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Review

Can Agroforestry Contribute to Food and Livelihood Security for Indonesia's Smallholders in the Climate Change Era?

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Abstract: In Indonesia, smallholders have historically practiced agroforestry, which warrants examination in terms of food and livelihood security within sustainable community forest frameworks. Based on a literature review, we analyzed these two forms of security related to smallholder agroforestry practices. Findings indicate diverse agroforestry systems, with 88% focusing on non-timber forest products (NTFPs) and 12% on timber. While 42% prioritize direct food supply, 58% emphasize income generation through product sales. However, agroforestry that does not produce food for direct consumption by smallholders generates revenue for purchasing food necessities. Agroforestry supports both food needs (46–61%) and income (51–54%) for smallholders, surpassing traditional agriculture (13%). Semi-commercial agroforestry (57%) is a predominant livelihood prospect. The remaining 27% are purely subsistence, and 15% are purely commercial. However, the commercialization of agroforestry that focuses only on high-value commodities results in a negative impact on biodiversity. There is a concomitant decrease in environmental services for climate change mitigation and adaptation. Biodiversity remains crucial for climate resilience, health care, and food security in rural communities. Semi-commercial agroforestry is a midpoint for achieving multifunctional agriculture (biodiversity, soil and water conservation, food security, and income) in the climate change era. The research directly related to food security and ecosystem services quantification remains limited, necessitating further investigation. Policy support and incentives are essential for smallholders practicing complex agroforestry for climate adaptation and mitigation.

Keywords: agroforestry; sustainability; subsistence; commercialization; community forestry

1. Introduction

Growing populations and the depletion of agricultural land are creating enormous challenges for the sustainability of food production and supply systems [1]. The declining

quantity and quality of agricultural land, together with water scarcity and climate variability, is not only threatening global food security but also overall rural livelihoods that are vastly dependent on agricultural production [2,3]. Approximately 80% of fresh water is used for agricultural activities to support food production, while only about 10% of irrigated water in developing countries comes from reused wastewater [4,5]. In this context, crops in agroforestry systems require less water due to their efficient use of available soil water content ('green water') than many monoculture systems [5].

Foods such as grains, vegetables, fruits, dairy, and meat are important to human nutrition [6]; the production of such foods in conventional agriculture has contributed to negative environmental and social effects, e.g., climate change, biodiversity, ecosystem and land degradation, water scarcity, and stressed social structures [7,8]. This is also because the intensification of conventional agriculture mostly relies on chemical fertilizers, excessive water use, mechanization, and hybrid genetic engineering [9,10]. Across the landscape, the conversion of forest land to agricultural land has had an impact on water availability, thus causing the loss of hydrological functions associated with infiltration [11] as well as climate change on a local to global scale [12], trigging a shift to sustainable and multifunctional agriculture [13]. Sustainable agricultural supply chains generate greater production and/or higher agricultural productivity while at the same time achieving enhanced environmental, economic, and social outcomes [14].

Multifunctional agriculture can improve food production and positively impact social and environmental aspects, contributing to sustainable development [8,15]. Combining the Sustainable Development Goals (SDGs) of the forestry sector (SDG 15) and agriculture (SDG 2) in integrated land management has the potential to achieve three broad groups of SDGs [16]. Agroforestry as regenerative farming by food producers suits the SDGs program [8,17]. Hence, it can potentially be the future of agriculture [18]. Conversely, unsustainable agriculture practices [13] can be transformed into environmentally friendly agroforestry [19]. Agroforestry systems create multifunctional landscapes for income diversity and environmental services (clean water, biodiversity, carbon sequestration, and cultural conservation) [20,21]. Land use is often characterized by an integration of forests, agroforestry, agriculture, and settlement areas, which have to meet many interests and conflicting needs to produce products and services that support the SDG agenda [19].

In general, land covered by trees with the dual functions of producing food and environmental services is called agroforestry [22]. Agroforestry must be developed to integrate forestry and agriculture [23]. The forms of an agroforestry system can be a combination of commodities, such as agri-silviculture, silvofishery, silvopasture, agrosilvofishery, agro-silvopasture, and apiculture. The main requirement of an agroforestry system is that there are tree stands as the main component. A 'forest', according to the Food Agriculture Organization of Global Forest Resource Assessment (FAO FRA) 2000 program, has a tree canopy cover of >10% and an area > 0.5 ha or 10–30% of the tree canopy area and conservation of tree diversity [16] for climate change mitigation [24] as well as social, market, goods, and ecosystem services [25]. In Indonesia, the forest represents land with a minimum area of 0.25 hectares, and that contains trees with a canopy cover of at least 30%, capable of reaching a minimum height of 5 m at maturity [26]. Agroforestry can provide forest ecosystem functions as well as food and other products. It is a system involving the use of natural resources based on ecology through the combination of trees and crops, with various kinds and benefits of products (social, economic, and environmental), in a sustainable manner [19,21,26].

Indonesia's agroforestry practices have been developed since ancient times [27,28]. Even in Southeast Asian countries, there is a trend to develop a relationship between agroforestry and food security. However, studies on agroforestry in Indonesia that focus on food security are still limited [29]. The assumption is that most agroforestry systems are still based on traditional subsistence practices [27], in which management intensification is needed to increase business prospects and sustainable food security [30]. The economic and environmental impacts of multifunctional agroforestry farms are influenced by several

factors, including scale, regional conditions, management practices adopted and landscape design [31]. However, no study classifies smallholder agroforestry practices in Indonesia in detail into three levels of business (subsistence, semi-commercial and commercial) as indicators of their contribution to smallholders' livelihood in the climate change era. Therefore, it is necessary to analyze the prospective business characteristics of smallholder agroforestry practices that have long been applied and their contribution to smallholder food security in rural Indonesia. This paper aims to evaluate agroforestry's contribution to food and livelihood security for smallholders in the climate change era.

Country Context

In Indonesia, smallholders' land in rural areas is typically spread among the home garden, fields (*tegalan*) and community forests with agroforestry practices. In its development, silviculture is defined as establishing and maintaining tree communities that produce tangible or intangible value to human beings, such as timber, non-timber forest products (NTFPs), food, and conservation and ecosystem value [32]. Forest and tree crop products can be a basis for income and food security [21]. Interrelating the concepts of food security, forests, agroforestry, environmental services, and sustainable development is still a challenge for Indonesia [22].

Indonesia's overall food production failed to meet the demand of its 270.20 million people in 2020 [33]. In 2023, Indonesia's population reached 277.7 million [34]; however, the overall farming area has decreased by 12.9% annually [35]. Conversion of rice fields to non-agricultural land occurred at a rate of around 80,000 ha per year [36], in the context in which the rate of expansion of such rice fields was around 20,000–30,000 ha per year [37]. The decline in rice production owing to a decrease in paddy fields was by up to 2.4 million tons over five years [38]. Moreover, climate change causes a decrease in rice production by 1.37% of the total production per year [39]. Therefore, the data show that rice imports reached 407,741.40 tons in 2021 [36].

The percentage of the population classified as 'food insecure' in Indonesia was 7.9% in 2019 [40]. Food must be accessible to communities in remote areas. In Indonesia, the population is spread over 83,931 villages, of which 3.3% are in forest areas (2768 villages), 22.18% are on the edge of forest areas (18,617 villages), and 74.52% are outside forest areas (62,546 villages). Among those, 99% of the villages located inside the forest depend on agricultural production as their main source of income, which is 93.8% and 79.4% for the villages located at the edge of the forest and outside the forest, respectively [33]. The ability to access food must be accompanied by ensuring viability, stability, and sustainability. Indonesia needs to develop widespread, sustainable, regenerative agriculture [10].

Indonesia's land area (191.1 million ha) features potential dry land of 144.5 million ha (76%), 42.7 million ha (22.4%) of wetlands, and 4.6 million ha for other uses. Dry land with a wet climate is spread across Sumatra, Kalimantan, and Java (133.7 million ha), and dry land with a dry climate is spread across Eastern Indonesia (10.7 ha) [41]. Nevertheless, based on the FAO FRA 2000 program, the rate of deforestation in Indonesia reached 0.78 million ha/year during 2010–2020. The latest data for 2020–2021 show that deforestation in Indonesia was 113,534.3 ha [42]. The agricultural land expansion rate for rice fields was around 20,000–30,000 ha annually [37].

Indonesia has already committed to promoting sustainable agriculture to achieve food security through more diverse food production systems using local resources [40,43]. Indonesia has 77 types of carbohydrate sources, 26 types of nuts, 389 types of fruits, 228 types of vegetables, and 110 types of spices and seasonings [39]. Local food consumed by a community can be sustainable [10] if it contributes positively to three aspects: (1) the environment (reducing greenhouse gas (GHG) emissions and sustaining the supply chain, e.g., reducing food loss and reducing packaging; (2) socio-economic (a local identity that can unite communities and provide income); and (3) health (providing healthy, diverse foods and reducing loss and waste [10]. People's reliance on rice in Indonesia as a source of carbohydrates can be reduced through food diversification, e.g., by consuming tubers, sago,

breadfruit, and sugar palm. Several types of tubers as alternative food sources include cassava, sweet potato, *suweg* (*Amorphophallus paeniifolius*), arrowroot (*Maranta arundinaceae*), taro (*Colocasia esculenta*), *kimpul* (*Xanthosoma sagottifolium*), *gembili* (*Dioscorea esculenta*), canna (*Canna edulis*), and *porang* (*Amorphophallus muelleri*) [39,44]. These food commodities are produced from agroforestry to various types of land use systems, cultivated by smallholder farmers.

In the era of climate change, one of the growing obstacles to sustainable agriculture is the availability of water resources. Hence, utilizing dry land for food production is a strategic challenge. The Government of Indonesia issued Law no. 16/2014 and Presidential Decree 61/2011 regarding Planning, Implementation and MRV Systems to Achieve Emission Reduction (*Rencana, Implementasi dan Sistem MRV untuk Mencapai Penurunan Emisi* or RAN-GRK) as part of the national commitment to the Paris Agreement, which includes the development of environmentally friendly (low carbon) agriculture. The Indonesian government issued Minister of Environment and Forestry Regulation No. 9/2021 concerning Social Forestry Management to provide opportunities for communities to gain access to and benefits from forest management. Ministry of Environment and Forestry Regulation 8 Number 2021 concerning Forest Management and Preparation of Forest Management Plans and Forest Utilization in Protected Forests and Production Forests encourages increased productivity of forest land by applying agroforestry and multi-business forestry. Agroforestry practices can also be applied to dry land areas because they are relatively efficient with water resources. Therefore, the option of promoting or linking agroforestry, tree crops, and household food security should be considered a critical theory (sustainable agriculture in climate change) [45] and climate-smart agriculture [46].

2. Materials and Methods

This study is based on a literature review of both peer-reviewed and grey literature [47]. The review mainly focused on six scientific areas of interest in English and Indonesian—agroforestry, *hutan rakyat* (community forest), smallholders, food security, business prospects, and Indonesia—through an intensive search of online publications that primarily appeared from 2000 onwards. A preliminary scoping study was conducted based on a Google Scholar search targeted at finalizing keywords and search phrases and contributing to the framing of the manuscript. After finalizing keywords and phrases, relevant literature was gathered using scientific research search sites, i.e., Google Scholar, Mendeley, Scopus, and Web of Science. The selection of papers in reputable journals and several proceedings was carried out to identify research directly related to the contribution of agroforestry to smallholder food security and business prospects in Indonesia. Papers about agroforestry related to climate change adaptation and mitigation were also examined. Previous studies have assumed that agroforestry is an appropriate practice in the era of climate change for adaptation and mitigation, so it still contributes to food security and livelihood [8,21,48]. After removing any duplicates and considering the timeframe for the study, we selected 38 documents for thorough review by considering their relevance. The stages of searching and screening the publications are shown in Figure 1.

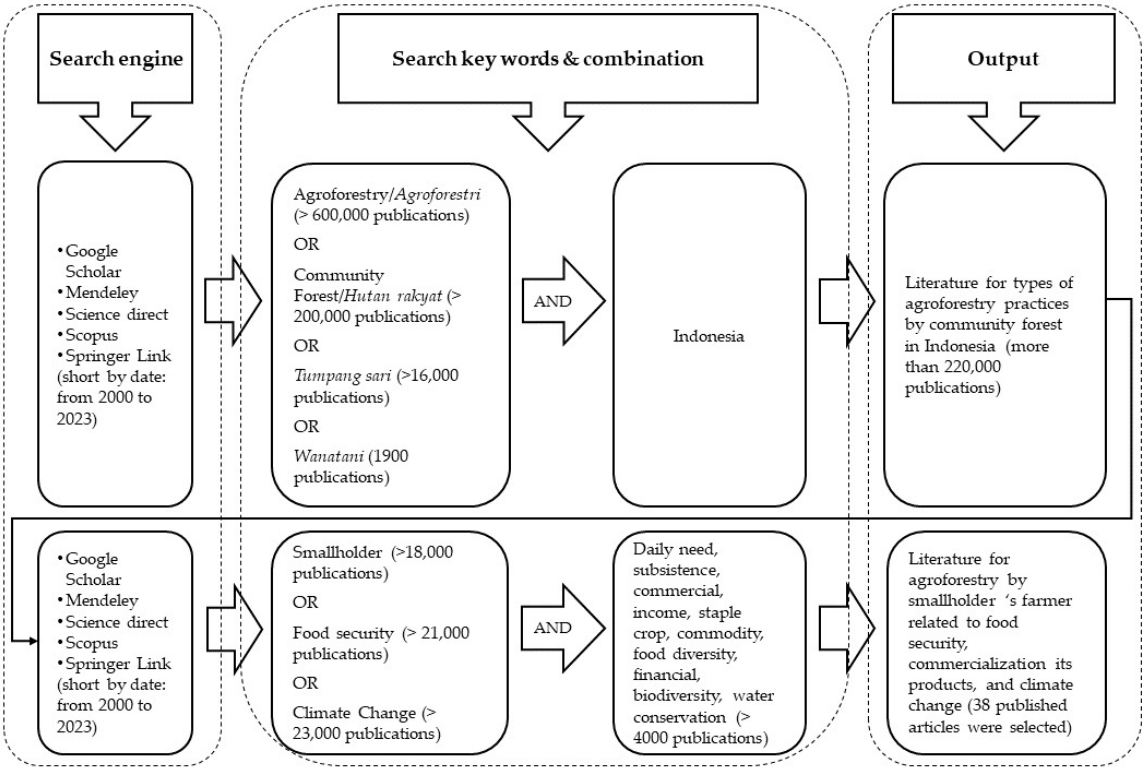

Figure 1. Stages of literature selection from various web-based databases. The process was adopted from Paudyal et al. [49].

The review was carried out by reading the content of the literature in detail. Relevant information was carefully compiled point by point, and scientific interpretations were made by using narrative qualitative and narrative compare analysis methods, including tables and figures [50]. The analysis process classified business and food security of smallholder agroforestry practices in Indonesia. Agroforestry businesses were classified as (1) subsistence, (2) semi-commercial, and (3) commercial [51]. 'Subsistence' agroforestry is typically applied to small areas with various crops in random planting arrangements and less intensive maintenance. Farmers manage subsistence agroforestry to meet their daily needs through day-to-day activities mainly related to providing family food. Any timber plantations are considered savings and a source of income when smallholders need money, with the timber being cut and sold. 'Semi-commercial' is an intermediate or transitional form of agroforestry, from subsistence to commercial, characterized by cultivating semi-commercial plant species with products that the household can consume and sell locally [51]. 'Commercial' agroforestry consists of two to three combinations of plant species, one of which may be the staple or main commodity developed on a broad scale with adequate technological input [51]. Commercial agroforestry requires professional management and a well-organized supply chain.

Food security consists of supply adequacy, simple physical or economic access, utilization, stability, and sovereignty [52]. Based on the World Food Program [53], food security is classified into six priority groups: 1 to 2: most vulnerable; 3 to 4: moderately vulnerable; and 5 to 6: food secure. The criteria used are food access, dietary diversity, nutritional security, and income [53]. Based on this method, related to food security, we found vulnerable food prospects on all islands in Indonesia: Sumatra (priorities 2–6); Kalimantan (priorities 3–6); Sulawesi (priorities 2–6); Java (priorities 2–6); and West Nusa Tenggara, East Nusa Tenggara, Maluku, and Papua (priorities 1–4) [29,53]. The logical framework of the literature study was qualitatively described, analyzed, and synthesized (Figure 2).

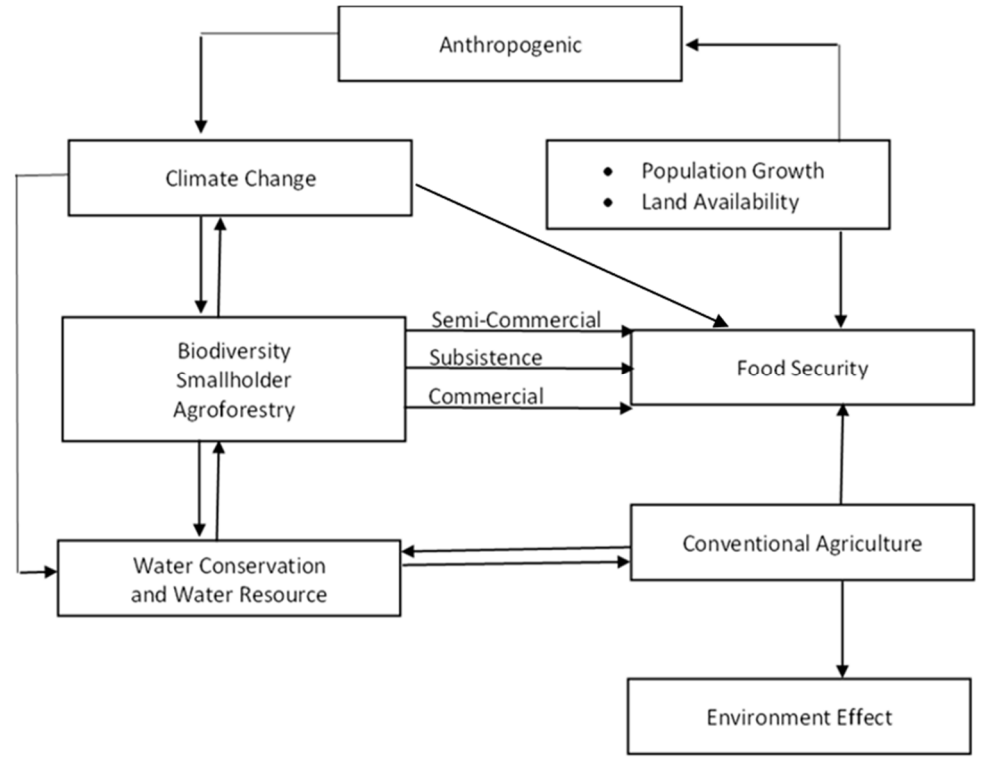

Figure 2. The logical framework of the literature study.

The criteria of the food security level in this study are determined by the level of food availability and dietary diversity. 'High' indicates an adequate staple food quantity that meets farmers' daily needs, with the example of agroforestry in which diverse food sources—such as staples, fruits and vegetables—are produced. 'Medium' indicates food produced only during particular seasons; typically, the diversity of crops is lower than the high level. 'Low' indicates restricted food availability and dietary diversity, even with no food crops in the agroforestry system. The level of food security, which reflects the level of crop diversity, is related to the resilience to climate change. The higher the contribution to food security and the higher the biodiversity from agroforestry practices, the higher the level of resilience and mitigation in the climate change era.

3. Results

Based on the representativeness of smallholder agroforestry practices in Indonesia (Figure 3), we found 33 references to be grouped into three business levels as indicators of their contribution to smallholders' livelihoods and local community food security. In total, 33 peer-reviewed studies were grouped into business types and their prospects for food security. In total, 8 peer-reviewed studies on subsistence agroforestry practices, 19 studies on semi-commercial agroforestry practices and 5 studies on commercial practices explicitly fit the definitions of the three business types.

Agroforestry practices are related to access to food, food diversity, nutritional security, and income of smallholder farmers in rural areas. Forty-two percent (42%) of the peer-reviewed studies were directly related to contributions to a community's food needs. At the same time, 19 (58%) peer-reviewed studies were related to the contributions of increasing income, which means an indirect contribution to meet a community's food needs. From 14 reviews of direct contributions to domestic food consumption, households were grouped into low (6 cases or 43%), medium (7 cases or 50%), and high (1 case or 7%) contributions.

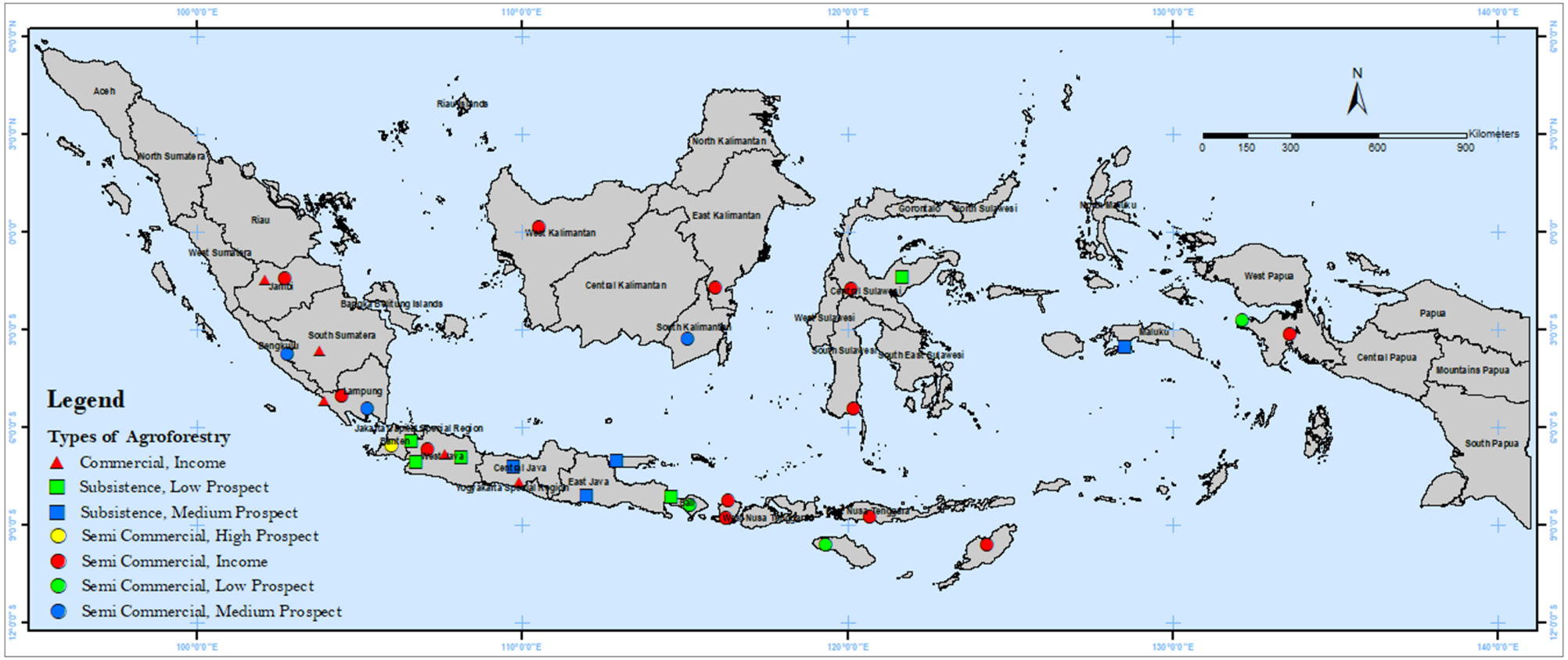

Figure 3. The prospect level of business and food security from different types of agroforestry practices in Indonesia.

Of the 33 peer-reviewed studies, we found that most smallholders practiced NTFP-based agriculture (29 studies), and only four cases practiced timber-based agrisilviculture. The results of the review indicate that the composition of plants in agroforestry was impacted by several factors, such as the width of the agroforestry area, the location, and the farmer's economic background, culture, and beliefs. Agroforestry plants were often cultivated in the form of (1) timber species, such as teak, *sengon* (*Falcataria falcata* (synonyms: *Albizia falcata*, *Falcataria moluccana* and *Paraserianthes falcataria*) and mahogany (*Swietenia* spp.); (2) multipurpose species, such as mango, durian, coconut and sugar palm; (3) food crops, such as upland rice, maize, cassava, taro, and sweet potatoes; (4) high-value commodity crops, such as cocoa, clove, nutmeg and coffee; (5) spices and medicinal plants, such as chili, ginger, turmeric, and galangal; and (6) fodder, such as *Leucaena leucocephala*, *Gliricidia* sp., and *Erythrina* sp. In some areas, the greater the area of land for agroforestry, the greater the proportion of trees compared with annual crops [54].

Moreover, agroforestry's contribution to the total revenue varies greatly depending on plant composition and land size [46,54–58]. Communities frequently practice agroforestry on small plots of land and prioritize supplying their basic needs. Therefore, the business classification of agroforestry in Indonesia is often 'subsistence' or 'semi-commercial'. Only 7 peer-reviewed studies provided detailed financial analysis, and most of the studies (26 articles) only stated the contribution to food production and the percentage of contribution to the total income of smallholders, which was related to complicated commodities, most of which were side businesses, meaning that such smallholder production was generally not recorded with detailed production inputs and outputs. From the seven peer-reviewed articles, six studies were classified as 'semi-commercial' agroforestry, and only one study was 'commercial' agroforestry. Agroforestry practices, which consist of high-value commodities—such as coffee, cocoa, rubber, and nutmeg—provide higher contributions to smallholders' incomes. The average NPV from this agroforestry system was more than IDR 4 million (≈USD 256 as of July 2023) per year. The Internal Rate of Return (IRR) was higher than the interest rate; the ratio of benefit and cost (BCR) was more than 1. The main contribution of this agroforestry system was income for smallholders, but a lack of food production is an issue, as illustrated in West Java, West Timor, West Nusa Tenggara, West Papua, and Central Java.

3.1. Subsistence Smallholder Agroforestry Practices

A 'subsistence-scale' business means that most products are consumed directly to meet the domestic needs of the household, and only a small portion, if any, is sold to the market. 'Subsistence-scale management' means cultivating various plants with non-intensive maintenance in the yard or field around a smallholder's house. This is similar to the type of complex agroforests, tree-dominated home gardens, or smallholder tree crop plantation agriculture that rural households have established to obtain short-, medium- and long-term income [59]. As an example, in West Bandung, most smallholders used their farm products for domestic consumption: only 3.03% sold their products [60].

Based on nine references (Table 1), the cases of intercropping crops under teak in West Java [61] and alley cropping in Bali [62]; *dusung* traditional agroforestry in Maluku [63], mixed cropping in Central Java [64] and Central Sulawesi [57]; home garden agroforestry in Central Java [65], West Java [66], and Madura [67]; and agroforestry farms (teak and fruits) in Gunung Salak, Bogor, West Java [68]; were grouped as 'subsistence' businesses (consisting of NTFP-based agrisilviculture (eight cases) and timber-based agrisilviculture (one case). Most of the studies focused on densely populated areas in Java, Madura, and Bali, with limited community forest land areas. The contribution prospects to food security were five cases (low), which included two cases of alley cropping, two cases of home garden and one case of farm agroforestry with mixed agroforestry. Only two cases had a medium contribution to food security.

The other characteristic of subsistence agroforestry is the variation in food crops. While the other studies had fewer direct links to food availability, some contained elements of

relevance to food access. The peer-reviewed studies showed that there were two cases of subsistence alley cropping of food crops (chili, rice, maize, peanut, cassava, and medicinal plants) among woody stands [61,62]. The tree species that made up this system were also relatively diverse, such as teak, *Azadiractha indica*, *Leucaena glauca*, *Swietenia macrophylla*, *Albizia falcataria* and *Dalbergia latifolia.* In the mixed cropping pattern (five cases), most were a combination of timber and fruit trees, annual food crops, *mpon-mpon* (medicinal plants) and fodder. This mixed cropping pattern was usually applied to fields and private forests owned by smallholders. The diversity of plant species in the mixed cropping pattern was relatively high, making it more multifunctional in its ability to meet various needs and positive adaptation to climate change. Home garden agroforestry featured food-oriented commodities for direct domestic consumption, such as chili peppers, tomatoes, spinach, long beans, and fruits and decorative and medicinal plants (two cases) [68,69].

3.2. Semi-Commercial Smallholder Agroforestry Practices

'Semi-commercial' is a transition from subsistence to commercial: the business may still be a mix of crops for subsistence and commodities for local-scale commercial sale. Our results show that applied agroforestry typically involves several crops, and each plays a subsistence and commercial function. Thus, the combination of crops produces multi-function agroforestry (semi-commercial). Table 2 features examples of semi-commercial agroforestry, including a combination of subsistence and commercial integration in mixed cropping in Lampung [70], cacao and coffee agroforestry in Central Sulawesi [71], rubber and fruit agroforestry in Jambi [72], fallow agroforestry system in East Kalimantan [73], coffee agroforestry in Lampung [74] and South Kalimantan [75], private forest agroforestry in Bogor, West Java [76], *huma* traditional agroforestry in West Java [77], *tembawang* traditional agroforestry in West Kalimantan [78], mixed garden in South Sumatra [79], *mamar* traditional agroforestry in West Timor [80], intercropping of agarwood in Flores [81], home garden agroforestry in South Sulawesi [54], *dusung* traditional agroforestry in Maluku [55], home garden with *trigona* [82] and mixed planting in West Nusa Tenggara [58], shifting cultivation garden [46] and yard agroforestry in West Papua [83] and mixed garden in Bali [84]. Nineteen agroforestry units are included in NTFP-focused agrisilviculture and only one is timber-focused agrisilviculture.

Agroforestry business contributes to food security in medium prospects (three cases), both a high contribution to food security (one case) and a low contribution (one case), and contributes to household income that can be used to buy staple foods (14 cases). MPTs and food crops in agroforestry play an important role in daily food availability for rural communities, although most only contribute to medium levels of food security. This is because agroforestry is only a side job for some rural communities. Semi-commercial agroforestry can be in the form of commodity crops and forestry plants (timber and NTFPs), including coffee, cocoa, candlenut, coconut, and rubber [51]. A semi-commercial type of business features various commodities that have subsistence and commercial functions. This is a form of balance between the interests of protecting biodiversity and commercialization, which, nevertheless, tends to reduce biodiversity.

Table 1. Subsistence business and food security of smallholder agroforestry practices in Indonesia.

No.	Type of Agroforestry	Agroforestry Commodity	Food Security	Business Prospect	Location and Source
1	Intercropping agricultural crops under teak	Teak (main species) and food crops (**)	L	S	West Java [61]
2	*Dusung* (traditional agroforestry)	Timber species, food crops, multipurpose tree species (MPTs), and high-value plantation crops (clove and nutmeg) (*)	M	S	Maluku [63]
3	Mixed cropping system agroforestry	Timber species, food crops, medicinal plants, and MPTs (*)	M + I	S	Central Java [64]
4	Home garden agroforestry	Food crops, spices, and MPTs (*)	M	S	Central Java [65]
5	Agroforestry farms (teak and fruits)	Teak (main species), other timber species, food crops, and MPTs (*)	L + I	S	West Java [68]
6	Home garden agroforestry	Food crops and medicinal plants (*)	L	S	West Java [66]
7	Mixed agroforestry	Timber species, high-value commodity crops (cacao), MPTs, fodder, spices, and medicinal plants (*)	L	S	Central Sulawesi [57]
8	*Taneyan lajang* (shared home garden)	Food crops, MPTs, fodder, spices, and medicinal plants (*)	M + I	S	Madura [67]
9	Alley cropping	Timber species (as main species), food crops, spices, and medicinal plants (**)	L	S	Bali [62]

Note: * NTFP-focused agrisilviculture; ** timber-focused agrisilviculture; S (subsistence); I (income); L (low-prospect food secure); M (medium-prospect food secure).

Table 2. Semi-commercial business and food security of smallholder agroforestry practices in Indonesia.

No.	Type of Agroforestry	Agroforestry Commodity	Food Security	Business Prospect	Source
1	Mixed cropping pattern/mixed garden	Timber species, MPTs, and high-value commodity crops (coffee, cocoa, and rubber) (*)	M (NPV: IDR 4,168,660.18/ha–IDR 4,589,627.36/ha)	SC	Lampung [70]
2	Cacao traditional agroforestry and coffee agroforestry	High-value commodity crops (cacao and coffee as main species) and fodder (*)	I	SC	Central Sulawesi [71]
3	Rubber agroforestry with fruit trees	Food crops, MPTs, and high-value plantation crops (rubber as a main species) (*)	I	SC	Jambi [72]
4	Fallow agroforestry system (oil palm, rubber, fruits, and rattan)	Food crops, MPTs, and high-value commodity crops (oil palm, rubber, and rattan as main species) (*)	I	SC	East Kalimantan [73]

Table 2. *Cont.*

No.	Type of Agroforestry	Agroforestry Commodity	Food Security	Business Prospect	Source
5	Protected forest (coffee agroforestry)	*Dalbergia latifolia*, high-value commodity crops (coffee as a main species), MPTs, and fodder (*)	I	SC	Lampung, Sumatra [74]
6	Private agroforestry	*Albizia moluccana* (main species), food crops, high-value commodity crop (clove) and MPTs (**)	I (NPV: IDR 64,197,125 (6 years); IRR 15%; BCR 2)	SC	West Java [76]
7	Coffee agroforestry with mixed garden and home garden/coffee and fruits)	High-value commodity crops (coffee as the main species) and MPTs (*)	M + I	SC	South Kalimantan [75]
8	*Huma* agroforestry	Food crops (rice as the main species), MPTs, and medicinal plants (*)	H	SC	Banten Province, Java [77]
9	*Tembawang* agroforestry	MPTs (main species), food crops, and medicinal plants (*)	I	SC	West Kalimantan [78]
10	Mixed garden and *talang*/*umo* agroforestry (traditional agroforestry)	MPTs, high-value plantation crops (coffee), and fodder (*)	M + I	SC	South Sumatra [79]
11	*Mamar* agroforestry	Timber species, food crops, MPTs, high-value commodity crops (cashew, cocoa, and coffee), and fodder (*)	I (NPV: IDR 19,862,245 (5 years); IRR 18%; BCR 1.63)	SC	Timor [56,80,85]
12	Intercropping of agarwood	Agarwood (as main species), high-value commodity crops (cacao, clove, coffee, and candlenut), MPTs (*)	I	SC	Flores [81]
13	Home garden	High-value commodity crops (cocoa, coffee, and cloves), MPTs, food crops, and fodder (*)	I	SC	South Sulawesi [54]
14	*Kaliwu*	Timber species, high-value commodity crop (coffee), and MPTs (*)	L + I (Income: IDR 103,100/month or IDR 4,520,863/year)	SC	Sumba, East Nusa Tenggara [86–88]
15	Home garden with *Trigona* sp.	MPTs and flowering plants (*)	L + I	SC	Lombok, West Nusa Tenggara [82]
16	Mixed planting	Mahogany, *Falcataria moluccana*, high-value commodity crops (cacao, coffee, and candlenut), and MPTs (*)	I (Income: IDR 14,942,031–38,547,093/year/ha	SC	Sesaot, West Nusa Tenggara [58]

Table 2. *Cont.*

No.	Type of Agroforestry	Agroforestry Commodity	Food Security	Business Prospect	Source
17	Shifting cultivation garden	*Instia bijuga*, high-value commodity crops (*Cryptocarya massoia*), MPTs, food crops, fodder, spices, and medicinal plants (*)	L + I (NPV: USD 10,965 or around IDR 163,334,000/ha (15 years))	SC	Teluk Patipi, Papua [46]
18	*Telanjakan, abian, kebon* mixed garden	Timber species, MPTs, food crops, fodder, spices, and medicinal plants (*)	L	SC	Bali [84,89]
19	Yard	Food crops, MPTs, high-value commodity crops (nutmeg), and spices (*)	I (Income: IDR 7,693,000/year)	SC	West Papua [83]

Note: * NTFP-focused agrisilviculture; ** Timber-focused agrisilviculture; SC (semi-commercial); I (income); L (low-prospect food secure); M (medium-prospect food secure); H (high-prospect food secure).

3.3. Commercial Smallholder Agroforestry Practices

Commercial agroforestry tends to be in the form of simple agroforestry with two or three combinations of plant species, one of which is a main commodity that is developed more intensively. Based on the reference (Table 3), our results show that this form of applied agroforestry features a few commodities, and each commodity plays a commercial function. Although this system is often a combination of commodities, it is typically only focused on two or three species for commercialization. So, the diversity of commercial agroforestry is significantly less compared to semi-commercial or subsistence agroforestry. This system cannot contribute directly to domestic needs (food) but obtains income, which increases consumption power to buy food. Commercial agroforestry will increase income but lower biodiversity. As an example, commercial vegetable agroforestry was found in home garden agroforestry systems in upstream West Java [90], dragon blood fruit agroforestry in South Sumatra [91], *repong damar* agroforestry in Lampung [92], oil-palm agroforestry in Jambi [93] and cardamom agroforestry in private forest in Central Java [94]. These cases were dominated by NTFP-focused agrisilviculture, with only one case of timber-focused agrisilviculture. All of them aimed at earning income and indirectly contributing to the fulfillment of domestic food needs of small holders. The income could be used for purchasing staple foods and meeting daily needs. Because the contribution of the commercial type of agroforestry is to obtain income, the possibility of contributing to food security, although not directly, is relatively high.

Table 3. Commercial business and food security of smallholder agroforestry practices in Indonesia.

No.	Type of Agroforestry	Agroforestry Commodity	Food Security	Business Prospect	Source
1	'Tradition to commerce' home garden agroforestry	MPTs, high-value commodity crops (onion, carrot, and cabbage) (*)	I	C	Upstream, West Java [90]
2	*Jernang* (dragon blood, *Daemonorps draco*) fruit agroforestry	Dragon blood (as the main species) and rattan (*)	I	C	Jambi and South Sumatra [91]
3	*Shorea javanica* agroforestry gardens (*repong damar*)	*Shorea javanica* (as the main species), other high-value commodity crops, food crops, or MPTs (*)	I	C	West Lampung, Lampung [92]
4	Oil-palm agroforestry	Oil palm and rubber trees (*)	I	C	Jambi [93]
5	Private forest agroforestry	*Falcataria moluccana* and cardamom (**)	I (NPV: IDR 33,599,884–IDR 112,039,098; IRR 13–35%; BCR 1.58–2.32 and revenue IDR 5,672,957–IDR 18,916,524/year	C	Central Java [94]

Note: * NTFP-focused agrisilviculture; ** Timber-focused agrisilviculture; C (commercial); I (income).

4. Discussion

Agroforestry in Indonesia is complex, as can be seen in the development of agroforestry as a form of community thought in the Indonesian archipelago. It shows the perseverance of agrarian communities in cultivating land that eventually becomes a distinctive hereditary culture in certain niches, thus creating diverse forms of agroforestry in Indonesia. Cultural background, preferences, and needs determine the peculiarities of agroforestry in each area. The influence of the surrounding environment and the information will also affect a person's decisions [95], including smallholders' decisions to plant species commodities on their land.

Agroforestry systems increased food production and improved environmental conditions, depending on the land management practices and tree management [96]. Silvicultural practices, such as planting, assisted migration, thinning, or natural regeneration, can cost-efficiently help reduce the impact of climate change on forest structure, composition, and function [97]. Smallholders with agroforestry systems are often aware of functionality in broad contexts, including different product uses, different tree characteristics (e.g., differences in phenology), or risk management options. For example, smallholders manage different species for different purposes, contributing to their livelihoods, addressing com-

petition between species, and assisting ecosystem processes [98]. The changing of a natural ecosystem to agroforestry practices and other uses has implications for livelihoods and ecosystem services [16,99].

Benefits from the impact of tree cover on climate at local, regional, and continental scales require broader acknowledgment [12]. Agroforestry provides smallholders resiliency to dryland conditions and climate change for accessing food, income, health, and ecosystem or environmental stability [29,53].

4.1. Food Security and Agroforestry Systems in Indonesia

The Indonesian smallholder has been developing agroforestry community forests as a source of food, NTFPs and timber since ancient times, demonstrating that community forests can be managed to meet the food needs of smallholders and contribute to national food security. As an illustration, community forests have been shown to contribute 61.34% of the daily food needs of communities, which were produced from 23 types of food crops [100]. In addition, agroforestry practices in community forests have been shown to produce 46.01% of food commodities, consisting of 12 types of food, for example, sugar palm (*Arenga pinnata*), cocoa (*Theobroma cacao*) and mango (*Mangifera indica*) [101]. Agroforestry practices in community forests in Lampung contributed to farmers' income by 53% and were sufficient for household food security [102]. However, communities with limited landholdings and a homogeneous local culture with traditional rice farming systems produce seasonal employment opportunities, reducing the risk of long-term tree cultivation with limited resources [19,96,103].

Complex agroforests with various commodity crops are the foundation of many businesses, which can be categorized as 'subsistence' for certain products and 'commercial' for others. Hence, it is not easy to determine whether an agroforest falls into 'subsistence' or 'commercial' prospects. For instance, agroforestry systems range from traditional to commercial in Bandung, West Java [90], rubber and fruit tree agroforestry in Jambi [72], fallow agroforestry (oil palm, rubber, rattan, and fruits) in East Kalimantan [104], and mixed garden (coffee and fruits) in South Kalimantan [75]. These four agroforests are forms of NTFP-focused agrisilviculture, which contribute to income and indirectly contribute to family food security. There is a mixed garden of coffee and fruit trees in South Kalimantan where fruits are consumed by the family, even though they are on a subsistence scale, and coffee is a commercial product. However, coffee agroforestry in Sumatra contributed 54% of household income compared to 12.5% from traditional agricultural components [74], and *damar* agroforestry contributed up to 51% of household income [92]. Smallholders' involvement in coffee agroforestry for the rehabilitation of degraded land resulted in greater social stability with an increase in incomes and greater access to agricultural land [34]. Several studies also highlighted a 'risk reduction' (specifically concerning lack of food from crop failure and income volatility) as an outcome of greater diversification through agroforestry [105–107].

The business feasibility of agroforestry is illustrated in the net present value (NPV), internal rate of return (IRR), and benefit/cost ratio (BCR) in some cases globally. The cases of agroforestry in Indonesia indicate that agroforestry is worthy of being cultivated as a business that achieves profits for smallholders. Income has been derived from timber species or high-value commodity crops such as coffee, cacao, cloves, and candlenuts. However, the commercial value of timber species and high-value commodity crops in agroforestry systems could decrease the availability or diversity of food crops. Smallholders could only cultivate food crops (corn, upland rice, peanut, banana, cassava, etc.) in the initial three years before the canopy of timber species or high-value crops closed [108].

Subsistence, semi-commercial, and commercial categories cannot always be a firm predictor of the prospect of income and welfare for landowners. Many factors make landowners choose this or that model of agroforestry. These factors include (1) the land area, which affects the prospect of land productivity; (2) the need for crops and the financial situation of the landowner; (3) the type and quality of commodities that can be cultivated;

and (4) market conditions (which are often influenced by access and transportation, which ultimately affect the demand and selling price of a commodity). The ability of the land to produce economic value can also be different in each area, depending on the tenacity of the cultivator, property security, type of commodity, smallholder's capital ability, market access, crop quality, and seasonal suitability. All of the above factors are intertwined and shape the pattern of agroforestry in Indonesia today. For example, the results of research in East Priangan [109] show that owing to lost demand during the peak of the COVID-19 pandemic, agroforestry products, which were originally for semi-commercial purposes, became full subsistence, with many crops not absorbed by the market because of poor road access, which further dropped commodity prices.

Several agroforestry practices were described as 'living savings accounts' by others, and they primarily became a significant source of revenue [90,110]. Agroforestry was a method to increase food production from the forest and a new source of income for smallholders, with increases ranging from 41.32–68.67% of total income [111,112]. Nonetheless, about 60.97% of smallholders in Lampung were classified as 'poor' [112]. This demonstrates that agroforestry, in this case, is a small business that can only fulfill basic livelihood needs by either using agroforestry products for domestic consumption or sale. Although the latter indirectly contributes to food production (particularly in commercial agroforestry), the income may also play a role in increasing the system's stability and resilience. Dependency on rice as a staple food will be reduced by diversifying agricultural commodities for subsistence prospects of semi-commercial systems.

On the other hand, the commercialization of agroforestry in rubber, coffee, cacao, and vegetables in uplands and palm-oil commodities elsewhere decreases plant diversity and smallholders' preference to grow food, mostly in semi-commercial and subsistence prospects [113]. This occurred, for example, in the Upper Citarum Watershed, West Java, where commercialization of short-term perennials with high international demand (e.g., cacao, coffee, and pepper) reduced the planting area for other fruit trees and food crops. In the same case, the commercialization of vegetables decreased the diversity of agroforestry [90]. Further, owing to a 20% decline in species diversity caused by the transition from subsistence to commercial agroforestry, some ecological and sociocultural functions were dramatically reduced [90]. Whereas commercial home gardens throughout the region directly increased food availability and utilization through income generation, the outputs were recognized as less diverse than traditional home gardens [29]. In Java, agroforestry practices in smallholder systems reduced access to food subsistence, and negative ecological effects could be reduced by planting fruit trees [68]. The commercialization of agroforestry tends to apply simple agroforestry (a mix of perennial and annual crops) with one tree species and one-to-a-few annual crops, which are ecologically not as good as complex agroforestry (a complex vegetation structure that looks like a forest) [59].

4.2. Food Security and Water Conservation in Agroforestry

In Indonesia, agroforestry has been applied predominantly to dry or marginal land in yards, fields, private forests, buffer lands of forest areas, and community forests. These lands are usually without irrigation, so they are very efficient in using water and relatively resistant to climate change. Although the increase in water productivity due to the microclimatic modification by tree crops tends to be limited [20,114], the existence of forests and trees as an agroforestry system plays a role in soil and water conservation and water use efficiency. Although the greater productivity of agroforestry is mainly due to the higher amount of water used [20,114], an agroforestry system is more resilient in the face of climate change and various drought and flood disasters [21,99,115–117]. The water function of natural forests with high biodiversity is impossible to reproduce if changed to oil-palm monoculture with shallow roots [118]. This can be anticipated by planting fruit or nut trees (such as stinky bean and jackfruit) using an agroforestry system, which promotes the development of multifunctional landscapes to conserve or increase the quality of catchment areas [17,119].

Agroforestry increases water productivity in two ways: (1) tree transpiration and (2) the resulting tree biomass [120]. Trees can link local to regional and global water cycles through modification of infiltration, water use, hydraulic redistribution of groundwater, and their role in rainfall recycling. Agroforestry contributes to improving ecosystem services for water, including transmission, buffering peak flows, increased infiltration, water quality, slope and riparian stability, reduced erosion, modified microclimate, coastal protection, and rainfall triggering [17]. Trees also affect a soil's ability to capture, store, and release water. The presence of litter (organic matter) assists soil in retaining water and improving soil structure and porosity [121]. In areas with limited water resources, the presence of trees as shade for coffee agroforestry systems can protect agricultural crops by reducing soil evaporation and coffee transpiration. Shade trees affect the microclimate (light, temperature, water saturation, vapor pressure deficit) and radiant energy in a system [122]. Tree canopy cover, understorey vegetation, and litter necromass are strong indicators of watershed health in terms of low run-off and high soil infiltration [11].

An illustration of quality enhancement in an agroforestry system is the shifting of cacao monoculture to cacao agroforestry, which increased the soil organic carbon by 1 g kg^{-1} (0.1%) and soil water capacity by 6% [123]. The application of agroforestry affected watershed quality indicators, such as controlling 97% of erosion, increasing 100% of water retention, and CN (curve number) below 80 [124]. In an upstream watershed, >55% of tree canopy cover was associated with infiltration rates, while in the midstream, >80% of tree canopy cover was qualified as an 'infiltration-friendly' land use [11,124]. In another example, in Palu Watershed, Central Sulawesi, various agroforestry patterns (alley cropping, alternate rows, random mixture, and trees along borders) resulted in low erosion rates: 5.17 g ha^{-1}; 4.93 g ha^{-1}; 0.78 g ha^{-1}; and 0.47 g ha^{-1}, respectively [125]. Additionally, agroforestry in mangrove forests with a silvofishery pattern enhanced water quality owing to the removal of nutritional pollutants (absorb nitrate, ammonia, and nitrite), oxygen level and pH improvement, and nitrate fixation, as well as shrimp culture production improvement [126–128]. In addition, agroforestry considerably improves smallholders' access to food in the face of potential severe famine crises triggered by climate change [129,130]. It also boosts livelihood resilience by reducing the reliance on remote product markets [68]. Smallholder agroforestry, practiced in a home garden, *tegalan*/dry land, or community forest, needs to be preserved as a form of natural ecosystem service for the adaptation and mitigation of climate change by providing biodiversity and soil and water conservation for the sustainability of future results [19,103].

4.3. Food Security and Biodiversity of Smallholder Agroforestry in Climate Change

Food security is one of the various ecosystem services that can be provided by agroecosystems (Figure 4). If an agroforestry area is focused on obtaining financial profit, then the form of agroforestry only tends to become more monocultural and will lose its multifunctionality [131]. In the era of climate change, the more biodiverse the agroforestry, the higher the carbon absorption and productivity, benefitting the livelihoods of rural communities and protecting nature [103,132]. In contrast to conventional agriculture, this smallholder agroforestry practice is clearly a form of smallholder resilience in obtaining food and livelihoods in the modern era, which positively affects the environment. Therefore, the practice of diverse trees in agroforestry needs to be maintained in order to provide ecosystem services and increase production for climate change adaptation and mitigation.

Figure 4. Three ecosystem services from agroforestry systems, adapted from Palacios and Bokelmann, 2017 [133].

There are two issues related to biodiversity in the implementation of agroforestry. First, the biodiversity constituents of agroforestry land: to ensure that agroforestry land has a variety of functions—provisioning, regulating, and cultural ecosystem services [95]—the biodiversity of species will contribute positively [134]. Biodiversity will help to reach ecological equilibrium at the household farm prospect, combat climate change, achieve food security, and expand market opportunities for communities [135–138]. In addition, Garí [139] concludes that for indigenous people, the preservation of biodiversity is crucial for ecological resilience, health care, and food security.

Second, the diversity of animal biodiversity: agroforestry is very likely to provide habitat but will not be able to replace the role of natural forests. Compared to old-growth forests, agroforests supported around 23% fewer species and 47% fewer endemic species [140]. It should also be noted that even in natural forests in Indonesia, wildlife is extremely difficult to find owing to poaching [141], especially on agroforestry land with easier access and where protection of animal biodiversity is not the core business of agroforestry farmers. There have been many studies that explain that wildlife and human conflicts often occur owing to the destruction of habitats whereby wildlife food security is affected by the establishment of agricultural (including agroforestry) businesses [107,142–146]. Forestry practices that frequently result in habitat homogenization, habitat heterogeneity, and forest biodiversity reduction are tightly related [147]. Ecosystems subjected to intensive management experience a decline in biodiversity as well as services, and forests that are subjected to intensive management show significantly reduced multifunctionality, which recovers more slowly the longer the practice is continued [148]. In general, expecting agroforestry land to be able to provide maximum environmental benefits and building intact forest–agroforestry gardens seem to be the best approaches, even though these require larger areas of land so that there may still be high prospects of both commercial value and food security.

Tree biodiversity resulting from agroforestry practices is a form of adaptation and mitigation of climate change. Climate change will affect the economic and environmental productivity of agroforestry practices. The higher the biodiversity, the higher the agroforestry productivity in the climate change era [51,138]. Increasing human populations will further increase anthropogenic activities that affect climate change [52,149]. Conventional agriculture's approach to increasing food production has been proven to have a negative impact on the environment, while agroforestry has been proven to be good from an environmental perspective (water and soil conservation, climate change adaptation, and biodiversity enhancement) [20,150]. Agroforestry businesses have built rural livelihoods that have contributed to food security, biodiversity, and environmental services to realize sustainable development [21]. Indirectly, agroforestry practices are related to the protection of rural ecosystems in providing income and food for the community in climate change conditions.

The ambition to strengthen food security in Indonesia is still great owing to the vast land resources. The Global Forest Watch summarized research results from Potapov et al. [151] and concluded that 24.1 million hectares of Indonesian forests were 'disturbed'. These degraded forests require reforestation, which can be an opportunity for society, biodiversity, and the climate to win [103]. Smallholders and biodiversity will both benefit from the restoration of degraded land [140]. The most recent project for reforestation is through the social forestry program, which covers 12.7 million hectares [152] and in which agroforestry has become the major activity. Having successful social forestry and reforestation programs will certainly help to improve food security in Indonesia.

Until recently, agroforestry in Indonesia has been challenged to achieve sustainability, and its adoption of characteristics of success at a broader scale is required [153]. There are technical, financial, market, and social constraints to agroforestry development, especially for smallholders [154]. This sector requires policy support from the government [155], indicated by currently unfavorable inter-sectoral policies, viz. legal frameworks and coordination between different government mandates, such as agriculture, forestry, rural development, environment, and trade [116]. In rural development planning, agroforestry is a strategically advantageous land use if the inherent complexities are considered in policy measures [156]. Successful agroforestry systems are characterized by well-functioning institutions, management, capacity building, and infrastructure [45].

5. Conclusions

Agroforestry in Indonesia is a crucial form of land utilization. The practice of agroforestry, particularly among small landholders, demonstrates adaptability to land conditions, household needs, and market opportunities, resulting in a diversity of agroforestry implementations. Most smallholders use agroforestry systems to earn income from product sales, timber as 'savings accounts', and food for daily consumption. Some smallholders do not produce food for domestic consumption from their agroforestry practices; however, they generate income from selling products that increase their purchasing power for food needs (57% of peer-reviewed case studies). Two studies show that agroforestry can contribute to smallholder's food needs by 46% to 61% and three studies state that agroforestry contributes to small farmers' income by 51–54%. The contribution of agroforestry to the income of smallholders is greater than that of traditional agriculture.

Furthermore, agroforestry contributes to SDGs through climate change mitigation (SDG 13) since unsuitable agricultural land can still substantially contribute to food provision (SDGs 2 and 15). Traditional subsistence agroforestry practices show high diversity in producing food, medicine, NTFPs, and timber (27% of peer-reviewed case studies). The commercialization of agroforestry with the intensification of several high-value plant commodities (oil palm, cardamom, vegetables, and dragon fruit) has reduced the environmental services produced in climate change adaptation and mitigation (15% of peer-reviewed case studies). The limited land availability for small landholders poses a constraint to meeting their food and income.

Nevertheless, the role of agroforestry remains highly significant, especially in the context of semi-commercial agroforestry, as it provides irreplaceable social security for small landholders in Indonesia. Semi-commercial agroforestry with a mixture of trees—commercial and subsistence species—has higher diversity, a form of 'local wisdom' in maintaining community forest sustainability and contributing to family income and food needs. Smallholder agroforestry practices in Indonesia are shifting from traditional subsistence agroforestry to semi-commercial agroforestry. It is necessary to promote complex semi-commercial agroforestry to maintain productivity in times of climate change with compensation or incentives for smallholders. Agroforestry practices can maintain landscape ecosystems with soil and water conservation and biodiversity to continue sustainably producing food and income for rural communities in an era of climate change. Therefore, it is not surprising that agroforestry practices are at the core of various forestry programs, including peatland, mangrove, critical land rehabilitation, and social forestry. Agroforestry plays a key role in environmental improvement efforts while delivering direct and indirect economic benefits to communities. This study confirms these findings. The weakness of this review is the limited quantification of agroforestry ecosystem services and the direct link between agroforestry and food security, so further research is needed. It is necessary to measure food production and livelihoods from the agroforestry sector outside the conventional agricultural sector by the Central Bureau of Statistics.

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