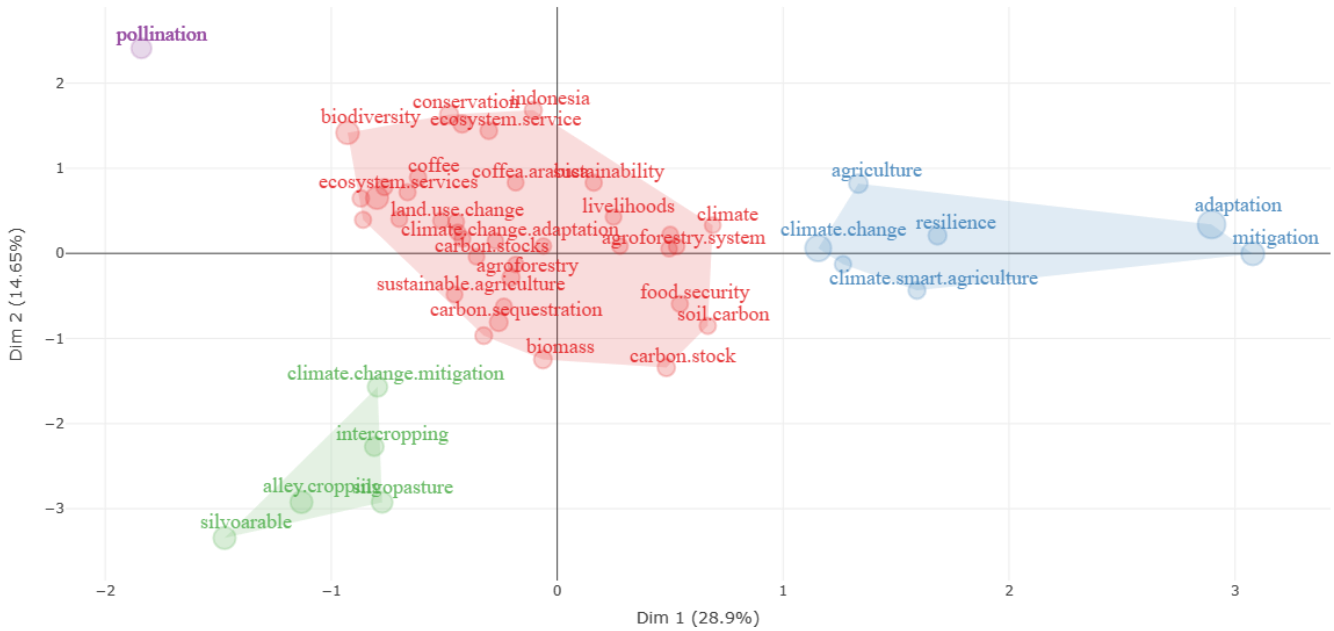

Figure 9: Word map using multiple-correspondence analysis of high-frequency authors keywords

4. Discussion

4.1 Overview of the studies on agroforestry systems

The findings of this bibliometric analysis provide valuable insights into the trends and research features on ecosystem services of agroforestry systems, particularly agroforestry parkland. The findings shed light on the countries that have been actively involved in this field of research, as well as the key research topics and keywords that have garnered significant attention. There is a global interest and recognition of the importance of agroforestry systems in providing ecosystem services. The international scope of agroforestry research is underscored by contributions from 106 countries, indicating widespread recognition of agroforestry systems' potential to promote sustainability. Notably, China, India, and Indonesia, alongside developed countries such as the United States, Brazil, Canada, the United Kingdom, Germany, France, and Spain, lead in research outputs. This diversity in geographical representation emphasizes that agroforestry's benefits transcend socio-economic contexts, making it relevant to both developing and developed nations (Mbow, van Noordwijk, et al., 2014). For instance, the engagement of countries like China and India underscores agroforestry's role in addressing issues such as land restoration and carbon sequestration, which are critical for regions with high population pressures and land degradation challenges (Jose, 2009). African countries also exhibit substantial engagement in agroforestry research. Kenya, Ethiopia, Cameroon, Ghana, Burkina Faso, South Africa, and Nigeria are notable contributors from the continent, reflecting agroforestry's essential role in supporting livelihoods, enhancing food security, and fostering climate resilience within Africa (Garrity, 2004; Garrity et al., 2010; Mbow, Smith, et al., 2014). Agroforestry's potential to address climate vulnerabilities and food insecurity, especially in Sub-Saharan Africa, is widely recognized, with studies highlighting its contributions to sustainable land management and rural development (Luedeling et al., 2016; Sileshi et al., 2008). The growth in publication volume and citation rates reflects a recognized value of agroforestry as a sustainable land-use strategy contributing to ecological health, socio-economic development, and climate resilience (Kombate et al., 2022). These findings underscore the global importance of agroforestry and highlight the potential for continued research focus,

particularly in regions most affected by climate change and biodiversity loss, where agroforestry's contributions can be most impactful (Jose, 2009; Leakey, 2012; Nair, 2012). Agroforests and other mixed tree covers can maintain or increase the degree of integration of forest into the multifunctional landscape for biodiversity maintenance and conservation while providing a source of income for local people (Dewi et al., 2013). The review found that forest agroforestry promotes greater biodiversity than open-land agroforestry, but that it essentially represents forest degradation, whereas open-land agroforestry rehabilitates formerly forested open land (Martin et al., 2020). Thus, they recommend that land-use history be incorporated into land-use policy to avoid encouraging forest degradation (Kombate et al., 2022) and to exploit the potential of agroforestry for ecosystem services and biodiversity (Martin et al., 2020). Cotton growers should adopt agroforestry practices to enhance their cropping systems while mitigating the negative impacts of cotton and Maize farming on biodiversity and ecosystem services (Atakpama et al., 2024; Ganiou et al., 2024).

Moreover, the analysis of author keywords sheds light on the focal points within the research on ecosystem services of agroforestry parkland. The most frequently used author keywords include "Agroforestry", "climate change", "ecosystem service," "forestry", and "carbon sequestration". Agroforestry systems offer a holistic approach to land management that integrates trees with crops or livestock, providing multiple ecosystem services simultaneously (Hübner et al., 2021; Mbow, Smith, et al., 2014). The inclusion of "climate change" as a prominent keyword reflects the increasing recognition of agroforestry parkland as a climate change mitigation and adaptation strategy (Banlipo et al., 2023; Bekele, 2018). The emphasis on "ecosystem services" and "forestry" keywords demonstrates the recognition of the broader benefits provided by agroforestry systems, including biodiversity conservation, soil carbon stock, biomass production, and climate regulation. These ecosystem services are vital for maintaining sustainable agricultural systems and enhancing resilience to environmental changes (Norgrove & Beck, 2016). Additionally, "carbon sequestration" emerged as a significant keyword, indicating the interest in quantifying the potential of agroforestry systems to sequester carbon dioxide from the atmosphere. Agroforestry is an effective nature-based solution for mitigating climate change by storing carbon in biomass and soils (Middendorp et al., 2018; Moreno et al., 2018). This aligns with the increasing global recognition of the importance of ecosystem services and their role in addressing environmental challenges. These keywords reflect the interdisciplinary nature of the research, with an emphasis on the role of agroforestry parkland in mitigating climate change impacts, providing various ecosystem services, and promoting sustainable resource management.

4.2. Agroforestry parklands: insight for climate change mitigation and biodiversity conservation

Overall, ecosystems and their associated species are disappearing at an alarming rate, they are essential to human well-being and the planet's balance (Amadu et al., 2020; Jose, 2009; Norgrove & Beck, 2016). This underlines the urgency of implementing effective conservation strategies, a subject that is attracting the attention of scientists and decision-makers worldwide. Among the emerging approaches, agroforestry is emerging as a key solution for sustaining biodiversity, particularly in tropical and temperate regions(Aryal et al., 2019; Fahad et al., 2022; Mbow, Smith, et al., 2014). Numerous studies have shown that agroforestry systems provide a habitat for species capable of tolerating disturbance, preserving the genetic heritage of vulnerable species, climate change mitigation and reducing the pressure on natural habitats by providing a more sustainable alternative to conventional agriculture, which is often destructive (Amadu et al., 2020; Hoehn et al., 2010; Sheppard et al., 2020; Steffan-Dewenter et al., 2007). Agroforestry also enhances connectivity between forest fragments by creating corridors that facilitate the movement of species and preserve local ecosystems. It also provides services such as erosion control and groundwater recharge, helping to preserve economic and natural resources for local communities (Abdul-Salam et al., 2022).

Major research topics within the field of ecosystem services provided by agroforestry parkland can be broadly categorized into four major themes. The first category, represented by the red group, highlighted the relationship between agroforestry management and various ecosystem services such as soil carbon stock, biomass production, biodiversity conservation, climate regulation,

and food security. We named it "Agroforestry management and ecosystem services". Numerous studies have explored the positive impacts of agroforestry parkland on these ecosystem services (Bayala et al., 2014; Beillouin et al., 2021; Garrity et al., 2010; Jose, 2009; Sinare & Gordon, 2015). By integrating trees into agricultural systems, agroforestry practices enhance soil fertility, increase carbon storage, promote biodiversity, regulate microclimates, and provide sustainable food production options (Abdulai et al., 2018; Fahad et al., 2022; Ramachandran Nair et al., 2009). The second category is "Agroforestry as a climate change adaptation strategy". Researchers in this field have explored how agroforestry systems, such as smart agriculture approaches, can contribute to adaptive and resilient strategies for mitigating the impacts of climate change (Lipper et al., 2014; Mensah et al., 2021). Agroforestry parkland can serve as a buffer against extreme weather events, mitigate soil erosion, and improve water management, thus enhancing the resilience of agricultural landscapes (Bayala et al., 2014). Furthermore, studies that investigated specific agroforestry practices such as intercropping, alley cropping, and sylvopastoralism can be encompassed as "Agroforestry system as Sustainable Practices for Climate Change Mitigation". These practices aim to mitigate the effects of climate change while simultaneously conserving ecosystem services sustainably (Scarano, 2017). Intercropping and alley cropping, for instance, promote efficient resource use, enhance soil fertility, and diversify farm outputs, leading to improved climate change resilience and ecological sustainability (Bayala et al., 2014). Finally, for "Pollination services and biodiversity conservation "agroforestry parkland focused on the critical role in supporting pollination services and biodiversity conservation. Agroforestry systems provide habitat and resources for a diversity of insects, including pollinators, which are vital for gene flow and the maintenance of species populations. Protecting pollinators through the conservation of agroforestry parkland contributes to both biodiversity conservation and human well-being (Miller et al., 2019).

4.3. Implications and challenges of agroforestry parklands

Agroforestry systems can indeed be complex and difficult to manage. These systems involve the integration of trees, crops, and livestock on the same piece of land, requiring careful planning, monitoring, and maintenance. The interaction between different components of the system can be intricate, and farmers need to have a deep understanding of various ecological and agricultural principles to successfully manage agroforestry systems (Kombate et al., 2022). This complexity can pose challenges, particularly for farmers who are unfamiliar with such integrated approaches. For example, Jose et al. (2004) highlight the complexity of agroforestry systems and the need for integrated management. They emphasize that a successful geosystem requires an understanding of tree crops interactions, nutrient cycling, water dynamics and pest control. Additionally, there is a lack of comprehensive knowledge about the long-term effects of agroforestry systems. While there is evidence supporting the benefits of agroforestry, such as improved soil fertility, biodiversity conservation, and climate change mitigation, the long-term impacts on ecosystem dynamics and agricultural productivity are still not fully understood (Tschora & Cherubini, 2020). According to Ramachandran Nair *et al.* (2009), the long-term effects of agroforestry may depend on factors such as tree selection, the resilience, stability and productivity of agroforestry systems over time. This knowledge gap makes it difficult for farmers to predict and optimize the outcomes of adopting agroforestry systems. It also hampers the dissemination of best practices and limits the scalability of these systems. Furthermore, a significant obstacle to the widespread adoption of agroforestry systems is the lack of sufficient financial incentives for farmers (Abdul-Salam et al., 2022). Traditional farming practices often prioritize short-term economic gains, while the benefits of agroforestry systems are usually realized in the long run. Farmers may hesitate to invest time, effort, and resources into establishing and managing agroforestry systems without clear financial incentives that offset the initial costs and compensate for the longer payback period. Without adequate support, such as subsidies, grants, or market mechanisms that recognize the environmental and social benefits of agroforestry, farmers are less likely to adopt these systems. To address these challenges, it is crucial to invest in research and knowledge dissemination related to agroforestry systems. Long-term studies can help uncover the ecological, economic, and social impacts of these systems, providing farmers with the necessary information

to make informed decisions. Governments and organizations should also introduce financial incentives, such as tax breaks, subsidies, or certification schemes, to encourage farmers to adopt agroforestry practices. Moreover, capacity-building programs and extension services should be developed to provide technical support and training for farmers to effectively manage agroforestry systems (Reed et al., 2013).

5. Conclusion

This bibliometric analysis has provided valuable insights into the trends and research features on ecosystem services of agroforestry parkland. The findings reveal the global distribution of research efforts, with countries from different regions actively contributing to the field. The identified research topics and clusters highlight the multifaceted nature of agroforestry parkland research, encompassing areas such as agroforestry management, climate change adaptation, sustainable practices for climate change mitigation, and biodiversity conservation. The results of this analysis have important implications for policymakers, researchers, and practitioners involved in agroforestry parkland management. The diversity of countries engaged in research signifies the global recognition of agroforestry as a viable and sustainable land management practice. It emphasizes the need for knowledge-sharing and collaboration among countries to promote the adoption of agroforestry systems worldwide.

Furthermore, the identified research topics provide guidance for future studies in the field. The focus on ecosystem services, climate change, and biodiversity underscores the interconnectedness of these topics within agroforestry parkland research. Future research should continue to explore the multifunctional benefits of agroforestry systems, develop innovative approaches for climate change adaptation and mitigation, and evaluate the role of agroforestry in biodiversity conservation.

This bibliometric analysis has shed light on the global research landscape of ecosystem services in agroforestry parkland. The findings contribute to the existing body of knowledge by highlighting key research countries, topics, and clusters. By synthesizing the current state of research, this analysis provides a foundation for further investigations and informs policy and practice in agroforestry parkland management. Despite the growth in research, certain gaps remain. For instance, while agroforestry's role in climate change mitigation and biodiversity conservation is widely studied, there is limited research on the socio-economic impacts of these systems at the community level. Further, studies on agroforestry parklands' resilience to extreme climate events, especially in vulnerable regions, are insufficient. Addressing these gaps would enhance our understanding of the role agroforestry plays in fostering resilient landscapes under increasing climate threats. Additionally, more studies are needed on the local adaptation of agroforestry practices to specific ecological and socio-economic conditions, especially in regions facing rapid land-use changes. Therefore, future research should focus on exploring the socio-economic benefits of agroforestry, particularly for marginalized communities that rely on these systems for their livelihoods. Furthermore, enhancing collaboration between countries and regions to share insights, tools, and strategies, especially for regions where agroforestry research is less developed.

Acknowledgment

The authors would like to express their profound gratitude to Serge ADOMOU and Jacques AYANA for their invaluable contribution to this document.

Authors' contributions

Contributor's role	Authors' names
Conceptualization	Yabi Chaffra Charles and Gouwakinnou Nounagnon Gérard
Data management	Yabi Chaffra Charles, Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier
Formal analysis	Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier
Survey and investigation	Yabi Chaffra Charles, Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier
Methodology	Yabi Chaffra Charles, Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier
Supervision Validation	Gouwakinnou Nounagnon Gérard
Writing - Preparation	Yabi Chaffra Charles, Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier
Writing - Revision	Yabi Chaffra Charles, Biaou Séverin and Ahouandjinou Enagnon Benoit Olivier and Gouwakinnou Nounagnon Gérard

Références

Abdulai, I., Vaast, P., Hoffmann, M. P., Asare, R., & ... (2018). Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun. *Global change Biology*, 24 (1), 273-286. https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.13885

Abdul-Salam, Y., Ovando, P., & Roberts, D. (2022). Understanding the economic barriers to the adoption of agroforestry: A Real Options analysis. *Journal of Environmental Management*, *302*, 113955. https://doi.org/10.1016/j.jenvman.2021.113955

Albrecht, A., & Kandji, S. T. (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems & Environment*, *99*(1), 15-27. https://doi.org/10.1016/S0167-8809(03)00138-5

Amadu, F. O., Miller, D. C., & McNamara, P. E. (2020). Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi. *Ecological Economics*. https://www.sciencedirect.com/science/article/pii/S0921800918316793

Aria, M., & Cuccurullo, C. (2017). bibliometrix : An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959-975. https://doi.org/10.1016/j.joi.2017.08.007

Aryal, K., Thapa, P. S., & Lamichhane, D. (2019). Revisiting agroforestry for building climate resilient communities: A case of package-based integrated agroforestry practices in Nepal. In *Emerg Sci J*. pdfs.semanticscholar.org. https://pdfs.semanticscholar.org/248a/2be72df140d4b5ce03654fe62ae2db9e723d.pdf

Atakpama, W., Kokou, K. B., Abdoumissamilou, I., Folega, F., Koffigan, A., Manuella, D. A. C. C., & Batawila, K. (2024). Améliorer les rendements de maïs (Zea mays L.) grâce à une approche agro-écologique au Togo. *Revue Ecosystèmes et Paysages*, *4*(1). https://doi.org/10.59384/recopays.tg4104

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377-386. https://doi.org/10.1162/qss_a_00019

Banlipo, D., Marra, D., Folega, F., Kombate, B., Egbelou, H., Robijaona, B., Batawila, K., & Akpagana, K. (2023). Typologie et structure des systèmes agroforestiers de la zone soudanienne du Togo. *Revue Ecosystèmes et Paysages*, *3*(2), 1-18. https://doi.org/10.59384/recopays.tg3220

Bayala, J., Sanou, J., Teklehaimanot, Z., Kalinganire, A., & Ouédraogo, S. (2014). Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. *Current Opinion in Environmental Sustainability*, *6*, 28-34. https://doi.org/10.1016/j.cosust.2013.10.004

Beillouin, D., Ben-Ari, T., Malézieux, E., Seufert, V., & Makowski, D. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global Change Biology*, *27*(19), 4697-4710. https://doi.org/10.1111/gcb.15747

Bekele, S. E. (2018). Parkland agroforestry of Ethiopia; key to production, productivity, biodiversity conservation and climate change mitigation: A review. *Open Journal of Forestry*, *8*(04), 472-488. https://doi.org/10.4236/ojf.2018.84030.

Bertoli-Barsotti, L., & Lando, T. (2017). The h-index as an almost-exact function of some basic statistics. *Scientometrics*, *113*(2), 1209-1228. https://doi.org/10.1007/s11192-017-2508-6

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of environmental management*, *114*, 26-35. https://doi.org/10.1016/j.jenvman.2012.10.036

Derviş, H. (2019). Bibliometric Analysis using Bibliometrix an R Package. *Journal of Scientometric Research*, *8*(3), 156-160. https://doi.org/10.5530/jscires.8.3.32

Dewi, S., van Noordwijk, M., Ekadinata, A., & Pfund, J.-L. (2013). Protected areas within multifunctional landscapes: Squeezing out intermediate land use intensities in the tropics? *Land Use Policy*, *30*(1), 38-56. https://doi.org/10.1016/j.landusepol.2012.02.006

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., Pradhan, A., Jinger, D., Rawale, G., Yadav, D. K., Kumar, V., Farooq, T. H., Ali, B., Sawant, A. V., Saud, S., Chen, S., & Poczai, P. (2022). Agroforestry Systems for Soil Health Improvement and Maintenance. *Sustainability*, *14*(22), Article 22. https://doi.org/10.3390/su142214877

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *The FASEB Journal*, *22*(2), 338-342. https://doi.org/10.1096/fj.07-9492LSF

Folega F, Kanda M, Fandjinou K, Bohnett E, Wala K, Batawila K, Akpagana K. (2023) Flora and Typology of Wetlands of Haho River Watershed, Togo. Sustainability. 2023; 15(3):2814. https://doi.org/10.3390/su15032814

Fousseni F, Bilouktime B, Mustapha T, Kamara M, Wouyo A, Aboudoumisamilou I, Oyetunde D, Kperkouma W, Komlan B, Koffi A. (2023) Land Use Change and the Structural Diversity of Affem Boussou Community Forest in the Tchamba 1 Commune (Tchamba Prefecture, Togo). Conservation. 2023; 3(3):346-362. https://doi.org/10.3390/conservation3030024

Ganiou, A., Hountondji, P., & Tovignan, D. (2024). Analyse des efficacités techniques des exploitations en Transition agroécologique en zone cotonnière au Nord du Bénin. *Revue Ecosystèmes et Paysages*, *3*, 1-15. https://doi.org/10.59384/recopays.tg3219

Garrity, D. P. (2004). Agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems*, *61*(1), 5-17. https://doi.org/10.1023/B:AGFO.0000028986.37502.7c

Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., Larwanou, M., & Bayala, J. (2010). Evergreen Agriculture: A robust approach to sustainable food security in Africa. *Food Security*, *2*(3), 197-214. https://doi.org/10.1007/s12571-010-0070-7

Githongo, M., Kiboi, M., Muriuki, A., Fliessbach, A., Musafiri, C., & Ngetich, F. K. (2023). Organic Carbon Content in Fractions of Soils Managed for Soil Fertility Improvement in Sub-Humid Agroecosystems of Kenya. *Sustainability*, *15*(1). https://doi.org/10.3390/su15010683

Guler, A. T., Waaijer, C. J. F., & Palmblad, M. (2016). Scientific workflows for bibliometrics. *Scientometrics*, *107*(2), 385-398. https://doi.org/10.1007/s11192-016-1885-6

Hoehn, P., Steffan-Dewenter, I., & Tscharntke, T. (2010). Relative contribution of agroforestry, rainforest and openland to local and regional bee diversity. *Biodiversity and Conservation*, *19*(8), 2189-2200. https://doi.org/10.1007/s10531-010-9831-z

Hübner, R., Kühnel, A., Lu, J., Dettmann, H., Wang, W., & Wiesmeier, M. (2021). Soil carbon sequestration by agroforestry systems in China: A meta-analysis. *Agriculture Ecosystems & Environment*, *315*, 107437. https://doi.org/10.1016/j.agee.2021.107437

IPCC. (2021). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, S. L. Pirani, C. Connors, S. Péan, N. C. Berger, Y. Chen, G. I. G. Goldfarb, M. Huang, K. Leitzell, E. Lonnoy, T. Km. Matthews, T. Waterfield, O. Yelekçi, R. Yu, & R. Zhou (Éds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds).

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits : An overview. *Agroforestry Systems*, *76*(1), 1-10. https://doi.org/10.1007/s10457-009-9229-7

Jose, S., Gillespie, A. R., & Pallardy, S. (2004). Interspecific interactions in temperate agroforestry. *Agroforestry Systems*, *61*, 237-255. https://doi.org/10.1023/B:AGFO.0000029002.85273.9b

Kirby, K. R., & Potvin, C. J. (2007). *Variation in Carbon Storage Among Tree Species: Implications for the Management of a Small-Scale Carbon Sink Project*. http://repository.si.edu/xmlui/handle/10088/11974

Klein, A.-M., Steffan-Dewenter, I., Buchori, D., & Tscharntke, T. (2002). Effects of land-use intensity in tropical agroforestry systems on coffee flower-visiting and trap-nesting bees and wasps. *Conservation Biology*, *16*(4), 1003-1014. Scopus. https://doi.org/10.1046/j.1523-1739.2002.00499.x

Klein, A.-M., Steffan–Dewenter, I., & Tscharntke, T. (2003). Fruit set of highland coffee increases with the diversity of pollinating bees. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *270*(1518), 955-961.

Kombate, B., Dourma, M., Fousseni, F., Atakpama, W., Wala, K., Komlan, B., & Koffi, A. (2022). Modélisation spatiale multifactorielle de la vulnérabilité des unités d'occupation du sol face au changement climatique dans la Région Centrale au Togo. *Revue Ecosystèmes et Paysages*, *2*, 34-52. https://doi.org/10.59384/recopays.tg2203

Leakey, R. R. B. (2012). Multifunctional Agriculture and Opportunities for Agroforestry: Implications of IAASTD. In P. K. R. Nair & D. Garrity (Éds.), *Agroforestry—The Future of Global Land Use* (p. 203-214). Springer Netherlands. https://doi.org/10.1007/978-94-007-4676-3_13

Lewis, S. L., Wheeler, C. E., Mitchard, E. T., & Koch, A. (2019). Restoring natural forests is the best way to remove atmospheric carbon. *Nature*, *568*(7750), 25-28. https://doi.org/10.1038/d41586-019-01026-8

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., … Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12). https://doi.org/10.1038/nclimate2437

Liu, T., Yang, L., Mao, H., Ma, F., Wang, Y., & Zhan, Y. (2021). Knowledge domain and emerging trends in podocyte injury research from 1994 to 2021: A bibliometric and visualized analysis. *Frontiers in pharmacology*, *12*, 772386. https://doi.org/10.3389/fphar.2021.772386

Luedeling, E., Smethurst, P. J., Baudron, F., Bayala, J., Huth, N. I., Noordwijk, M. van, Ong, C. K., Mulia, R., Lusiana, B., Muthuri, C., & Sinclair, F. (2016). *Field-scale modeling of tree–crop interactions: Challenges and development needs*. http://hdl.handle.net/10883/16824

Martin, D. A., Osen, K., Grass, I., Hölscher, D., & ... (2020). Land-use history determines ecosystem services and conservation value in tropical agroforestry. *Conservation …*. https://conbio.onlinelibrary.wiley.com/doi/abs/10.1111/conl.12740

Mbow, C., Smith, P., Skole, D., Duguma, L., & Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*, *6*, 8-14. https://doi.org/10.1016/j.cosust.2013.09.002

Mbow, C., van Noordwijk, M., Prabhu, R., & Simons, T. (2014). Knowledge gaps and research needs concerning agroforestry's contribution to Sustainable Development Goals in Africa. *Current Opinion in Environmental Sustainability*, *6*, 162-170. https://doi.org/10.1016/j.cosust.2013.11.030

Mensah, H., Ahadzie, D. K., Takyi, S. A., & Amponsah, O. (2021). Climate change resilience: Lessons from local climate-smart agricultural practices in Ghana. *Energy, Ecology and Environment*, *6*(3), 271-284. https://doi.org/10.1007/s40974-020-00181-3

Middendorp, R. S., Vanacker, V., & Lambin, E. F. (2018). Impacts of shaded agroforestry management on carbon sequestration, biodiversity and farmers income in cocoa production landscapes. *Landscape Ecology*, *33*(11), 1953-1974. https://doi.org/10.1007/s10980-018-0714-0

Miller, D. C., Ordoñez, P. J., Brown, S. E., Forrest, S., Nava, N. J., Hughes, K., & Baylis, K. (2019). The impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in low-and middle-income countries : An evidence and gap map. *Campbell Systematic Reviews*, *16*(1), e1066. https://doi.org/10.1002/cl2.1066

Moreno, G., Aviron, S., Berg, S., Crous-Duran, J., Franca, A., de Jalón, S. G., Hartel, T., Mirck, J., Pantera, A., Palma, J. H. N., Paulo, J. A., Re, G. A., Sanna, F., Thenail, C., Varga, A., Viaud, V., & Burgess, P. J. (2018). Agroforestry systems of high nature and cultural value in Europe: Provision of commercial goods and other ecosystem services. *Agroforestry Systems*, *92*(4), 877-891. https://doi.org/10.1007/s10457-017-0126-1

Nair, P. K. R. (2012). Climate Change Mitigation: A Low-Hanging Fruit of Agroforestry. In P. K. R. Nair & D. Garrity (Éds.), *Agroforestry—The Future of Global Land Use* (p. 31-67). Springer Netherlands. https://doi.org/10.1007/978-94-007-4676-3_7

Norgrove, L., & Beck, J. (2016). Biodiversity Function and Resilience in Tropical Agroforestry Systems Including Shifting Cultivation. *Current Forestry Reports*, *2*(1), 62-80. https://doi.org/10.1007/s40725-016-0032-1

Ntawuruhunga, D., Ngowi, E. E., Mangi, H. O., Salanga, R. J., & Shikuku, K. M. (2023). Climate-smart agroforestry systems and practices: A systematic review of what works, what doesn't work, and why. *Forest Policy and Economics*, *150*, 102937. https://doi.org/10.1016/j.forpol.2023.102937

Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W., Whitmore, A. P., Hirsch, P. R., & Goulding, K. W. T. (2011). Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy*, *36*, S72-S87. https://doi.org/10.1016/j.foodpol.2010.11.025

Pritchard, A. (1969). Statistical bibliography or bibliometrics. *Journal of documentation*, *25*(4), 348-349. https://cir.nii.ac.jp/crid/1570009750342049664

R Core Team. (2017). *R: A language and environment for statistical computing. R Foundation for Statistical Computing, URL* [Logiciel]. https://www.R-project.org

Rahman, S. A., Jacobsen, J. B., Healey, J. R., Roshetko, J. M., & Sunderland, T. (2017). Finding alternatives to swidden agriculture: Does agroforestry improve livelihood options and reduce pressure on existing forest? *Agroforestry Systems*, *91*(1), 185-199. https://doi.org/10.1007/s10457-016-9912-4

Ramachandran Nair, P. K., Mohan Kumar, B., & Nair, V. D. (2009). Agroforestry as a strategy for carbon sequestration. *Journal of Plant Nutrition and Soil Science*, *172*(1), 10-23. https://doi.org/10.1002/jpln.200800030

Reed, M. S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., Letson, D., Nainggolan, D., Prell, C., Rickenbach, M. G., Ritsema, C., Schwilch, G., Stringer, L. C., & Thomas, A. D. (2013). Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. *Ecological Economics: The Journal of the International Society for Ecological Economics*, *94*, 66-77. https://doi.org/10.1016/j.ecolecon.2013.07.007

Reith, E., Gosling, E., Knoke, T., & Paul, C. (2020). How Much Agroforestry Is Needed to Achieve Multifunctional Landscapes at the Forest Frontier? Coupling Expert Opinion with Robust Goal Programming. *Sustainability*, *12*(15). https://doi.org/10.3390/su12156077

Scarano, F. R. (2017). Ecosystem-based adaptation to climate change: Concept, scalability and a role for conservation science. *Perspectives in Ecology and Conservation*, *15*(2), 65-73. https://doi.org/10.1016/j.pecon.2017.05.003

Sheppard, J. P., Bohn Reckziegel, R., Borrass, L., Chirwa, P. W., Cuaranhua, C. J., Hassler, S. K., Hoffmeister, S., Kestel, F., Maier, R., Mälicke, M., Morhart, C., Ndlovu, N. P., Veste, M., Funk, R., Lang, F., Seifert, T., du Toit, B., & Kahle, H.-P. (2020). Agroforestry: An Appropriate and Sustainable Response to a Changing Climate in Southern Africa? *Sustainability*, *12*(17). https://doi.org/10.3390/su12176796

Sileshi, G., Akinnifesi, F., Ajayi, O. O., & Place, F. (2008). Sileshi, G., Akinnifesi F.K., Ajayi O.C., and Place F. (2008). Meta-analysis of maize yield response to planted legume fallows and green manures in sub-Saharan Africa. Plant and Soil 307:1-19. *Plant and Soil*, *307*, 1-19. https://doi.org/10.1007/s11104-008-9547-y

Sinare, H., & Gordon, L. J. (2015). Ecosystem services from woody vegetation on agricultural lands in Sudano-Sahelian West Africa. *Agriculture, Ecosystems & Environment*, *200*, 186-199. https://doi.org/10.1016/j.agee.2014.11.009

Sossa, C. L. G., Sanogo, S., Naab, J. B., & Sintondji, L. O. (2022). Trends and research features on greenhouse gas emissions from rice production: Review based on bibliometric analysis. *Environmental Science and Pollution Research*, *29*(49), 73828-73841. https://doi.org/10.1007/s11356-022-22921-0

Steffan-Dewenter, I., Kessler, M., Barkmann, J., Bos, M. M., Buchori, D., Erasmi, S., Faust, H., Gerold, G., Glenk, K., Gradstein, S. R., Guhardja, E., Harteveld, M., Hertel, D., Höhn, P., Kappas, M., Köhler, S., Leuschner, C., Maertens, M., Marggraf, R., Tscharntke, T. (2007). Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences*, *104*(12), 4973-4978. https://doi.org/10.1073/pnas.0608409104

Tschora, H., & Cherubini, F. (2020). Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. *Global Ecology and Conservation*, *22*. https://doi.org/10.1016/j.gecco.2020.e00919

Usman, M., & Ho, Y.-S. (2020). A bibliometric study of the Fenton oxidation for soil and water remediation. *Journal of Environmental Management*, *270*, 110886. https://doi.org/10.1016/j.jenvman.2020.110886

Verchot, L. V., Van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K. V., & Palm, C. (2007). Climate change: Linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change*, *12*(5), 901-918. https://doi.org/10.1007/s11027-007-9105-6