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Limitations of Sustainable Cocoa Agroforestry: A Literature Review

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Abstract: Agroforestry is a climate-smart strategy adopted in cocoa farms to help cocoa crops adapt to climate change, maintain biodiversity, and improve cocoa yield. Meanwhile, its sustainability is of major concern to farmers. This study brings to the fore the common and persistent factors that pose a threat to the sustainability of cocoa agroforestry, presented through a systematic literature review approach, and further discussed using the United Nations' Sustainable Development Goals (SDGs) model as the focal point. A number of serious limitations have been identified in the study as limiting the sustainability of cocoa agroforestry, including a lack of technical support for planting trees, an increase in pests and diseases, the intense competition for nutrients between shade trees and cocoa trees, weak land tenure policies, and numerous other factors. The eleven identified limitations were further categorized and analyzed under Environmental, Economic, and Social Limitations, and policy directions were drawn and discussed. Based on the findings of the study, Cocoa Agroforestry must not only support both cocoa production and forest conservation simultaneously but also satisfy all three Sustainable Development Goals. For Cocoa Agroforestry to become an agricultural practice that is sustainable, it must address the environmental limitations, economic limitations, and social limitations simultaneously.

Keywords: Cocoa; Agroforestry; Limitations; Sustainability; Shade-grown cocoa.

INTRODUCTION

Cocoa agroforestry is a natural way to mitigate global challenges such as climate change, biodiversity loss, land degradation, nutrient depletion, food and nutrient insecurity, and rural poverty (Kouassi et al. 2021). As cocoa agroforestry intensifies, it can reduce deforestation and forest degradation emissions (REDD+), increase productivity, and improve cocoa plants' microclimates to create a more productive environment (Alemagi et al. 2015). Cocoa agroforestry by way of shade-grown cocoa farming appears to be very beneficial due to its ability to regulate the amount of light on the crops and buffer temperature (Blaser-Hart et al. 2021). Moreover, shade-grown cocoa in its purview increases biodiversity conservation, income generation through timber harvesting, and reduces the scale of forest exploitation (Minang et al. 2014). Blaser-Hart et al., (2021) further emphasized that agroforestry is a climate-smart strategy adapted by agricultural stakeholders to mitigate climate change and improve agricultural production sustainability. Iterating sustainability is the key panacea to safeguarding successful cocoa agroforestry in the long term.

However, the sustainability of cocoa agroforestry in the various economies is difficult to establish. As meeting the demands of agricultural production and biodiversity conservation is parallel to climate change mitigation, and has proven to be a challenging task (Blaser et al. 2018). Furthermore, the implementation of crop production in the agroforestry system may not satisfy all the goals of agroforestry simultaneously. For instance, while shaded trees help in regulating direct sunlight on the crops and buffering temperature, they compete for soil nutrients as well as water, and this may not have a significant impact on crop yield in the short term. Researchers in diverse fields

have examined the complexities and limitations of cocoa agroforestry, and concerns have been raised over its success in comparison to monoculture cocoa production. (Blaser et al. 2018). There are also some dynamics to the implementation of the shade-grown cocoa farming systems that may pose a threat to the effectiveness and sustainability of cocoa agroforestry. For instance, the height and canopy size of the shaded trees might have an impact on cocoa agroforestry as well as the percentage of shade cover on the effectiveness of cocoa agroforestry (Blaser et al. 2018; Blaser-Hart et al. 2021). Other areas that have observed limitations in agroforestry including obstacles to tree planting (Alemagi et al. 2015), challenges with pests and diseases (Sonwa et al. 2005), and the impact of intercropping on soil nutrients (Isaac et al. 2007).

Over the past two decades, empirical research into the major limitations to sustainable cocoa agroforestry has been very few with a majority focusing only on one indicator of sustainable agroforestry at a time. Bringing all these limitations together to identify the major barriers to cocoa agroforestry, and finding a common solution that could tackle them at a goal is a necessary step towards achieving a sustainable cocoa agroforestry system. In this context, this literature review focuses on the major limitations of sustainable cocoa agroforestry. The study seeks to: 1) identify the existing publications on the challenges and limitations of sustainable cocoa agroforestry in the last two decades (2001 – 2022), 2) identify and discuss the major limitations of sustainable cocoa agroforestry, and 3) Outline future directions based on dominant findings

Consequently, these objectives will not only fill the literature gap but also provide reliable scores to rank the various institutions and countries that have contributed to the strengthening of the foundation of cocoa agroforestry in the previous years. With respect to the attention drawn to climate-smart cocoa production and forest conservation, this research provides a checklist of the major drawbacks of cocoa agroforestry that principal stakeholders and farmers must address to empower farmers to practice sustainable cocoa agroforestry. It will also entice further investigations into sustainable cocoa agroforestry so that more complex cocoa agroforestry problems can be addressed in the near future. Thus, the study brings to light important areas for further research.

Sustainability through the Eyes of Cocoa Agroforestry

Sustainability in a larger spectrum is seen as the stakeholder's capability to safeguard a particular process or system over a continuous duration. According to Barkemeyer et al. (2014), there is no generally accepted definition for sustainability except the one expatiated by the Brundtland Commission. The Brundtland Commission defined sustainability as "the integration of ecological principles into activities that minimizes the release of harmful substances onto the environment by human beings, preservation of the environment, improvement of human capital, and utilization of societal and economic models to solve problems that advance the production process and preserves natural resources for unborn generations" (Brenya et al. 2022; Khomah et al. 2021; and Klychova et al. 2019). This assertion supports the United Nations Sustainable development goals SDGs in pursuing the achievement of agriculture sustainability, fiscal certainty, and social protection (Harlem Brundtland 1987). Furthermore, scientists emphasize the incorporation and preservation of the environment as a component of sustainable agriculture, whereas politicians see this as sustainable agriculture intensification. (Janker et al. 2018). Hence, sustainable cocoa integration and conservation can therefore be measured through the triple bottom line of sustainable development proposed to include: Environment, Economy, and society (Parkin et al. 2003).

The study enunciated specific indicators for analyzing cocoa agroforestry, *inter alia,* which may include how it affects crop yield, farmers' income, soil nutrients and chemicals, pest control and diseases, adaptation to and mitigation of climate change, and biodiversity conservation (Blaser-Hart et al. 2021; Garnett et al. 2013; Lipper et al. 2014; Blaser et al. 2018; Niether et al. 2020). Various scholars postulated that the efficient and effective way to avoid the adverse impact of climate change is to practice sustainable agricultural practices matching with reliable strategies that empower environmental security (Derero et al. 2021; Djuideu et al. 2020). However, the practice of cocoa agroforestry is faced with some criticisms and challenges about its sustainability. For instance, cocoa agroforestry does not impart much of a difference in crop yield compared to the monoculture system in the short term. Others may include inadequate diseases and pest control, soil nutrient competition, and many others. In this regard, the growing concern about cocoa agroforestry's major limitations warrants an effective investigation.

METHODS

Retrieval and Analysis of Literature

An extensive review of existing literature on cocoa agroforestry limitations was undertaken using the Systematic Literature Review method. The Systematic Literature Review method analyzes present literature through article identification, selection, evaluation, and analysis as used by other studies (Akomea-Frimpong et al. 2021, Aarseth et al. 2017, Brenya et al. 2022; Velten et al. 2015). The steps used in retrieving and analyzing literature on the limitations of sustainable cocoa agroforestry are as follows:

Step 1: Article search in Scopus. Relevant articles related to this study were searched online on the Scopus database and downloaded to be used for data retrieval and analysis. The search style and keywords used in retrieving relevant articles were unconventional. Keywords were inputted in concepts and then merged to produce the keyword combination to search for the specific category of articles that would be relevant for the study: Concept 1: "limitations" OR "challenges" OR "barriers" OR

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Figure 1. Systematic Review Framework

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"hindrances" OR "problems", Concept 2: "sustainable" OR "sustainability" OR "effective" OR "successful", Concept 3: "cocoa", and Concept 4: "agroforestry" OR "shade-grown" and then the concepts were combined with the following key combinations: #1 AND #2 AND #3 AND #4 with the period limited to the last two decades (2001 to 2022). 38 articles were retrieved from Scopus at this stage.

Step 2: Inclusion and exclusion Analysis. The articles collected were further screened using the inclusion and exclusion procedure. An article is included if the article is related to peer-reviewed sustainable cocoa agroforestry, and challenges facing cocoa agroforestry intensification. In the same way, articles published in journals with a less rigorous review process, such as conference proceedings, personal notes, and short essays, are excluded from consideration. In addition, articles that mentioned cocoa agroforestry but did not review the limitations or barriers to its sustainability were excluded as well. Therefore, only articles that discussed the limitations of sustainable cocoa agroforestry were analyzed to fulfill the main objectives of this research. It is worth noting that, due to this robust strategy, the number of articles for this review was less than what we intended to use. The snowballing approach was used to find additional articles from other database sources such as Science Direct, Web of Science, and Research gates to boost the number of articles after the analysis of the inclusions and exclusions in step 2. 26 articles were finally accepted for analysis.

Step 3: Article acceptance and final analysis. The number of articles resulting from step 2 was analyzed using A combination of qualitative and quantitative methods. Coding and theming were used to identify key limitations of cocoa agroforestry, and the quantitative method was used to rank contributors to research on the limitations of sustainable cocoa agroforestry, as well as other statistical analyses.

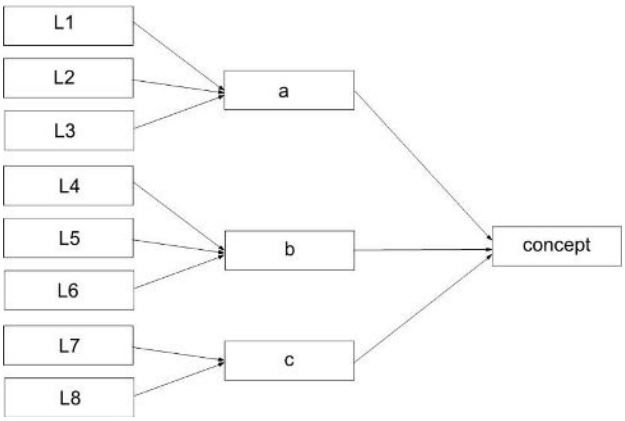

Figure 2. Selective Coding Method

Data and Collection Method:

The coding and theming method were used for identifying the list of limitations of cocoa agroforestry and categorizing them into the various aspects of the Sustainable development goals of the United Nations based on underlying factors. The coding method allows data to be defined and categorized from embedded themes revealed in the data (Williams and Moser 2019). Specifically, selective coding which allows the already grouped coded items to be further narrowed into concepts and theories (Williams and Moser, 2019) was adopted for the study. Figure 2 presents a pictorial example of selective coding drawn from the concept of Williams and Moser (2019).

The challenges or barriers limiting the sustainability of the cocoa agroforestry systems expressed by various authors from the relevant retrieved articles were captured and coded using the selective coding approach. A ranking of the identified limitations was also conducted to determine which is the most critical problem that policymakers need to address firsthand. A Wilcoxon test was carried out to test any significant differences in the limitations identified in the various research analyzed using Paleontological Statistical software (PAST)

Furthermore, the contributions of the authors were assessed based on the score matrix proposed by Howard et al. (1987), in Table 1 below. The matrix score is based on the allocated position given to authors' denoting the highest score for the first author position. The authors' affiliation addresses were used to ascertain the country representation of the authors. Countries that more authors represent among the articles under review obtained higher scores than the countries represented by lesser authors. Ten (10) countries and Institutions were shortlisted and ranked for this purpose.

Table 1. Authors' position calculation score

Number of authors	Order of Authorship				
	1	2	3	4	5
1	1.00				
2	0.60	0.40			
3	0.47	0.32	0.21		
4	0.42	0.28	0.18	0.12	
5	0.38	0.26	0.17	0.11	0.08

Reference: (Howard et al. (1987)

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RESULTS AND DISCUSSION

Research into the limitations to sustainable cocoa agroforestry has been fewer than expected. This may strongly be attributed to the complex nature of cocoa agroforestry and the fact that researchers tend to focus on one aspect of cocoa agroforestry at a time. While some researchers have focused their research on the conservation of biodiversity and adaptation to climate change, others have examined its impact on crop yield level, production dynamics, and crop quality. (Isaac et al. 2007; Tschora and Cherubini, 2020). Moreover, the cocoa agroforestry concept is relatively new and research into the concept is still in the exploratory phase. During this review, about 26 relevant articles were reviewed out of which 11 limitations were identified including the lack of technical support for tree planting, Limited credit facilities to support tree planting, too much shade-cover in agroforestry farms, the poor canopy architecture of shade trees in agroforestry farms, the inconsistent growth requirements of cocoa trees, the impact of intercropping in cocoa agroforestry, Pests and diseases, the unwillingness of farmers to adopt cocoa agroforestry practices, competition for soil nutrients, the low income-earnings of smallholder cocoa farmers, and weak land tenure policies. There was a significant difference between the number of specific limitations identified in the various studies that were examined ($W = 66$, $p = 0.000977$)

Research Contributions to the Study

Authors Contribution

As shown in Table 3, Ghana was ranked 1st on author contribution with a score of 4.59. with 13 authors from 8 different institutions, and contributing 9 articles to the topic under review which shows that Ghana is one of the countries with great concern about the sustainability of cocoa agroforestry. As a result, Switzerland was ranked 2nd with an impact score of 3.22, followed closely by Cameroon, ranked 3rd with an impact score of 2.44. More so, Germany was ranked 4th with an impact score of 2.28 contributing to 3 articles on the limitations of cocoa agroforestry. The United States of America was ranked 5th with a 2.04 score, and Kenya was ranked 6th with a 1.09 score contributing to 4 articles on the limitations of sustainable cocoa agroforestry. The United Kingdom had 2 authors coming from 2 institutions with an impact score of 1.47, and Australia was ranked 8th recording 1.03 in the matrix score. Brazil was the only South American country that contributed to the research on the limitations of sustainable cocoa agroforestry and ranked as the 10th country with a score of 1.00. Cote D'Ivoire has ranked 9th ahead of Brazil even though they both recorded 1.00 because Cote D'Ivoire recorded 4 institutions and 4 authors' contributing to research into the limitations of cocoa agroforestry.

Table 3. Countries Ranking based on authors' contributions

Ranks	Country	Institutions	Authors	Papers	Scores
1	Ghana	8	13	9	4.59
2	Switzerland	5	6	7	3.22
3	Cameroon	5	8	4	2.44
4	Germany	4	10	3	2.28
5	USA	4	4	2	2.04
6	Kenya	3	4	4	1.90
7	UK	2	2	2	1.47
8	Australia	2	2	2	1.03
9	Ivory Coast	4	4	1	1.00
10	Brazil	2	2	1	1.00

Contribution by Major Research Centers

Table 4 presents the major research center's involvement in the research into the limitations of sustainable cocoa agroforestry challenges. Among the top-ranked institutions were the Swiss Federal Institute of Technology in Switzerland with a score of 1.77, followed by Ghana's Council for Scientific and Industrial Research, Germany's Georg-August University, Ghana's Kwame Nkrumah University of Science and Technology, and Ghana's Cocoa Research Institute, all of which had impact scores of 1.47, 1.21, 1.20, and 1.18 respectively. These four research centers have been very instrumental in the identification of the key limitations of sustainable cocoa agroforestry collectively contributing up to 12 articles to this literature review. The CABI Bioscience in the UK, Ghent University in Belgium, Kenya Forestry Research Institute, the Norwegian University of Science and Technology, and the University of Buea in Cameroon, all recorded impact scores of 1.00 and were ranked 6th, 7th, 8th, 9th, and 10th respectively in alphabetical order. There was a noticeable dominance of African and European research centers in the top 10. The research centers from America and Asia recorded fewer impact scores.

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Table 4. Ranking of the major research centers based on authors' contributions

Rank	Institution	Country	Research	Scores
1	Swiss Federal Institute of Technology	Switzerland	4	1.77
2	CSIR - Council for Scientific and Industrial Research	Ghana	4	1.47
3	Georg-August University	Germany	2	1.21
4	Kwame Nkrumah University of Science and Technology	Ghana	4	1.20
5	Cocoa Research Institute	Ghana	2	1.18
6	CABI Bioscience	UK	2	1.00
7	Ghent University	Belgium	1	1.00
8	Kenya Forestry Research Institute	Kenya	1	1.00
9	Norwegian University of Science and Technology	Norway	1	1.00
10	University of Buea	Cameroon	1	1.00

Research Methodologies:

Furthermore, the research methodologies used in the articles under review were also reviewed (Figure 3). This was done to measure the trend of methods used for analyzing the challenges involved in sustainable cocoa agroforestry. The results indicate a variety of methods adopted by various authors depending on the technicalities involved in their research. The survey method was mostly used, followed closely is the experimental design approach. Case studies ranked third, followed by quantitative modeling, review methods, and interviews. It could be deduced that due to the nature of cocoa agroforestry system, researching into this area will involve a lot of scientific experiments, observations, and testing, explaining why the survey, experimental design, and the case study were recorded as the most used research methods

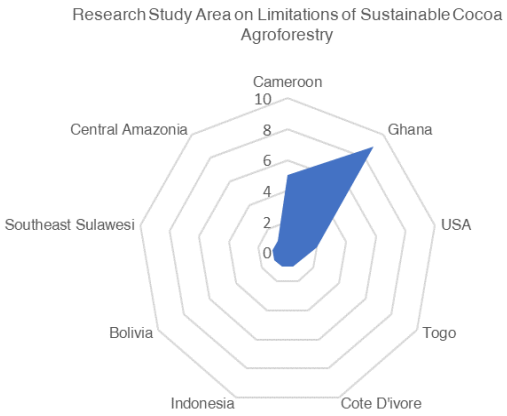

Figure 3. Research Methodologies used for studies on Limitations of Sustainable Cocoa Agroforestry

Study Areas:

As denoted in Figure 4, the research study areas identified in the articles used for the study were also reviewed. This fills in the literature gap with concern to research locations that boost the interest in sustainable cocoa agroforestry, and provide options to researchers for further studies. Among the relevant articles under review, Ghana had the most studies on the limitations of cocoa agroforestry with nine, followed by Cameroon with five studies. The United States of America recorded three studies. Togo, Cote D'Ivoire, South East Sulawesi, Central Amazonia, Bolivia, and Indonesia all recorded 1 study each in their locations. The rest of the articles were reviews which had no locations. It could be said that Africa is the continent of attraction when it comes to research into the limitations of sustainable cocoa agroforestry. Furthermore, the western and central Africa has one of the finest tropical climates which is suitable for the practice of cocoa agroforestry. Ghana happens to be one of the biggest exporters of cocoa in the world so there are enough cocoa farms for conducting research.

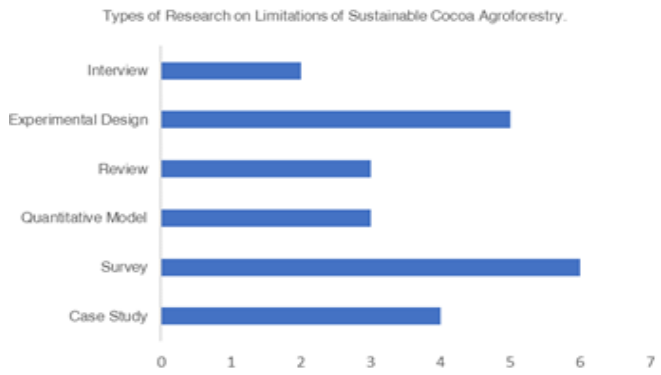

Figure 4. Research Study Area on Limitations to Sustainable Cocoa Agroforestry

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Publications per Year:

The trend accompanying the year of publication among the articles under review was also analyzed (Figure 6). The year 2020 and 2021 saw the majority of the papers being published recording 3 articles each out of the 26 relevant articles under review. This confirms the growing concern on the sustainability of cocoa agroforestry in recent years. It also explains the low record of articles retrieved for the study even though the timeline was 20 years. In fact, the issue of sustainable cocoa agroforestry and its limitations had not gained much attention until the year 2020.

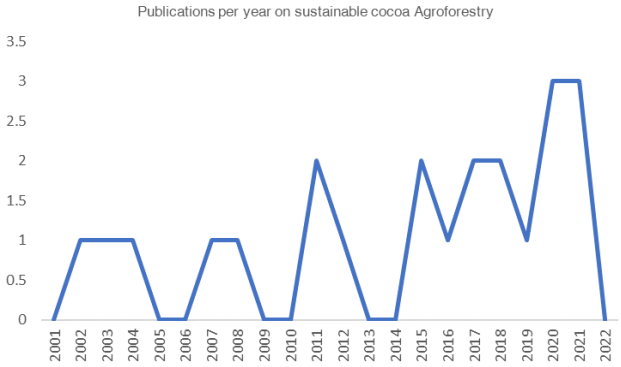

Figure 5. Publications per year on sustainable cocoa Agroforestry

Key Limitations of Sustainable Cocoa Agroforestry Identified:

The Lack of Technical Support as an obstacle to Tree Planting

Tree planting is an important component of cocoa agroforestry systems (Asante et al. 2021a; Blaser-Hart et al. 2021). However, one major obstacle facing local farmers is the lack of technical support to help them plant and maintain trees on their cocoa farms (Alemagi et al. 2015; Makee 2016; Oduro et al. 2018). With cocoa agroforestry gaining acceptance around the world, one of the strategies for making it sustainable is to do away with the hurdles that may hinder the practice of tree planting in small-scale cocoa farms. Technical information on tree planting: among them are the application of inputs to plants, soil conservation, and seed proliferation (Fonjong 2004) need to be provided to farmers to enhance their capacity to plant and manage trees on their cocoa farms. According to Derero et al. (2021), a farmer-led approach is needed to increase tree cover on farms and landscapes, since seedling survival and growth varies between tree species. To increase tree cover, farmers should understand plant species as well as planting niche preferences, as well as provide and manage seedlings properly. Moreira et al. (2012) also state that plants in the same ecosystem differ in nutritional uptake and nutritional requirements. A strategic specie combination is therefore necessary for the sustainable management of cocoa agro-forest land spaces. Farmers need to be equipped with the technical knowledge and tree planting techniques in order to intensify the efficiency of tree planting to achieve sustainable cocoa agroforestry.

Limited Access to credit facilities to support Tree Planting

The limited availability of credit facilities and incentives is one of the primary challenges affecting the use of inputs on farms and the planting of trees (Alemagi et al. 2015; Makee 2016). The use of inputs in farms is necessary to boost the performance of planted trees. As part of the challenges recorded by (Alemagi et al. (2015) In farms, limited credit facilities were the biggest hurdle in utilizing inputs and tree planting. According to Oduro et al. (2018), financial barriers to tree stock development on farms are often cited by farmers as being one of the major obstacles, and providing incentives to farmers such as grants and inputs is an effective way to encourage them to plant trees on their farms (Oduro et al. 2018).

Too much shade cover in Cocoa Agroforestry Farms

As much as growing shade trees in cocoa farms are purposed for climate change adaptation and mitigation, there is a school of thought that has reservations about the expediency of increasing shade trees on the overall performance of the cocoa agroforestry system. Too many shade trees may be a limiting factor to the success and sustainability of cocoa agroforestry (Andres et al. 2018, Bisseleua et al. 2009; Blaser et al. 2017, 2018; Clough et al. 2011). Blaser et al. (2018) further asserted that cocoa farms with shade cover of over 50 percent may suffer from intense competition for light, water, and nutrients, resulting in a decline in cocoa yield, while also contributing little to mitigating climate change. Blaser et al. (2017), also pointed out that, increasing shade tree cover in cocoa agroforestry does not have a significant positive impact on cocoa production, soil fertility, and carbon sequestration. Consequently, up to a 30% level of shade cover in cocoa agroforestry is considered ideal with a positive impact on both cocoa yield and climate change adaptation (Blaser et al. 2017, 2018).

Poor Canopy architecture of shade trees

The architecture of the shade trees plays a critical role in the effectiveness of cocoa agroforestry systems. According to Blaser-Hart et al. (2021), it is estimated that shade trees with elevated crowns hold more carbon and produce more crops than shade trees with low crowns. On the shape of the crown of shade trees, “spreading to cylindrical”, and elongated crown shapes are most suitable to be incorporated into cocoa agroforestry systems (Asante et al. 2021). Shade trees with low crowns tend to have minimal effect on carbon storage and have the capacity to largely reduce incoming light which can result in low cocoa crop yield (Blaser-Hart et al. 2021). Therefore, cocoa agroforestry systems with their shade tree architecture falling under this category may pose a limiting factor to its sustainability.

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The Inconsistent growth requirements of Cocoa Trees

the dynamics in the stages of growth of a cocoa tree can be a limitation in cocoa agroforestry, given that the condition created by matured shade trees in a particular region may last for a long time. A long-term crop such as cocoa experiences a dynamic growth process where the crop's needs change as it matures. (Blaser-Hart et al. 2021, Tscharntke et al. 2011; Wood et al. 2015). Cocoa agroforestry may require fewer shade trees at the mature stage than during the initial stages, for instance, because seedlings and young trees require more shade than mature trees. This may be a big challenge as felling shade trees can be destructive to the crops on the farm.

The impact of Inter Cropping in Cocoa Agroforestry:

An important purpose of intercropping in agroforestry is to enhance complementary interactions between crops, trees, and fauna (Jose et al. 2004). However, its impact on cocoa crop yield and production dynamics may discourage cocoa farmers and limit sustainable cocoa agroforestry. According to Isaac et al. (2007), intercropping may limit cocoa biomass production as compared to cocoa monoculture. It may also suppress the K uptake of cocoa foliage, and delay decomposition rates. Also, Plant species for intercropping, if not accurately selected may cause interspecific competition and minimize its environmental benefits (Jose et al. 2004). Thus, this is a concern since it will negatively affect cocoa yields and limit sustainability.

Pests and Diseases

Pests and diseases are identified as one of the major problems confronting cocoa crop yield and sustainability of cocoa agroforestry (Djuideu et al. 2020; Makee 2016; Oduro et al. 2018; Sonwa et al. n.d., and Tschora and Cherubini, 2020). According to (Sonwa et al. (2005), the spread of the diseases may be attributed to the presence of the host trees. For instance, some tree species that are linked to cocoa production are hosts to the phytophthora fungus which is known to cause black pod disease (Djuideu et al. 2020; Holmes et al. 2003; Opoku et al. 2002; Sonwa et al. n.d.).

The Unwillingness of farmers to adopt Cocoa Agroforestry

One major indicator of cocoa agroforestry adoption is the perception and willingness to adopt cocoa agroforestry as their farming system (Kouassi et al. 2021b; and Wartenberg et al. 2018). According to Wartenberg et al. (2018), farmers' perceptions of the benefits of shade trees in cocoa farms such as soil fertility, cocoa yield, and income of farmers, were profound and leaned more towards a high percentage of adoption rate. However, a few farmers were reluctant to adopt cocoa agroforestry for a number of reasons including the excessive number of trees present on their farms, lack of space to accommodate shade trees, reduced cocoa production, lack of knowledge about trees, damage from loggers, and the shade trees being a source of the black pod disease, among others. Therefore, the above-mentioned factors impede small-scale cocoa farmers' adoption of cocoa agroforestry.

Competition for Soil Nutrients

The tendency of shade trees to compete with cocoa crop trees for soil nutrients is eminent and of great concern. Moreira et al. (2012), in their study, has proven that a strategic selection of plant species combination for agroforestry is necessary to maintain efficient utilization of soil nutrient due to different nutrient requirement from different species. Cocoa crops have fine roots which means they mainly utilize the above-ground soil nutrients so any shade tree species or tropical plants that have fine roots will compete with the cocoa crops for soil nutrients, and deep-rooted trees would not compete with the cocoa trees (Niether et al. 2019). The downside to cocoa agroforestry is that agroforestry trees compete with main crops (Alemagi et al. 2015, Blaser et al. 2017; Niether et al. 2019; Tschora and Cherubini, 2020), and this has been linked strongly to the decline of cocoa yield over time. According to Niether et al. (2019), the entanglement of cocoa crop roots and the roots of the cover crops created intense competition for soil nutrients which affected the cocoa crop yield.

The Low-Income earnings of Smallholder farmers

Among smallholder cocoa agroforestry families in Ghana, only 15% are able to gain enough income to reach the living income level stipulated by the World Bank (Boeckx et al. 2020). Cocoa agroforestry is a system that requires additional labor and capital investment in order to improve cocoa yield (Scudder et al. 2022). Furthermore, smallholder farmers who have low incomes find it difficult to adopt the agroforestry system. According to Scudder et al. (2022), According to the findings of the study, cocoa agroforestry had a negative net present value for farmers in Papua New Guinea, and their mean hourly income was lower than the minimum wage. Likewise, relevant issues such as excessive input costs, management, and labor cost, and inadequate financial support equally hinder the adoption of the cocoa agroforestry system (Alemagi et al. 2015; Boeckx et al. 2020; Oduro et al. 2018; Scudder et al. 2022).

Weak Land Tenure Policies

When it comes to investing in trees, land tenure is a big factor, and to make cocoa agroforestry and tree planting sustainable, cocoa farmers need both formal land tenure and informal rights to on-farm trees (Boeckx et al. 2020; Makee 2016). However, smallholder cocoa farmers continue to face challenges in land tenure. According to Alemagi et al. (2015), the absence of land title is listed as

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one of the hurdles to tree planting on cocoa farms which is linked to land tenure. For farmers to confidently adopt tree planting on their farms, they need to be assured of the security of both the land and the trees. It was, therefore, suggested in their research that strong policies to favor smallholder cocoa farmers be implemented to influence farmers to adopt the cocoa agroforestry system.

Table 2. Key Limitations of sustainable cocoa agroforestry

Code	Limitations	References
L1	The lack of technical support for tree planting	Alemagi et al. (2015), Derero et al. (2021), Fonjong (2004), Makee (2016); Moreira et al. (2012); Oduro et al. (2018)
L2	Limited access to credit facilities to support tree planting	Alemagi et al. (2015) Blaser et al. (2017), Blaser et al. (2018), Makee (2016), Oduro et al. (2018)
L3	Too much shade covers in cocoa agroforestry farms	Andres et al., (2018), Blaser et al. (2017), Blaser et al. (2018), Clough et al. (2011)
L4	Poor canopy architecture of shade trees	Asante et al. (2021) Blaser-Hart et al. (2021)
L5	The inconsistent growth requirements of cocoa trees	Blaser-Hart et al. (2021), Tscharntke et al. (2011), Wood et al. (2015)
L6	The impact of intercropping on cocoa agroforestry	Isaac et al. (2007), Jose et al. (2004)
L7	Pests and Diseases	Djuideu et al. (2020), Holmes et al. (2003), Oduro et al. (2018), Opoku et al. (2002), Sonwa et al. (2005), Tschora and Cherubini, 2020)
L8	The unwillingness of farmers to adopt cocoa agroforestry	Kouassi et al. (2021b), Wartenberg et al. (2018)
L9	competition for soil nutrients	Alemagi et al. (2015), Blaser et al. (2017), Makee, (2016), Moreira et al. (2012), Tschora and Cherubini, (2020), Niether et al. (2019)
L10	Low-income earnings of smallholder farmers	Alemagi et al. (2015), Boeckx et al. (2020), Oduro et al. (2018), Scudder et al. (2022)
L11	Weak land tenure policies	Alemagi et al. (2015), Boeckx et al. (2020), Makee (2016)

"L" represents "Limitation"

Percentage distribution of the Limitation:

The percentage contributions of the limitations identified in the study were analyzed. The purpose of this was to identify the most prevalent factors hampering the progress and sustainability of cocoa agroforestry that may need more attention for immediate and greater focus in terms of addressing them. From figure 6, the lack of technical support to tree planting, pests and diseases, and competition for soil nutrients obtained the highest percentage with all three recording 14% each, followed by limited access to credit facilities to support tree planting with 11%. Too much shade cover in cocoa agroforestry farms, and the low-income earnings of smallholder farmers came next with 9% each, and then the inconsistent growth requirements of cocoa trees, and weak land tenure policies recording 7% each. Poor canopy architecture of shade trees, the unwillingness of farmers to adopt cocoa agroforestry, and the impact of intercropping on cocoa agroforestry were the least prevalent limitations found in the articles under review recording 5% each. It could therefore be said that while attempting to address all these identified limitations of cocoa agroforestry, policymakers may consider addressing the factors pertaining to the lack of technical support to tree planting, pests and diseases, competition for soil nutrients, the limited access to credit facilities to support tree planting, too much shade cover in cocoa agroforestry, and the low-income earnings of smallholder farmers, as pressing concerns.

Conceptual Framework:

The limitations of sustainable cocoa agroforestry have been conceptualized in three phases based on the UN's Sustainable Development goals which are found in the Brundtland's Commissions Report on sustainability (Harlem Brundtland 1987).

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These are the Economic, social, and Environmental Limitations. The SDG report provides a platform for identifying limitations of sustainable cocoa agroforestry that cross over into climate change adaptation. biodiversity conservation, cocoa yield and profit interests, and the propagation of afforestation. (Brenya et al. 2022; Tschora and Cherubini 2020; Minang et al. 2014)

Environmental Limitations:

These limitations are the factors that hinder the progress of the environmental goals of cocoa agroforestry. They are the outcomes of cocoa agroforestry practices that affect the

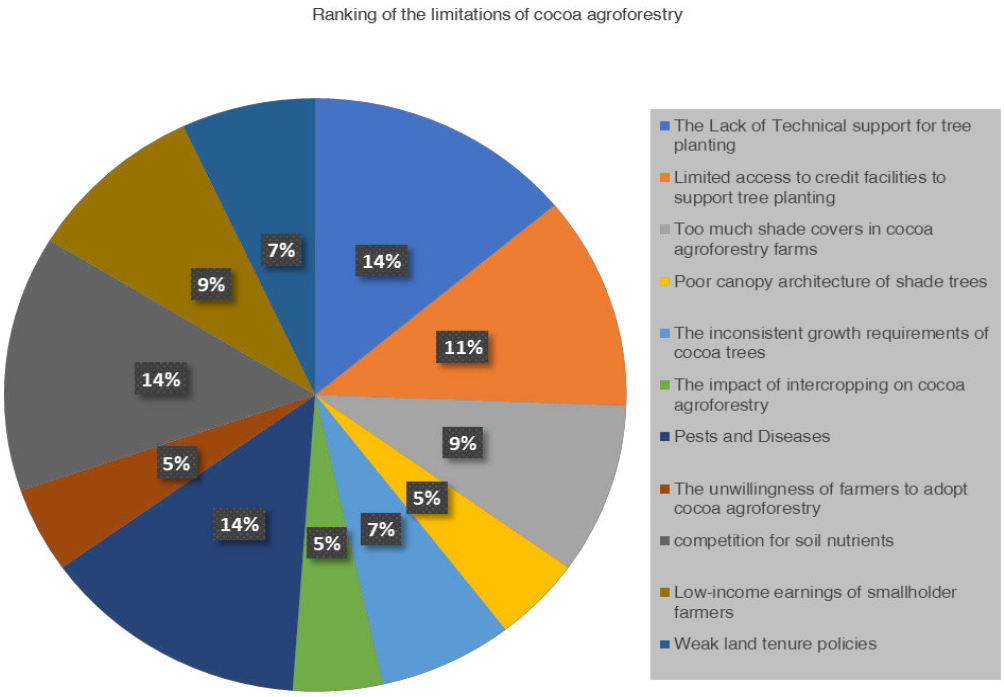

Figure 6. Percentage distribution of the limitations of Cocoa Agroforestry

climate change mitigation and adaptation of cocoa crops, the general health of the cocoa crops, and the biodiversity conservation aspect of the cocoa agroforestry system. Also, these limitations frustrate the full utilization of the benefits that the climate and the ecosystem provide to the cocoa crops: such as sunlight, and soil nutrients (Blaser et al. 2018) affecting the cocoa crop yield. The limitations embedding this theme were identified as: Too much shade covers in cocoa agroforestry farms, the poor canopy architecture of shade trees, the inconsistent growth requirements of cocoa trees, the impact of intercropping on cocoa agroforestry, Pests and diseases, and the competition for soil nutrients, all represented in figure 7.

Economic Limitations:

Two aspects of the economic limitation construct are involved: factors that impede the planting and incorporating shade-trees into cocoa farms, and the effect of cocoa agroforestry on cocoa farmers' incomes. Generally, farmers who want to include shade trees in their cocoa farms are faced with the challenge of limited technical knowledge on how to manage and sustain the planted trees, and the necessary funding to fuel the purchase of seedlings and inputs that would aid the course. Receiving technical support and financial assistance in this direction remains a challenge at the moment (Alemagi et al. 2015). Secondly, farmers might find it economically inviable to invest in cocoa agroforestry since it doesn't have a significant positive impact on their revenue (Scudder et al. 2022). The lack of technical support for tree planting, the limited access to credit facilities to support tree planting, and the low-income earnings of smallholder farmers are the limitations that fall under this theme.

Social Limitations:

The social limitations in this context are the social factors that tend to inhibit the general acceptance and interest of cocoa farmers to adopt agroforestry practices on their farms. They are geared toward security concerns

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of farmers in terms of shade tree ownership, the dangers from loggers, and inadequate space to accommodate shade trees (Wartenberg et al. 2018). In addition, there have not been enough governmental policies and laws to encourage land and tree ownership of farmers, so as to boost the interest in tree planting in small-scale cocoa farms. Hence, the need for governments to facilitate processes of obtaining land titles and certificates. (Alemagi et al. 2015). Two limitations form this theme which are: the unwillingness of farmers to adopt cocoa, and the weak land tenure policies which is a discouragement for cocoa agroforestry adoption.

In order to reach a level of sustainability in cocoa agroforestry, solutions that can tackle the environmental limitations, economic limitations, and social limitations are needed. Policies and strategies must therefore fulfill all three without neglecting any of these limitation categories.

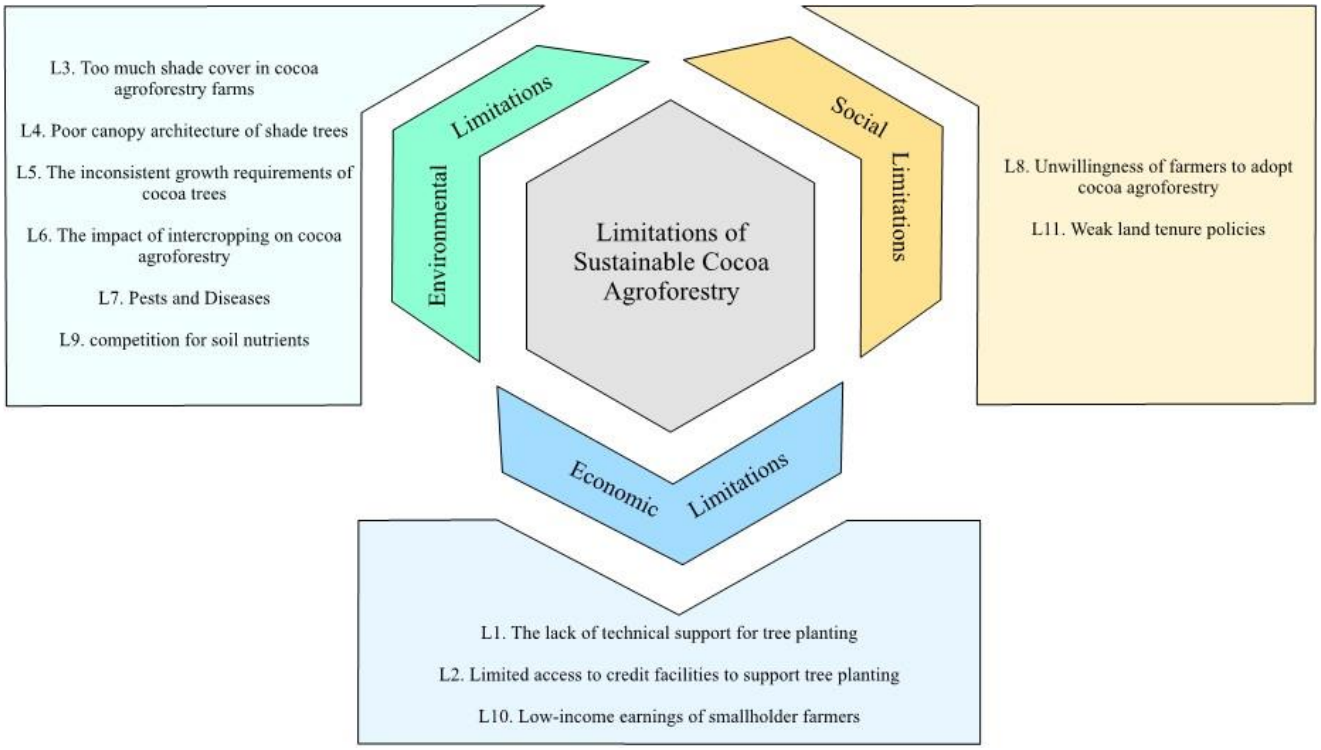

Figure 7. Conceptual Framework

CONCLUSION

This study presented the various limitations of sustainable cocoa agroforestry based on previous studies on the problems associated with cocoa agroforestry production. The key limitation factors include lack of technical support for tree planting, limited access to credit facilities, too much tree cover, poor canopy architecture of the shade trees, the increase of pests and diseases, the inconsistent growth requirements of cocoa trees, farmers' unwillingness to adopt agroforestry practices, the impact of intercropping on cocoa agroforestry, competition on soil nutrients, the low income of small-scale farmers, and weak land tenure policies. Among the major contribution of this study is filling the literature gap, and identifying the key factors that limit the progress and sustainability of cocoa agroforestry. Also, the results from this study further expand the global trend in cocoa agroforestry, paving way for designing effective measures that could address the challenges facing cocoa agroforestry worldwide. Bringing all these limitations together and contextualizing them is a step in the right direction toward clearing the ambiguity that exists in the challenges of cocoa agroforestry. The findings of this study provide a good basis for exploring agroforestry challenges further. The study identified 6 main limitations that were prevalent in the relevant articles under review that government authorities and policymakers can pay much attention to and tackle immediately. These limitations are the lack of technical support for tree planting, pests and diseases, competition for soil nutrients, limited access to credit facilities, too much shade cover in cocoa agroforestry farms, and the low-income earnings of smallholder farmers. In view of this, governments, agencies, and stakeholders must intensify training on the technicalities involved in the planting and management of trees. Additionally, credit facilities such as loans and grants, and free seedlings should be made easily available to farmers in order to motivate them to intensify tree planting in their cocoa farms. Farmers need to be

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educated on the types of shade-tree species to incorporate into their cocoa farms as well as the level of shade-tree cover on farms that would minimize the attraction of pests and diseases, and limit competition for sunlight and soil nutrients. In order for the social limitation aspect of the sustainable cocoa agroforestry framework to be represented among the pressing limitation concerns, it is imperative to highlight on the need for the policymakers to facilitate easy access to land ownership rights and certification in order to boost the confidence of farmers to invest in tree planting in their farms devoid of the fear of losing their land or their trees to loggers in future. Meanwhile, for cocoa agroforestry to be intensified and made sustainable, the limitations represented in all three arms of the sustainable cocoa agroforestry framework must be addressed.

Limitations and Recommendations for Future Studies

These research gaps and recommendations may be relevant for future studies, policy implications, and practice.

First, this review found that the number of studies that have been conducted in the area of challenges to sustainable cocoa agroforestry is very few (26 related articles in total). Therefore, further studies may be needed to reveal new and more global factors that stand to hinder the sustainability of cocoa agroforestry in the world in the near future. It is recommended that researchers conduct more scientific agricultural research in the area of cocoa agroforestry to dig out more hidden limitation factors that threaten the sustainability of cocoa agroforestry, as well as test existing data to strengthen existing results

Second, most of the studies included in this review were geographically biased toward the western world. The majority of the studies were conducted on African soil, with Ghana and Cameroon being the most researched cocoa agroforest lands. This depicts that sustainable cocoa agroforestry has not gained much attention in the European, American, and Asian regions. It is recommended that more researchers turn to these geographical regions to assess the effectiveness of cocoa agroforestry as well as the limitations to its sustainability in order to attain a more diversified and vast representation of results.

Thirdly, this study revealed a lack of comparative assessments of sustainable cocoa agroforestry. By comparing the limitations of sustainable cocoa agroforestry, better solutions and implementation strategies can be devised to improve sustainability. Therefore, comparative studies among different cocoa agroforestry farms and methods with emphasis on different climatic conditions, soil types, types of shade trees etc. are highly recommended. In addition, this review has been able to categorize the limitations of sustainable cocoa agroforestry into three areas using the UN's SDG model to enable policymakers and governmental agencies to view the limitations through the lens of sustainability for effective analysis and policy-making. Research on the identification of factors that could address these limitations is a viable recommendation for further studies.

Conflict of Interest

The authors declared there were no conflicts of interest.

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