Review

Not peer-reviewed version

Challenges and Opportunities in Sustainable Production Systems in the Brazilian Amazon

Matheus de Miranda Ribeiro Borges *, Liliane Marques de Sousa, Giovana Ghisleni Ribas

Posted Date: 31 October 2024

doi: 10.20944/preprints202410.2474.v1

Keywords: agroforestry systems; forest management; pasture management; sustainable agriculture

Review

Challenges and Opportunities in Sustainable Production Systems in the Brazilian Amazon

Matheus de Miranda Ribeiro Borges *, Liliane Marques de Sousa and Giovana Ghisleni Ribas

Department of Plant Production, University of São Paulo – ESALQ/USP, Padua Dias Avenue, 11 – Piracicaba/SP – CEP 13418-900, SP, Brazil; liliane.marques@usp.br (L.M.S); gribas@usp.br (G.G.R)
* Correspondence: matheusborges@usp.br; Tel: +55 (91) 98177-5198

Abstract: The insertion of the Amazon into the global commodities market requires ensuring the rational use of resources to meet market and political-social demands, such as the UN 2030 Agenda. Therefore, responsible production practices, given the current demand for sustainable use of land and its resources, are essential. Thus, the objective of this study was to identify opportunities and challenges linked to the implementation and consolidation of sustainable production systems in the Amazon through a systematic literature review. To this end, articles were prospected in four databases (Science Direct, SpringerLink, Scopus and Wiley) covering the period from 2004 to 2024. A total of 5,385 articles were evaluated, and after the selection stages, only 39 were included. A low distribution of studies among states in the Brazilian Amazon was observed, with a peak in studies starting in 2015. The studies developed mostly addressed agroforestry systems and forest management. Although there are sustainable production systems and practices, research and public policies need to be promoted to help the different actors involved in agricultural production in the Amazon, generating income and quality of life

Keywords: agroforestry systems; forest management; pasture management; sustainable agriculture

---

1. Introduction

At a global level, tropical ecosystems contain a large part of the planet's biological diversity, which is responsible for the supply of raw materials and ecosystem services. These services benefit not only local communities, but society as a whole [1–3]. The Amazon rainforest represents approximately 40% of the remaining tropical forests, contributing to the dynamic balance of climate and water, in addition to offering a socioeconomic alternative to local communities and meeting society's demand for its products [4–8].

However, many tropical ecosystems, such as the Amazon, have faced intensive and large-scale use of their natural resources. This has resulted in regional geoeconomic change, from an essentially extractive economy to one based on agriculture and livestock farming and, in some sub-regions, agribusiness, inserting the Amazon into the global context of commodities as a territory of expansion of globalized agriculture [1,9,10].

Therefore, ensuring the rational use of natural resources, increasing productivity in a sustainable manner and meeting the interests of today's society must be a constant concern for the different actors involved in agricultural production. It is necessary to align production models with the Sustainable Development Goals, such as goal 12 – Responsible Consumption and Production, of the UN 2030 agenda, aiming to ensure sustainable consumption and production patterns in the different production chains[1,11].

Climate change, population growth and the ongoing search for improved quality of life are putting pressure on the use of natural resources, especially with regard to agricultural production. Ensuring a balance between production and consumption to guarantee livelihoods is a challenge, especially in the Amazon, as the economic use of natural resources changes the productive and market structure [1,9,11–14].

In these production systems, many farmers face difficulties with infrastructure and logistics for the flow of production, acquisition of inputs, specialized labor, technical assistance, credit financing, production certification, among others. These factors compose the search for alternatives that enable the continuity of sustainable production [2,11].

In this context, the need for responsible production systems and practices in the Amazon is evident, given the current demand for processes and production methods that optimize the use of natural resources. In addition, there are greater restrictions on the market for products resulting from production processes that deteriorate the environment [12].

1.1. Historical context of agricultural production in the Brazilian Amazon

Historically, the dynamics of occupation and integration of the Brazilian Amazon, considered one of the most important tropical biomes on the planet and one of the last agricultural frontiers in the world, has been permeated by development plans, large projects, tax incentives (subsidies and agricultural credits) led largely by the federal government, where the particular ecosystems of the Amazon are taken over by the logic of development, which often goes against the logic of nature [13–15].

When it comes to agricultural activities in Amazonian soils, conventional practices have not proven promising, mainly due to low soil productivity, resulting in low profitability of crops such as sugar cane and tobacco, brought by the Portuguese when they occupied the forests, in an attempt to make the region an extension of the colonial economy based on agricultural production [15]. As a result, the extraction of the so-called "drogas do sertão" such as cocoa, cloves, guarana, annatto, poaia and vanilla in the second half of the 17th century was consolidated as the dominant practice of collection extraction [15].

However, extractive production in the Amazon has gone through ups and downs, first due to the cocoa crisis during the colonial period. In the 19th century, the region experienced the so-called "golden rubber boom," which was characterized as the peak of the extractive economy in the region. This agricultural ideal was also significantly encouraged by government policies. However, in 1920, with the crisis in the rubber plantation economy and the end of the rubber boom, investment began in agricultural development strategies to consolidate the region's economic and social development [15].

In 1966, with the Operação Amazônia and the National Integration Program in 1970, led by the military government, tax incentives were increased for large companies (national and international) for the construction of infrastructure (BR-230-Transamazonica, ports, airports, hydroelectric projects) to facilitate the flow of agricultural products and inputs necessary for production, aiming at the implementation and consolidation of large-scale agricultural activities as the basis for regional development. In addition, they caused the region to be occupied by activities such as logging and mining [1,16].

At the same time, global agriculture was undergoing transformations in the way it was produced, as it was experiencing the Green Revolution, and this fact contributed to Brazil emerging as one of the largest producers and exporters of agricultural products, generating pressure for the expansion of agricultural frontiers in the country, reaching the Amazon [1,16]. Despite the economic gains, there were serious consequences for society and the environment caused by inadequate agricultural practices [1].

Prior to the introduction of large agricultural enterprises such as soybeans, agriculture was based on slash and burn, also driven by logging and beef cattle farming, the latter being considered one of the main direct causes of deforestation [17].

In this context, agriculture and the dynamics of occupation of the Amazon region are closely related and constitute a constant paradox. Modern agriculture, seeking sustainability in fact and in law, must be based on productive systems capable of reproducing sustainable ecosystems (water resources, soil, forest resources, fauna), and not on a logic based on aggressive forms of exploitation, reducing natural elements to a condition of mere resources for production and dispute over their possession and use. When well managed, these elements benefit the various actors involved [18].

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

Therefore, solving or alleviating a problem originating from the land (deforestation, fires, conflicts) and linked to an activity that depends on the soil (agriculture and livestock farming) with a land-based solution (less aggressive production through more sustainable practices and production systems) is extremely necessary for the sustainability of modern agriculture, especially in complex biomes such as the Amazon[13].

For all these reasons, the objective of the present study was to evaluate the current state of sustainable production systems practiced in the Amazon, and thus identify the challenges and opportunities for implementing and consolidating these systems, through a systematic review of the literature.

2. Materials and Methods

2.1. Protocolo Para Obtenção de Artigos

Prior to the systematic literature review, a review protocol was developed. For this, the systematic review applied the recommendations and checklist of The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The articles were selected using the bibliographic databases: Science Direct, Springer Link, Scopus and Wiley. The period covered was from 2004 to 2024.

After obtaining the articles, duplicate results were excluded. For the selection process, the articles obtained with each combination of words in the search using Boolean operators were evaluated for the adequacy of the information contained in the title and abstract to the scope of the review. The articles were then analyzed for their content, and those that answered one or more research questions were selected.

The evaluation process was carried out independently by two authors and, in case of disagreement between the authors, the article was evaluated again until consensus was reached. The Parsifal platform was used to assist in the selection of articles.

2.2. Research Questions

In order to guide the selection of articles, the following research questions were developed:

1. What are the main sustainable production models applied in the Amazon?
Precepts: Identification and description of the most commonly used sustainable production models in the Amazon region; analysis of the principles, practices and key characteristics of each sustainable production model.
2. What are the main difficulties encountered in applying these models?
Precepts: Identification and analysis of the main barriers and challenges faced in the implementation of sustainable production models in the Amazon, such as legal issues, lack of financial incentives, cultural resistance, access to resources and inadequate infrastructure. Assessment of the impacts of government policies, regulations and external pressures on the development and adoption of sustainable production models.
3. What are the opportunities observed in the Amazon region for consolidating the use of these production systems?
Precepts: Identification and analysis of emerging opportunities to promote and consolidate the use of sustainable production systems in the Amazon region, such as incentive programs, specific financing, public-private partnerships and development of sustainable value chains. Assessment of the role of local communities, non-governmental organizations, research institutions and companies in the promotion and implementation of sustainable agricultural practices.

2.3. Search Protocol

Science Direct (Limit 8 Boolean operators at a time): Amazon OR "Amazon Rainforest" OR “Brazilian Amazon” AND Sustainable OR "Sustainable production systems " OR " Sustainable Agriculture " OR “Sustainable intensification” AND Agroforestry OR Agroecological OR "Organic" OR "Direct Planting" OR “Forest Management” OR “Silvipastoral” OR “Fish Farming” OR

 doi:10.20944/preprints202410.2474.v1

"Pisciculture" OR "Intercropping" OR "Integrated Crop-Livestock" OR "Integrated Crop-Forestry" OR "Integrated Crop-Livestock-Forestry" OR "Integrated Livestock-Forestry" OR "Degraded Pastures" "Integrated Fruit Systems").

SpringerLink: (Amazon OR "Amazon Rainforest" OR "Brazilian Amazon") AND (Sustainable OR "Sustainable production systems " OR " Sustainable Agriculture " OR "Sustainable intensification") AND (Agroforestry OR Agroecological OR "Organic" OR "Direct Planting" OR "Forest Management" OR "Silvipastoral" OR "Fish Farming" OR "Pisciculture" OR "Intercropping" OR "Integrated Crop-Livestock" OR "Integrated Crop-Forestry" OR "Integrated Crop-Livestock-Forestry" OR "Integrated Livestock-Forestry" OR "Degraded Pastures" Integrated Fruit Systems").

Scopus: (Amazon OR "Amazon Rainforest" OR "Brazilian Amazon") AND (Sustainable OR "Sustainable production systems " OR " Sustainable Agriculture " OR "Sustainable intensification") AND (Agroforestry OR Agroecological OR "Organic" OR "Direct Planting" OR "Forest Management" OR "Silvipastoral" OR "Fish Farming" OR "Pisciculture" OR "Intercropping" OR "Integrated Crop-Livestock" OR "Integrated Crop-Forestry" OR "Integrated Crop-Livestock-Forestry" OR "Integrated Livestock-Forestry" OR "Degraded Pastures" Integrated Fruit Systems").'

Wiley: Amazon OR "Amazon Rainforest" OR "Brazilian Amazon" AND Sustainable OR "Sustainable production systems " OR " Sustainable Agriculture " OR "Sustainable intensification" AND Agroforestry OR Agroecological OR "Organic" OR "Direct Planting" OR "Forest Management" OR "Silvipastoral" OR "Fish Farming" OR "Pisciculture" OR "Intercropping" OR "Integrated Crop-Livestock" OR "Integrated Crop-Forestry" OR "Integrated Crop-Livestock-Forestry" OR "Integrated Livestock-Forestry" OR "Degraded Pastures" Integrated Fruit Systems")

2.4. Article Selection and Exclusion Criteria

Documents considered as gray literature, such as books, book chapters and conference abstracts, were not included in the review. Considering the geographical delimitation of the area under study (Brazilian Amazon), only articles written in English and Portuguese were considered for inclusion of publications in international and national journals, respectively. Duplicate articles were excluded. After reading the title and abstract, articles that did not address the scope of the review were excluded.

During the full reading, fifty articles were excluded for the following reasons: 1) They addressed the topic, but did not mention in the abstract that the research was conducted outside the Amazon or in another country with the same biome. Thus, they were excluded when the location was identified in the full reading; 2) They addressed the roles of actors in sustainable production in the Amazon, but not specifically the production systems.

Articles that were appropriate to the scope of the work but did not answer at least one of the research questions were eliminated from the review.

2.5. Research Limitations

This review did not consider books, book chapters and event abstracts, which may omit important information not covered in more depth in journals.

The diversity of terms used to nomenclature the different types of sustainable production systems could not be applied in the research. For example, the production system that integrates Crop-Livestock-Forestry has terms such as "agrosilvopastoral system", "intercropping", "ICLF System", which were summarized in "Integrated Crop-Livestock-Forestry", which may have omitted important articles.

The period defined for the review was 20 years (2004 to 2024), due to the increase in the volume of publications on the topic from this period observed in the initial analyses, thus, relevant articles published in years prior to 2004 were not covered in the review, which may have omitted important information.

3. Results

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

3.1. Quantitative Analysis

Of the 5385 articles identified in the four research databases, 93 met the inclusion criteria and were considered eligible for full reading. Of these, only 39 studies were selected for inclusion in this review, as they answered at least one of the research questions (Figure 1).

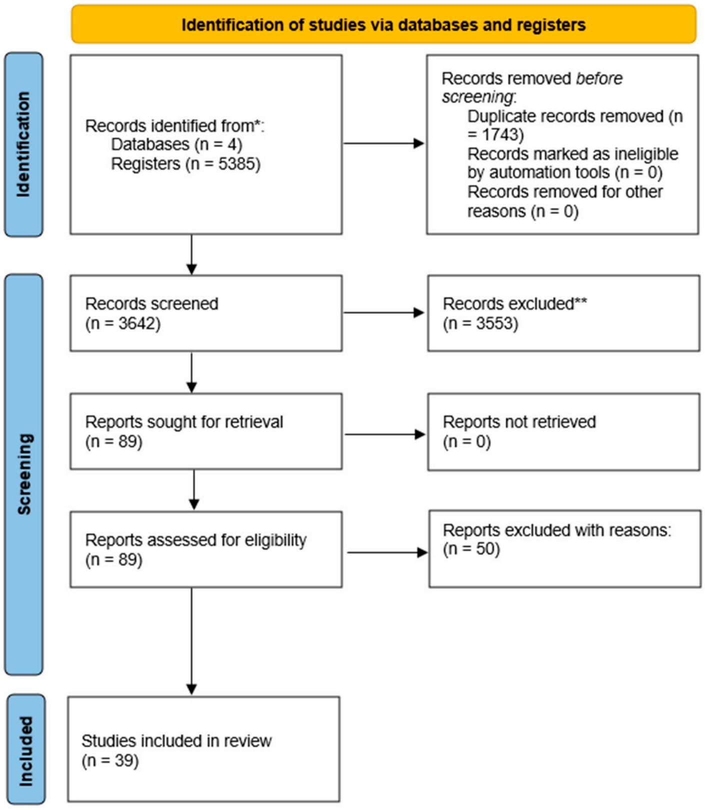
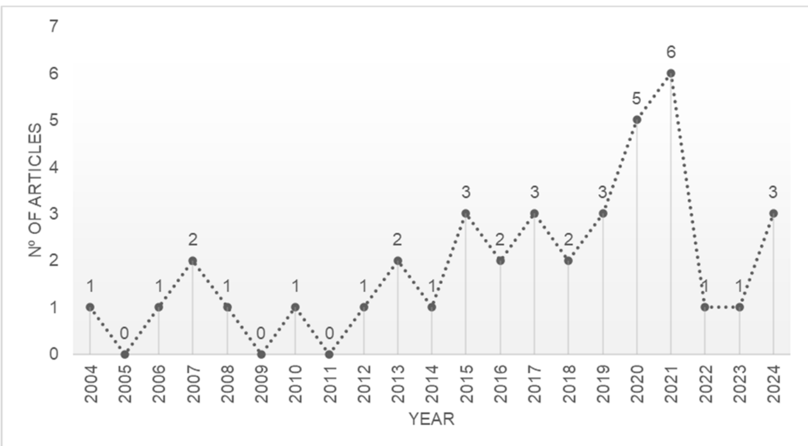


Figure 1: PRISMA Flow Diagram For Systematic Review

During the period evaluated, there was an increase in the frequency of publications from 2015 onwards in the databases evaluated, reflecting the interest in promoting sustainable production in the Amazon biome (Figure 2). This interest may be associated with the UN 2030 Agenda, which comprises 17 Sustainable Development Goals, three of which are at the core of sustainable production in the Amazon: Zero Hunger and Sustainable Agriculture (goal 2), Responsible Consumption and Production (goal 12) and Action Against Global Climate Change (goal 13). Thus, the Amazon is at the center of interest for research that aims to promote environmentally friendly production processes.



 doi:10.20944/preprints202410.2474.v1

Figure 2. Number of publications addressing challenges and opportunities for implementing sustainable production systems in the Amazon between 2004 and 2024.

3.2. Qualitative Analysis

Among the selected articles, agroforestry systems (n=18), pasture management (n=2), aquaculture (n=1), forest management (n=10), silvopastoral (n=5), agropastoral (n=1) and conservation systems (n=2) comprised the scope of the review (Figure 3). The experimental studies included were concentrated in the states of Pará (n=15), Mato Grosso (n=12), Rondônia (n=4), Amazonas (n=4), Maranhão (n=1), Amapá (n=1) and Acre (n=1), which belong to the region of Brazil that encompasses the nine states of the Amazon basin, the Legal Amazon. No studies were found that met the research criteria of this review in the states of Tocantins and Roraima, also in the legal Amazon.

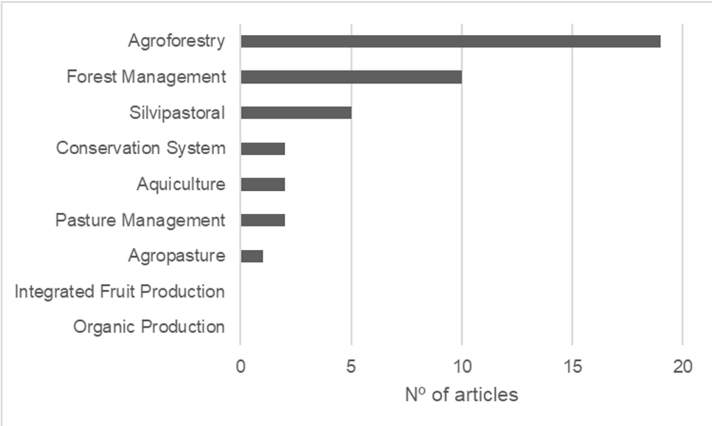


Figure 3. Number of publications by production system.

Agroforestry systems presented the highest number of publications. For this system, most of the works are concentrated in the states of Pará (n=6) and Mato Grosso (n=6). Regarding forest management, the fieldwork found was predominantly carried out in the state of Pará (n=5). This result indicates a low volume of research in states affected by the loss of vegetation cover such as Acre, Roraima, Rondônia, Maranhão and Tocantins (Figure 4), which have areas where deforestation is spreading and could benefit from technical information that reconciles sustainability and timber and non-timber production.

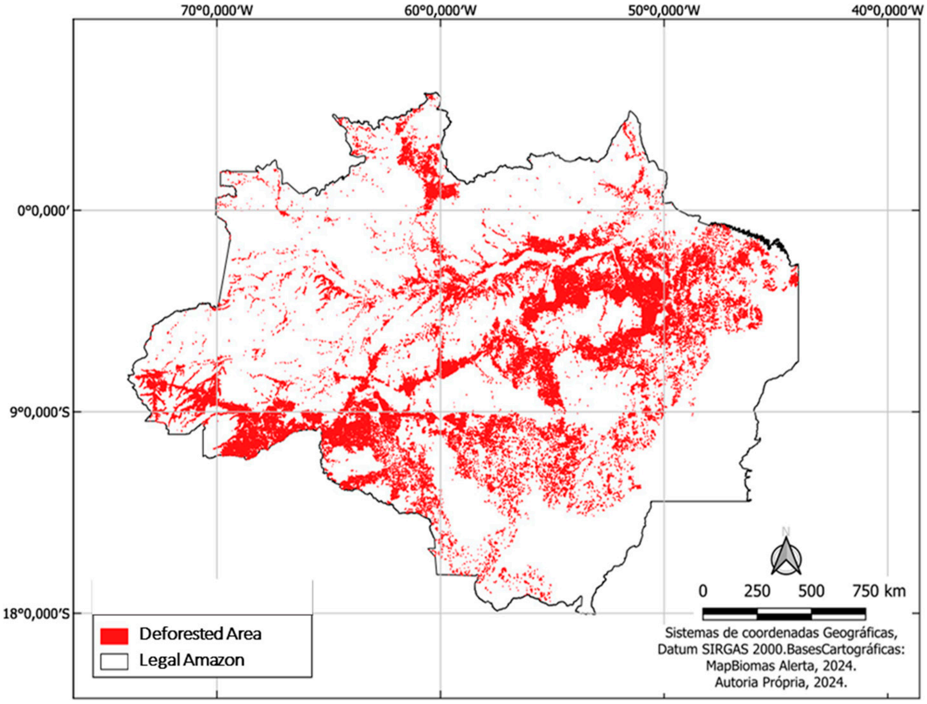


Figure 4. Deforested area in the legal Amazon region.

In this literature review, we expected to prospect publications on sustainable systems and practices adapted to the Amazon environment. However, despite their importance for rational agricultural production, systems such as aquaculture (n=1), conservationist systems (n=2), productive backyards (n=0), organic production (n=0) and integrated fruit production (n=0) returned few or no articles on the subject.

It was also found that, although there are financial and fiscal incentives, the Amazon biome still needs more support and research to encourage intensive agricultural production in a sustainable manner, thus fulfilling the objectives based on the United Nations Sustainable Development Goals related to population growth, climate change and food security.

4. Discussion

4.1. Challenges for Implementing and Consolidating Sustainable Production Systems in the Amazon

In the broader perspective, authors such as [19] reiterate the diffuse concept of "agroforestry", which makes it difficult to formulate policies that support the transition from the agribusiness-based model (monoculture) to forest production models. Agroforestry is seen as a solution to environmental and social problems [20,21], but it is often an ambiguous and poorly defined concept, with a wide variety of agroforestry practices in different parts of the world. The authors recommend studies that address the broader political and economic aspects of these systems rather than biotechnical studies at the property level. Furthermore, it is important to consider agroforestry transitions as a system-level issue, thus, research that includes political, social equity and justice issues should be carried out [19].

In a study evaluating the challenges for implementing agroforestry systems in the Amazon, [22] identified labor, implementation costs, and know-how as the challenges most emphasized by producers in Mato Grosso, and in relation to the forestry element, implementation costs and marketing were the most important challenges. Other factors such as farm size, farmer resources, and cultural preferences were also cited as influencing the adoption of integrated systems. In addition, the same study highlights the importance of policies to encourage low-carbon agricultural production, such as the ABC plan. In a study focused on the perception of rural producers in the states of Rondônia, Acre, Mato Grosso, and Pará, [23] discussed the difficulties in adopting integrated

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

crop-livestock systems and identified several obstacles, including the lack of qualified labor, few marketing options, inadequate infrastructure, unfavorable regulatory environment, and, in some areas, poorly drained soils. Furthermore, non-income-related reasons, such as maintaining quality of life and preserving traditions, have diverted producers from the pursuit of profit maximization. A broader range of policies, beyond credit subsidies, is needed to encourage the adoption of sustainable intensification strategies. These include educational programs, compensation for ecosystem services, and improvements in transport and logistics infrastructure, which can support intensification and foster an environment conducive to innovation. Agroforestry systems have proven to be an effective option for increasing pasture productivity. Public policies should, in particular, prioritize the dissemination of sustainable agroforestry practices in the Amazon biome, where the growth of cattle herds and pastures has been most significant in recent decades [24]. Regarding SAF as a strategy for restoring vegetation cover and ecosystem services, these systems have not proven to be efficient in a short period of time and in sandy soils. Furthermore, previous degradation resulted in high variability in plant development and carbon stocks[25]. The promotion of sustainable systems in the Amazon motivated by government benefits for associations and cooperatives does not impact the intensity of adoption of these practices by organizations. Conditions such as particularities of the producer, the associate, financial and management characteristics, attributes of sustainable practice and psychological attributes are preponderant factors in the adoption of sustainable practices. Furthermore, agricultural policies should, in addition to economic support, consider continuous training on new technologies for the sustainable natural resources market [26].

However, despite the use of integrated systems, conceptually, aggregating benefits between the elements of the system, for [27] in the Amazon conditions in the state of Mato Grosso, the use of a silvopastoral system with eucalyptus did not reduce the thermal stress of animals, despite the better conditions under the tree canopy. According to [24], in the Amazon biome, no significant impacts were identified on livestock stocking rates or total value of agricultural production in agroforestry, thus not qualifying the intensification of land use.

In intensive fish farming in the Amazon, low water renewal and high fish density are factors that compromise water quality. These conditions negatively affect zootechnical indices and animal welfare, resulting in reduced production yields [28].

Regarding sustainable forest management, there is interest in its adoption by small farmers, but in the study by [29] none of them systematically manage the forest. According to farmers, the recovery of degraded areas on their properties is hindered by the lack of economic incentives and high initial costs (seeds and seedlings). For about 40% of farmers, the collection of non-timber forest products (Brazil nuts and hearts of palm) for subsistence is one of the ways they use the forest, but policies to encourage the extraction of non-timber products from the forest are limited for this population.

For [30], community forestry is dominated by external decisions, which promotes industrial-scale forestry practices at the community level or prioritizes the interests of external agents. In this study, the authors indicate that timber is only one of several livelihoods for producers, thus, goals beyond timber and more comprehensive should be considered. "Bottom-up" actions allow defining goals that are more important to beneficiaries and ensure the success of the forest management project.

Regarding sustainable forestry in the Amazon, the competition between timber from sustainable sources and areas of agricultural expansion is uneven. The domestic market for non-certified timber is more accessible to sawmills, which typically have small profit margins and follow the flow of the agricultural frontier in the Amazon. In this sense, developing means for community-based family exploitation to be more sustainable is essential to creating a basis for sustainable timber production in the Amazon. In addition, the decentralization and democratization of forest land ownership through the creation of extractive reserves and autonomy for states and municipalities to demarcate land is also essential for timber exploitation in a way that does not harm the environment [31].

However, sustainable timber production on public lands is highly dependent on low-impact logging, which does not consider factors such as sustainable harvest cycles for forest stands and

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

individual species, and planting and regeneration of seedlings for high-value species that occur at low densities. Furthermore, low-impact logging, when not combined with forestry, leads to volume reduction and imminent extirpation of high-value timber. Moreover, the regulatory and technical capacity to implement low-impact logging in new areas does not currently exist, and there is a disparity between demand and human resources in government agencies [32]. This scenario hinders the monitoring of illegal logging.

Forest management of natural populations, such as açaí, can lead to gradual impoverishment of the flora over the decades due to thinning to favor the species of interest. Therefore, multi-taxonomic studies are needed to support management plans for economic-ecological zoning in Amazonian floodplain forests managed for açaí, aiming to avoid large-scale loss of cryptic biodiversity [33]. In addition, the use of integrated pollination, that is, the use of wild and managed pollinators, can reduce pollination by wild bees, and this can mean increased environmental and socioeconomic risks associated with the activity. Therefore, it is suggested that producers prioritize the preservation of forest areas on their properties to safeguard pollination services and the sustainability of açaí production in the Amazon [34].

Current indications of models for predicting biomass for the exploitation of endangered species, such as rosewood (*Aniba rosaeodora* Ducke) are not appropriate for measuring productivity, representing a serious obstacle to subsidizing the activity [35].

4.2. Opportunities for Implementing and Consolidating Sustainable Production Systems in the Amazon

Agroforestry systems are promising for above-ground carbon sequestration and reestablishing nutrient cycling when compared to natural succession [25]. According to [36], AFSs with oil palm are equally efficient for nitrogen immobilization in soil microbial biomass as secondary forests. [37] indicates that there is a possible difference in the microbial community of plants present between AFS (açaí and cocoa), cocoa monoculture and adjacent forest, which may allow greater ecological diversity and nutrient richness in the soil. However, further studies are needed to understand the diversity, relationships and functions of the microbial community in the system addressed.

Biodiversity maintenance can be promoted by AFS in the sense of retaining natural species; however, even with restoration planting, there may still be biodiversity loss. Re-agroforestry of degraded areas with tree and understory crops can also help in the food security of producers; however, it is important to prevent the encroachment on native forest and to intensify the system [26].

Soil protection provided by AFS vegetation cover contributed to reducing soil vulnerability to erosion and mercury leaching processes, comparable to mature forests; however, this vegetation protection did not completely prevent leaching. The transition to this cultivation system is challenging, so it is necessary to prioritize initiatives to support them in the implementation of this agricultural model [38].

The adoption of integrated crop-livestock-forestry systems can be stimulated by public/private partnerships to strengthen the flow of information and allow investment in infrastructure, since despite adherence, it is still a challenge to encourage them to adopt this system in the country [39].

The application of this production model contributes to the improvement of macroaggregates and an increase in carbon and nitrogen stocks in soils [39,40]. However, further research is needed to better understand the driving forces and impediments to the accumulation of organic C in the soil in integrated systems, including studies on the stability of organic matter [39].

Also considering aspects of ecological recovery capacity that integrated systems have, and their importance in the Amazon, [41] infers that agropastoral systems can be agroecological models, with increased self-sufficiency, resilience to market shocks and reduced environmental impacts when the links between system elements (soil, crops and animals) follow agroecological principles (diversity of land use and biotic and abiotic resources, maximization of ecological and production interactions, among others), improving its performance.

The practice of livestock farming in the Amazon is a paradigm full of controversies, which is why the adoption of technologies and management supported by incentive policies for more

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

intensive and sustainable livestock farming in the Amazon is a viable alternative for increasing productive and economic yields, and consequently reducing pressure on forests. However, this adoption by livestock farmers, especially small farmers, will require strong political will through government subsidies, such as the ABC program [40].

Regarding the benefits arising from the use of AFS, with regard to the factor for animal production, studies linked to the synergy between the elements of the system are abundant. The production of beef cattle in integrated systems allows performance as advantageous as the monoculture of grasses, when managed correctly; in addition, the synergy between the components of the crop-livestock-forest integration indicates that this system has an even greater potential to increase cattle production in the Amazon [42,43], however, long-term studies are recommended [42].

According to [44], the shading caused by eucalyptus on Marandu grass (*Urochloa brizantha*) at a distance of three meters, where the shading was longer, significantly affected the composition and characteristics of the canopy; however, the grass is resistant at greater distances from the tree rows. Pastures with Marandu grass shaded in silvopastoral systems, with a reduction of up to 30% in PAR, maintain leaf productivity similar to that of a monoculture. In the long term, pruning, thinning and east-west woodland reduce the shading effect on forage [45]. According to [46], if well managed, the cropping system can store carbon, resulting in benefits such as increased meat production and improved soil quality. Additionally, the inclusion of plantations and forests in these livestock systems enhances these benefits, highlighting the potential of integrated systems to offset greenhouse gas emissions.

Integrated crop-livestock systems can act as pathways for the accumulation and release of C, depending on the management and level of pasture degradation. Succession with soybean as the main crop without soil disturbance results in carbon accumulation, depending on the crop introduced, soil and climate conditions and time of use of the system [47].

The application of nutritional management strategies for conventional pasture fertilization (urea and ammonium sulfate) can contribute to mitigating greenhouse gas emissions, improving forage accumulation and animal production. Furthermore, it enables sustainable forage intensification, avoiding the opening of new areas. Microorganisms such as *Azospirillum brasilense* can be recommended for supplying nutrients to pastures in the Amazon, but further studies to evaluate this technique are needed [48]. Although only one study on animal supplementation in silvopastoral systems in the Amazon was observed in the databases evaluated, the study by [49] observed that supplementation reduces the emission of methane and volatile fatty acids in vitro, the main source of energy for ruminants.

The use of spontaneous capoeira grass pastures by small farmers in the Bragantina region of the state of Pará is a strategy for producers who want to maintain the recovery capacity of their lands and already have a tradition of production in fallow areas after human impact and fires. However, this system has a lower performance than grass monoculture. These results should be considered with caution, since the study time for such conclusions is relatively short (3 years). Furthermore, these systems are not suitable for intensive livestock farming, but are an alternative for small producers who cannot afford the management and high initial investment of legume pastures [50,51].

Agricultural production in the Amazon presents alternative models for areas replacing traditional slash-and-burn, focusing on improving soil quality. In the northeastern region of Pará, [52] observed an improvement in the physical-chemical quality of soils after the application of the SHIFT-Tipitamba cultivation system (cutting and shredding of cover vegetation) when compared to the slash-and-burn system. For [53], slash-and-shred provides intermediate and variable values for most of the physical and hydraulic properties of the soil, in a certain way improving physical quality. Thus, these techniques can enable the viable intensification of agriculture in the Amazon. Thus, sustainable animal production in the Amazon can present specific conformations for the biome, which consider particularities of the regional historical evolution of agricultural/animal production [50].

The forest element in silvopastoral systems in the Amazon is considered an essential factor for the adaptation of these systems in the region. Agroforestry systems have the advantage of being able to sell timber, in addition to agricultural and animal production, in the same area. According to [54], the production of Paricá (*Schizolobium amazonicum*) in AFS is promoted when soil management practices are not carried out. However, when intercropped with soybeans (1 year) and corn (2 years), subsoiling, fertilization and inoculation of growth-promoting microorganisms are recommended. The quality of freijó (*Cordia goeldiana*) wood produced in AFS was similar to that obtained in monoculture or native forest [55]. The use of *Ficus insipida* in monoculture or AFS in floodplain areas can help to reduce pressure on the few remaining areas of intact floodplain forests. Furthermore, an additional benefit would be the improvement of the economic situation of the local riverside population in a relatively short period of time [56]

Sustainable aquaculture in the Amazon, through multitrophic integration, can be considered an important provider of ecosystem services to mitigate the eutrophication of receiving water bodies and sequester carbon dioxide from the atmosphere, revealing potential for intensification of this system when compared to conventional aquaculture. This model can be applied with cultivation in the biofloc system and can be an alternative to promote good conditions for intensive tambaqui cultivation, with minimal water exchange compared to breeding in clear water, as it maintains good zootechnical and animal welfare indices [28].

Commercial management and sequential management of biomass through pruning of endangered forest species, such as rosewood (*A. rosaeodora*), substantially reduces the volume of macro and micronutrients exported compared to cutting down entire trees, making it a satisfactory alternative for forest management [35].

Predictive equation models to estimate mass and volume can be an alternative for forest management in productive plantations under different conditions and management options, and can be applied by the legal devices that regulate the activity [57]. The application of the Weibull growth estimation model presents good performance to estimate the annual increase and diameter of *Manilkara elata*, allowing its use in forest production planning and growth and production prognosis in short-period remediation plantations of a given species or for species that do not form annual growth rings for dendrochronological studies [58]. Measures to assist in monitoring commercialized wood, such as analysis of wood anatomy and its availability in databases, allow the use of this information by government agencies to control illicit trade [59].

Forest management for non-timber forest products enables integrated crop pollination (ICP), i.e. the use of wild and managed pollinators, which contributes to conserving pollinator diversity while simultaneously ensuring effective pollination services and increasing crop yields [34].

5. Conclusions

The review revealed that studies addressing agroforestry and forest management systems contained a greater volume of information regarding the difficulties and opportunities faced by producers in the Amazon, creating a basis for the possibility of consolidating these systems, since this knowledge is essential for formulating public policies and for assisting researchers and professionals working in sustainable production. A low distribution of publications among states in the Brazilian Amazon was also identified, with studies concentrated in the states of Pará and Mato Grosso, which may be an obstacle to identifying local difficulties and may not reflect the complete scenario of sustainable production in the Amazon.

The development of studies addressing agroforestry systems that consider the social aspects of the producer, infrastructure, and legislation, and that understand the agroforestry transition as a complex phenomenon with particularities attributed to both the producer and the region, are necessary, thus providing support for the promotion of assertive and efficient public policies. The observed research covered opportunities for protecting and restoring soil quality, as well as protecting biodiversity, income, and resilience of producers. However, most of the studies emphasized opportunities for the system, with technical work, rather than opportunities for consolidating the system, and the interaction between actors (community, companies, and government) was rarely evaluated. Thus, there is a preference for research on the effects of agroforestry systems on the environment to the detriment of research understanding their effects on the socioeconomic reality of populations and their precepts/conditions for adopting or transitioning to these systems.

Research related to systems such as aquaculture, conservation systems, productive backyards, organic production and integrated production of fruit species was scarce. These systems are common in family farming, with adaptations both to the region in general and to areas within it, with distinct historical, socio-environmental contexts of land use. Therefore, studies deepening issues related to the optimization of these systems in order to improve income in a rational way are important for the implementation of sustainable production, ensuring human and environmental well-being.

Forest management in the Amazon faces challenges such as associated costs and lack of economic incentives, which make it difficult for small farmers to implement restoration areas. In addition, decision-making for forest management outside the community hinders its effectiveness as a production system, as it does not meet the needs of producers. Measures such as decentralization and democratization of forest land ownership, creation of extractive reserves, municipal autonomy for land demarcation, more efficient low-impact management techniques, and technical monitoring and regulation are necessary steps towards sustainable forest use.

The growing social demand for products and services with less impact on the environment results in greater pressure to adopt sustainable techniques in agricultural production. Production systems in the Amazon can benefit from and assist in environmental conservation in the region and ensure food security for present and future generations. Therefore, further studies on the impediments to the implementation of less harmful production techniques in the Amazon that favor nature are essential. In addition, identifying opportunities for the consolidation of these systems can guide decision-making and ensure their establishment as a sustainable means of generating income and improving quality of life.

Author Contributions: Conceptualization, BORGES, M.R.R. and SOUSA, L.M. de.; writing—original draft preparation, BORGES, M.R.R. and SOUSA, L.M. de; writing—review and editing, BORGES, M.R.R., SOUSA, L.M. de, RIBAS, G.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding.

Acknowledgments: We would like to thank the Fundação de Estudos Agrários Luiz de Queiroz—Fealq for the support and assistance provided for the publication of this manuscript.

Data Availability Statement: Data are available upon request to the corresponding author.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Description of studies included in the review.

Title	Author	Year	Production System	Database	Reference
Agroforestry transitions: The good, the bad and the ugly	Ollinaho, O.I.; Kröger, M.	2021	Agroforestry	Science Direct	[19]
The economic impacts of the diffusion of agroforestry in Brazil	Maia *et al.*	2021	Agroforestry	Science Direct	[24]
Crop-livestock-forestry systems as a strategy for mitigating greenhouse gas emissions and enhancing the sustainability of	Monteiro *et al.*	2024	Agroforestry	Science Direct	[46]

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

forage-based livestock systems in the Amazon biome					
Reduction of Soil Erosion and Mercury Losses in Agroforestry Systems Compared to Forests and Cultivated Fields in the Brazilian Amazon.	Béliveau *et al.*	2017	Agroforestry	Science Direct	[38]
The Microbial Community Structure in the Rhizosphere of Theobroma cacao L. and Euterpe oleracea Mart. Is Influenced by Agriculture System in the Brazilian Amazon	Sousa *et al.*	2024	Agroforestry	Science Direct	[37]
Modelling biodiversity responses to land use in areas of cocoa cultivation	Maney. C.; Sassen. M.; Hill, S. L. L.	2022	Agroforestry	Science Direct	[26]
Impact of Pasture, Agriculture and Crop-Livestock Systems on Soil C Stocks in Brazil.	Carvalho, J.L.N	2010	Agroforestry	Science Direct	[47]
Adoption and development of integrated crop–livestock–forestry systems in Mato Grosso, Brazil	Gil, J.; Siebold, M.; Berger, T.	2015	Agroforestry	Science Direct	[22]
Soil mineral and microbial nitrogen in oil palm-based agroforestry systems in eastern Amazon	Santiago *et al.*,	2013	Agroforestry	Scopus	[36]
Growth and Yield of Schizolobium parahyba var. amazonicum According to Soil Management in Agroforestry Systems: A Case Study in the Brazilian Amazon	Sales *et al.*,	2021	Agroforestry	Scopus	[55]
Physico-mechanical properties of the wood of freijó, Cordia goeldiana (Boraginacea), produced in a multi-stratified agroforestry system in the southwestern Amazon	Mascarenhas *et al.*	2021	Agroforestry	Scopus	[56]
Aggregation, carbon, and total soil nitrogen in crop-livestock-forest integration in the Eastern Amazon	Silva *et al.*	2018	Agroforestry	Scopus	[40]

Management Criteria for Ficus Insipida Willd. (Moraceae) in Amazonian White-Water Floodplain Forests Defined by Tree-Ring Analysis	Schöngart, *et al*	2007	Agroforestry	Scopus	[57]
Agroforestry systems: an alternative to intensify forage-based livestock in the Brazilian Amazon	Domiciano *et al*	2020	Agroforestry	Springer	[42]
Carbon sequestration and nutrient cycling in agroforestry systems on degraded soils of Eastern Amazon, Brazil	Celentano *et al*	2020	Agroforestry	Springer	[25]
Integrated Farming Systems for Improving Soil Carbon Balance in the Southern Amazon of Brazil.	Oliveira, J.D.M	2018	Agroforestry	Springer	[39]
Intensive cattle browsing did not prevent fallow recuperation on smallholder grass-capoeira pastures in the NE-Amazon	Hohnwald *et al*	2015	Agroforestry	Springer	[51]
Forage and animal production on palisadegrass pastures growing in monoculture or as a component of integrated crop–livestock–forestry systems	Carvalho *et al.*,	2019	Agroforestry	Wiley	[43]
Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon	Cortner *et al.*,	2019	Silvopastoral	Science Direct	[23]
The influence of trees on the thermal environment and behaviour of grazing heifers in Brazilian Midwest	Lopes *et al.*,	2016	Silvopastoral	Springer	[48]
Shading Effects on Marandu Palisadegrass in a Silvopastoral System: Plant Morphological and Physiological Responses	Gomes *et al.*,	2019	Silvopastoral	Wiley	[44]
In vitro ruminal fermentation parameters and methane production of Marandu	Santos *et al.*	2020	Silvopastoral	Wiley	[50]

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 October 2024 doi:10.20944/preprints202410.2474.v1

palisadegrass (*Urochloa brizantha*) in a silvopastoral system associated with levels of protein supplementation					
Shading effects on canopy and tillering characteristics of continuously stocked palisadegrass in a silvopastoral system in the Amazon biome	Gomes *et al.*,	2020	Silvopastoral	Wiley	[45]
Agroecological principles for the redesign of integrated crop–livestock systems	Bonaudo *et al.*,	2014	Agropastoral	Science Direct	[41]
Integrating cattle into the slash-and-burn cycle on smallholdings in the Eastern Amazon, using grass-capoeira or grass-legume pastures	Hohnwald *et al*	2006	Pasture Management	Science Direct	[52]
Nitrous oxide emissions and forage accumulation in the Brazilian Amazon forage-livestock systems submitted to Ninput strategies	Nascimento *et al*	2021	Pasture Management	Wiley	[49]
Growth performance and health of juvenile tambaqui, *Colossoma macropomum*, in a biofloc system at different stocking densities	Santos *et al.*,	2021	Aquaculture	Wiley	[27]
Floristic impoverishment of Amazonian floodplain forests managed for açaí fruit production	Freitas *et al.*,	2015	Forest Management	Science Direct	[33]
How long does the Amazon rainforest take to grow commercially sized trees? An estimation methodology for *Manilkara elata* (Allemão ex Miq.) Monach	Ferreira *et al.*,	2020	Forest Management	Science Direct	[59]
Forestry control in the brazilian amazon III: anatomy of wood and charcoal of tree species from sustainable forest management	Silva *et al.*,	2024	Forest Management	Science Direct	[32]
Tropical Forest Management and Silvicultural Practices by Small Farmers in the Brazilian	Summers, P.M.; Browder,	2004	Forest Management	Science Direct	[28]

Amazon: Recent Farm-Level Evidence from Rondônia	J.O.; Pedlowski, M.A.				
Community Forests for Forest Communities: Integrating Community-Defined Goals and Practices in the Design of Forestry Initiatives	Hajjar, R.; Kozak, R.A.; El-Lakany, H.; Innes, J.L.	2013	Forest Management	Science Direct	[29]
New Allometric Equations to Support Sustainable Plantation Management of Rosewood (*Aniba rosaeodora* Ducke) in the Central Amazon	Krainovic; Almeida; Sampaio	2017	Forest Management	Scopus	[58]
Sequential management of commercial rosewood (*Aniba rosaeodora* Ducke) plantations in central amazonia: seeking sustainable models for essential oil production	Krainovic *et al*	2017	Forest Management	Scopus	[35]
Novas Perspectivas Para a Gestão Sustentável Da Floresta Amazônica: Explorando Novos Caminhos.	Ros-Tonen, M	2007	Forest Management	Scopus	[30]
Technical Challenges to Sustainable Forest Management in Concessions on Public Lands in the Brazilian Amazon.	Schulze, M.; Grogan, J.; Vidal, E.	2008	Forest Management	Scopus	[31]
Forest Conservation Maximises Açaí Palm Pollination Services and Yield in the Brazilian Amazon.	Campbell, A.J.	2023	Forest Management	Wiley	[34]
Fire-Free Fallow Management by Mechanized Chopping of Biomass for Sustainable Agriculture in Eastern Amazon: Effects on Soil Compactness, Porosity, and Water Retention and Availability	Reichert, J.M.	2006	Conservation System	Wiley	[54]
Physicochemical Properties of Soils in the Brazilian Amazon Following Fire-Free Land Preparation and Slash-and-Burn Practices	Comte, I.	2012	Conservation System	Science Direct	[53]

References

1. Osorio, R.M.L. A Produção de Soja no Oeste do Pará: A Tomada de Decisão do Produtor Rural e as Características da Atividade Produtiva Em Meio à Floresta Amazônica. tese de doutorado, Universidade de Brasília, Centro de Desenvolvimento Sustentável.
2. Domingues, M.S.; Bermann, C. O Arco de Desflorestamento Na Amazônia: Da Pecuária à Soja. *Ambiente Soc.* **2012**, *15*, 1–22, doi:10.1590/S1414-753X2012000200002.
3. Silva-Souza, K.J.P.; Souza, A.F. Woody Plant Subregions of the Amazon Forest. *J. Ecol.* **2020**, *108*, 2321–2335, doi:10.1111/1365-2745.13406.
4. Kirby, K.R.; Laurance, W.F.; Albernaz, A.K.; Schroth, G.; Fearnside, P.M.; Bergen, S.; Venticinque, E.M.; Da Costa, C. The Future of Deforestation in the Brazilian Amazon. *Futures* **2006**, *38*, 432–453, doi:10.1016/j.futures.2005.07.011.
5. VITEL, C.S.M.N. Modelagem Da Dinâmica Do Desmatamento de Uma Fronteira Em Expansão, Lábrea, Amazonas.
6. Fasiaben, M. do C.R.; Andrade Andrade, D.C.; Reydon, B.P.; Garcia, J.R.; Romeiro, A.R. Estimativa de aporte de recursos para um sistema de Pagamento por Serviços Ambientais na floresta Amazônica brasileira. *Estim. Aporte Recur. Para Um Sist. Pagamento Por Serviços Ambient. Na Floresta Amaz. Bras.* **2009**, *12*, 223–239.
7. IBGE, M. da E.I.B. de G. e E. *série relatórios metodológicos*; IBGE, Coordenação de Recursos Naturais e Estudos Ambientais, 2009; p. 168;.
8. filho, P.G.C.; Souza, D.T. de; Martinho, P.R.R.; Souza, M.O. de Evolução da agropecuária da Amazônia Brasileira. *Revista de Política agrícola* **2023**, *3*, 51–68.
9. Correio, V.V. da S.C.; Correio, R.G. da C.S.; Correio, L.A.P.L. Geographia Opportuno Tempore. *ESTRUTURAÇÃO Front. Agríc. NO SUL ESTADO Amazon.* **2019**, *5*, 67–82.
10. Silva, L.M.; Andrade, D. lima de; Barbosa, K.L.S.; Rodrigues, L.S.; Milhomem, A.L.; OLIVEIRA, J.S.; Melo, L.F. de S. Revista Craibeiras de Agroecologia,. *Sist. BRAGANTINO UM MÉTODO INOVADOR E Altern. CULTIVO E PRODUÇÃO Agríc. QUE ENGLOBA ROTAÇÃO E CONSÓRCIO Cult. COM Téc. PLANTIO DIRETO* 2018, 2–6.
11. MENDONÇA, A.S.A. de; Oliveira, R.K.R. de; OLIVEIRA, K. de N.S. de; SOUZA, M. do S.P.; BISPO, J.A. de S. Anais do Agroecol: Manejo de Agroecossistemas Sustentáveis 2018, 8.
12. Hurtienne, T.P. Agricultura familiar e desenvolvimento rural sustentável na Amazônia. *Novos Cad. NAEA* **2005**, *8*, doi:10.5801/ncn.v8i1.47.
13. HANUSCH, M. *Grupo Banco Mundial*; Washington, NW, 2023; p. 351;.
14. Homma, A.K.O. *Sinergias de mudança da agricultura amazônica: conflitos e oportunidades*; 1st ed.; Embrapa Amazônia Oriental: Brasília, DF, 2022; ISBN 978-65-89957-00-3.
15. Costa, F. de A. *Ecologismo e questão agrária na Amazônia*; 1st ed.; NAEA: Belém/Pa, 1992;
16. Garrett, R.D.; Rausch, L.L. Green for Gold: Social and Ecological Tradeoffs Influencing the Sustainability of the Brazilian Soy Industry. *J. Peasant Stud.* **2016**, *43*, 461–493, doi:10.1080/03066150.2015.1010077.
17. Rivero, S.; Almeida, O.; Ávila, S.; Oliveira, W. Pecuária e Desmatamento: Uma Análise Das Principais Causas Diretas Do Desmatamento Na Amazônia. *Nova Econ.* **2009**, *19*, 41–66, doi:10.1590/S0103-63512009000100003.
18. Oliveira, M.C.C.D.; Almeida, J.; Silva, L.M.S. Diversificação Dos Sistemas Produtivos Familiares: Reflexos Sobre as Relações Sociedade-Natureza Na Amazônia Oriental. *Novos Cad. NAEA* **2011**, *14*, doi:10.5801/ncn.v14i2.502.
19. Ollinaho, O.I.; Kröger, M. Agroforestry Transitions: The Good, the Bad and the Ugly. *J. Rural Stud.* **2021**, *82*, 210–221, doi:10.1016/j.jrurstud.2021.01.016.
20. Weis, T. The Accelerating Biophysical Contradictions of Industrial Capitalist Agriculture. *J. Agrar. Change* **2010**, *10*, 315–341, doi:10.1111/j.1471-0366.2010.00273.x.
21. Patel, R.; Moore, J.W. *A History of the World in Seven Cheap Things: A Guide to Capitalism, Nature, and the Future of the Planet*; 1st ed.; University of California Press, Oakland, CA.: Oakland, CA., 2017; ISBN 978-0-520-29313-7.
22. Gil, J.; Siebold, M.; Berger, T. Adoption and Development of Integrated Crop–Livestock–Forestry Systems in Mato Grosso, Brazil. *Agric. Ecosyst. Environ.* **2015**, *199*, 394–406, doi:10.1016/j.agee.2014.10.008.
23. Cortner, O.; Garrett, R.D.; Valentim, J.F.; Ferreira, J.; Niles, M.T.; Reis, J.; Gil, J. Perceptions of Integrated Crop-Livestock Systems for Sustainable Intensification in the Brazilian Amazon. *Land Use Policy* **2019**, *82*, 841–853, doi:10.1016/j.landusepol.2019.01.006.
24. Gori Maia, A.; Eusebio, G.D.S.; Fasiaben, M.D.C.R.; Moraes, A.S.; Assad, E.D.; Pugliero, V.S. The Economic Impacts of the Diffusion of Agroforestry in Brazil. *Land Use Policy* **2021**, *108*, 105489, doi:10.1016/j.landusepol.2021.105489.
25. Celentano, D.; Rousseau, G.X.; Paixão, L.S.; Lourenço, F.; Cardozo, E.G.; Rodrigues, T.O.; E Silva, H.R.; Medina, J.; De Sousa, T.M.C.; Rocha, A.E.; et al. Carbon Sequestration and Nutrient Cycling in Agroforestry Systems on Degraded Soils of Eastern Amazon, Brazil. *Agrofor. Syst.* **2020**, *94*, 1781–1792, doi:10.1007/s10457-020-00496-4.

26. Maney, C.; Sassen, M.; Hill, S.L.L. Modelling Biodiversity Responses to Land Use in Areas of Cocoa Cultivation. *Agric. Ecosyst. Environ.* **2022**, *324*, 107712, doi:10.1016/j.agee.2021.107712.
27. Lopes, L.B.; Eckstein, C.; Pina, D.S.; Carnevalli, R.A. The Influence of Trees on the Thermal Environment and Behaviour of Grazing Heifers in Brazilian Midwest. *Trop. Anim. Health Prod.* **2016**, *48*, 755–761, doi:10.1007/s11250-016-1021-x.
28. Santos, R.B.; Izel-Silva, J.; Fugimura, M.M.S.; Suita, S.M.; Ono, E.A.; Affonso, E.G. Growth Performance and Health of Juvenile Tambaqui, *Colossoma Macropomum* , in a Biofloc System at Different Stocking Densities. *Aquac. Res.* **2021**, *52*, 3549–3559, doi:10.1111/are.15196.
29. Summers, P.M.; Browder, J.O.; Pedlowski, M.A. Tropical Forest Management and Silvicultural Practices by Small Farmers in the Brazilian Amazon: Recent Farm-Level Evidence from Rondônia. *For. Ecol. Manag.* **2004**, *192*, 161–177, doi:10.1016/j.foreco.2003.12.016.
30. Hajjar, R.; Kozak, R.A.; El-Lakany, H.; Innes, J.L. Community Forests for Forest Communities: Integrating Community-Defined Goals and Practices in the Design of Forestry Initiatives. *Land Use Policy* **2013**, *34*, 158–167, doi:10.1016/j.landusepol.2013.03.002.
31. Ros-Tonen, M. Novas Perspectivas Para a Gestão Sustentável Da Floresta Amazônica: Explorando Novos Caminhos. *Ambiente Soc.* **2007**, *10*, 11–25, doi:10.1590/S1414-753X2007000100002.
32. Schulze, M.; Grogan, J.; Vidal, E. Technical Challenges to Sustainable Forest Management in Concessions on Public Lands in the Brazilian Amazon. *J. Sustain. For.* **2008**, *26*, 61–76, doi:10.1300/j091v26n01_03.
33. Freitas, M.A.B.; Vieira, I.C.G.; Albernaz, A.L.K.M.; Magalhães, J.L.L.; Lees, A.C. Floristic Impoverishment of Amazonian Floodplain Forests Managed for Açaí Fruit Production. *For. Ecol. Manag.* **2015**, *351*, 20–27, doi:10.1016/j.foreco.2015.05.008.
34. Campbell, A.J.; Silva, F.D.D.S.E.; Maués, M.M.; Leão, K.L.; Carvalheiro, L.G.; Moreira, E.F.; Mertens, F.; Konrad, M.L.D.F.; De Queiroz, J.A.L.; Menezes, C. Forest Conservation Maximises Açaí Palm Pollination Services and Yield in the Brazilian Amazon. *J. Appl. Ecol.* **2023**, *60*, 1964–1976, doi:10.1111/1365-2664.14460.
35. Krainovic, P.; Almeida, D.; Desconci, D.; Veiga-Júnior, V.; Sampaio, P. Sequential Management of Commercial Rosewood (Aniba Rosaeodora Ducke) Plantations in Central Amazonia: Seeking Sustainable Models for Essential Oil Production. *Forests* **2017**, *8*, 438, doi:10.3390/f8120438.
36. Santiago, W.R.; Vasconcelos, S.S.; Kato, O.R.; Bispo, C.J.C.; Rangel-Vasconcelos, L.G.T.; Castellani, D.C. Nitrogênio Mineral e Microbiano Do Solo Em Sistemas Agroflorestais Com Palma de Óleo Na Amazônia Oriental. *Acta Amaz.* **2013**, *43*, 395–405, doi:10.1590/S0044-59672013000400001.
37. Sousa, R.D.S.D.R.D.; Lima, G.V.S.; Garcias, J.T.; Gomes, G.D.O.; Mateus, J.R.; Madeira, L.D.P.D.S.; Seldin, L.; Rogez, H.L.G.; Marques, J.M. The Microbial Community Structure in the Rhizosphere of Theobroma Cacao L. and Euterpe Oleracea Mart. Is Influenced by Agriculture System in the Brazilian Amazon. *Microorganisms* **2024**, *12*, 398, doi:10.3390/microorganisms12020398.
38. Béliveau, A.; Lucotte, M.; Davidson, R.; Paquet, S.; Mertens, F.; Passos, C.J.; Romana, C.A. Reduction of Soil Erosion and Mercury Losses in Agroforestry Systems Compared to Forests and Cultivated Fields in the Brazilian Amazon. *J. Environ. Manage.* **2017**, *203*, 522–532, doi:10.1016/j.jenvman.2017.07.037.
39. Oliveira, J.D.M.; Madari, B.E.; Carvalho, M.T.D.M.; Assis, P.C.R.; Silveira, A.L.R.; De Leles Lima, M.; Wruck, F.J.; Medeiros, J.C.; Machado, P.L.O.D.A. Integrated Farming Systems for Improving Soil Carbon Balance in the Southern Amazon of Brazil. *Reg. Environ. Change* **2018**, *18*, 105–116, doi:10.1007/s10113-017-1146-0.
40. Silva, J.C.N.; Silva, A.R.; Veloso, C.A.C.; Dantas, E.F.; Sacramento, J.A.A.S.D. Aggregation, Carbon, and Total Soil Nitrogen in Crop-Livestock-Forest Integration in the Eastern Amazon. *Rev. Bras. Eng. Agríc. E Ambient.* **2018**, *22*, 837–842, doi:10.1590/1807-1929/agriambi.v22n12p837-842.
41. Bonaudo, T.; Bendahan, A.B.; Sabatier, R.; Ryschawy, J.; Bellon, S.; Leger, F.; Magda, D.; Tichit, M. Agroecological Principles for the Redesign of Integrated Crop–Livestock Systems. *Eur. J. Agron.* **2014**, *57*, 43–51, doi:10.1016/j.eja.2013.09.010.
42. Domiciano, L.F.; Pedreira, B.C.; Da Silva, N.M.F.; Mombach, M.A.; Chizzotti, F.H.M.; Batista, E.D.; Carvalho, P.; Cabral, L.S.; Pereira, D.H.; Do Nascimento, H.L.B. Agroforestry Systems: An Alternative to Intensify Forage-Based Livestock in the Brazilian Amazon. *Agrofor. Syst.* **2020**, *94*, 1839–1849, doi:10.1007/s10457-020-00499-1.
43. De Carvalho, P.; Domiciano, L.F.; Mombach, M.A.; Do Nascimento, H.L.B.; Cabral, L.D.S.; Sollenberger, L.E.; Pereira, D.H.; Pedreira, B.C. Forage and Animal Production on Palisadegrass Pastures Growing in Monoculture or as a Component of Integrated Crop–Livestock–Forestry Systems. *Grass Forage Sci.* **2019**, *74*, 650–660, doi:10.1111/gfs.12448.
44. Gomes, F.J.; Pedreira, C.G.S.; Bosi, C.; Cavalli, J.; Holschuch, S.G.; Mourão, G.B.; Pereira, D.H.; Pedreira, B.C. Shading Effects on Marandu Palisadegrass in a Silvopastoral System: Plant Morphological and Physiological Responses. *Agron. J.* **2019**, *111*, 2332–2340, doi:10.2134/agronj2019.01.0052.
45. Gomes, F.J.; Pedreira, B.C.; Santos, P.M.; Bosi, C.; Pedreira, C.G.S. Shading Effects on Canopy and Tillering Characteristics of Continuously Stocked Palisadegrass in a Silvopastoral System in the Amazon Biome. *Grass Forage Sci.* **2020**, *75*, 279–290, doi:10.1111/gfs.12478.

46. Monteiro, A.; Barreto-Mendes, L.; Fanchone, A.; Morgavi, D.P.; Pedreira, B.C.; Magalhães, C.A.S.; Abdalla, A.L.; Eugène, M. Crop-Livestock-Forestry Systems as a Strategy for Mitigating Greenhouse Gas Emissions and Enhancing the Sustainability of Forage-Based Livestock Systems in the Amazon Biome. *Sci. Total Environ.* **2024**, *906*, 167396, doi:10.1016/j.scitotenv.2023.167396.
47. Carvalho, J.L.N.; Raucci, G.S.; Cerri, C.E.P.; Bernoux, M.; Feigl, B.J.; Wruck, F.J.; Cerri, C.C. Impact of Pasture, Agriculture and Crop-Livestock Systems on Soil C Stocks in Brazil. *Soil Tillage Res.* **2010**, *110*, 175–186, doi:10.1016/j.still.2010.07.011.
48. Do Nascimento, A.F.; De Oliveira, C.M.; Pedreira, B.C.; Pereira, D.H.; Rodrigues, R.R.D.A. Nitrous Oxide Emissions and Forage Accumulation in the Brazilian Amazon Forage-livestock Systems Submitted to N Input Strategies. *Grassl. Sci.* **2021**, *67*, 63–72, doi:10.1111/grs.12287.
49. Santos, A.R.M.D.; Barros, L.V.D.; Abreu, M.L.C.; Pedreira, B.C. *In Vitro* Ruminal Fermentation Parameters and Methane Production of Marandu Palisadegrass (*Urochloa Brizantha*) in a Silvopastoral System Associated with Levels of Protein Supplementation. *Grass Forage Sci.* **2020**, *75*, 339–350, doi:10.1111/gfs.12476.
50. Hohnwald, S.; Rischkowsky, B.; King, J.M.; Camarão, A.P.; Rodrigues Filho, J.A.; Zeppenfeld, T. Intensive Cattle Browsing Did Not Prevent Fallow Recuperation on Smallholder Grass-Capoeira Pastures in the NE-Amazon. *Agrofor. Syst.* **2015**, *89*, 813–828, doi:10.1007/s10457-015-9815-9.
51. Hohnwald, S.; Rischkowsky, B.; Camarão, A.P.; Schultze-Kraft, R.; Rodrigues Filho, J.A.; King, J.M. Integrating Cattle into the Slash-and-Burn Cycle on Smallholdings in the Eastern Amazon, Using Grass-Capoeira or Grass-Legume Pastures. *Agric. Ecosyst. Environ.* **2006**, *117*, 266–276, doi:10.1016/j.agee.2006.04.014.
52. Comte, I.; Davidson, R.; Lucotte, M.; De Carvalho, C.J.R.; De Assis Oliveira, F.; Da Silva, B.P.; Rousseau, G.X. Physicochemical Properties of Soils in the Brazilian Amazon Following Fire-Free Land Preparation and Slash-and-Burn Practices. *Agric. Ecosyst. Environ.* **2012**, *156*, 108–115, doi:10.1016/j.agee.2012.05.004.
53. Reichert, J.M.; Rodrigues, M.F.; Bervald, C.M.P.; Kato, O.R. Fire-Free Fallow Management by Mechanized Chopping of Biomass for Sustainable Agriculture in Eastern Amazon: Effects on Soil Compactness, Porosity, and Water Retention and Availability. *Land Degrad. Dev.* **2016**, *27*, 1403–1412, doi:10.1002/ldr.2395.
54. Sales, A.; De Oliveira Neto, S.N.; De Paiva, H.N.; Leite, H.G.; Siviero, M.A.; Vieira, S.B. Growth and Yield of Schizolobium Parahyba Var. Amazonicum According to Soil Management in Agroforestry Systems: A Case Study in the Brazilian Amazon. *Diversity* **2021**, *13*, 511, doi:10.3390/d13110511.
55. Mascarenhas, A.R.P.; Sccoti, M.S.V.; Melo, R.R.D.; Corrêa, F.L.D.O.; Souza, E.F.M.D.; Pimenta, A.S. Physico-Mechanical Properties of the Wood of Freijó, Cordia Goeldiana (Boraginacea), Produced in a Multi-Stratified Agroforestry System in the Southwestern Amazon. *Acta Amaz.* **2021**, *51*, 171–180, doi:10.1590/1809-4392202003001.
56. Schöngart, J.; Wittmann, F.; Worbes, M.; Piedade, M.T.F.; Krambeck, H.-J.; Junk, W.J. Management Criteria for Ficus Insipida Willd. (Moraceae) in Amazonian White-Water Floodplain Forests Defined by Tree-Ring Analysis. *Ann. For. Sci.* **2007**, *64*, 657–664, doi:10.1051/forest:2007044.
57. Krainovic, P.; Almeida, D.; Sampaio, P. New Allometric Equations to Support Sustainable Plantation Management of Rosewood (Aniba Rosaeodora Ducke) in the Central Amazon. *Forests* **2017**, *8*, 327, doi:10.3390/f8090327.
58. Ferreira, T.M.C.; De Carvalho, J.O.P.; Emmert, F.; Ruschel, A.R.; Nascimento, R.G.M. How Long Does the Amazon Rainforest Take to Grow Commercially Sized Trees? An Estimation Methodology for Manilkara Elata (Allemão Ex Miq.) Monach. *For. Ecol. Manag.* **2020**, *473*, 118333, doi:10.1016/j.foreco.2020.118333.
59. da Silva, A.A.; de Sousa, K.C.; de Souza, F.I.B.; Nobre, J.R.C.; de Paula Protásio, T.; de Lima Melo, L.E. Forestry Control in the Brazilian Amazon III: Anatomy of Wood and Charcoal of Tree Species from Sustainable Forest Management. *IAWA J.* **2024**, 1–38, doi:10.1163/22941932-bja10151.