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Agroforestry, Livelihood and Biodiversity Nexus: The Case of Madhupur Tract, Bangladesh

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Abstract: Agroforestry has long been considered one of the most important land-use practices for conserving species while also meeting the fundamental requirements of millions of poor people in developing countries. Thus, the objective of the study was to determine the impacts of agroforestry practices on the livelihood development of rural farmers and biodiversity conservation potency in the Madhupur tract, Bangladesh. The study was conducted in the Madhupur tract, a famous agroforestry region in Bangladesh, using a mix-method approach to data collection, such as face-to-face interviews of 100 agroforestry farmers for livelihood analysis and using sampling techniques across 50 quadrats (20 m $\times$ 20 m) for measuring biodiversity. The results showed that the agroforestry practices significantly increased farm income and provided more benefits to rural farmers. Agroforestry farmers were able to build a social platform while simultaneously increasing their capability through training programs. As a result, the development of agroforestry farmers' livelihood capital was significant. At the same time, the agroforestry practices introduced 34 plant species into the bare forestland and, therefore, provided higher-quality habitats for biodiversity conservation. The fast-growing tree species, mainly *Acacia* (diversity index of 0.366), in association with partial shade-loving crops such as pineapple, turmeric, and ginger, were the most dominant species in the agroforestry practices of the Madhupur tract. The study also revealed that agroforestry serves as a wildlife corridor and attracts birds for feeding and breeding. Finally, the agroforestry of the Madhupur tract is a viable land-use practice for biodiversity conservation and livelihood development of rural farmers in Bangladesh, and it is highly suggested that it be strengthened and disseminated.

Keywords: livelihood assets; benefit-cost ratio; species richness; species diversity; agroforestry

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1. Introduction

The global population is rapidly expanding, with the United Nations estimating that it will reach 8.6 billion in 2030 and 9.7 billion in 2050 [1–3]. This scenario, together with current challenges, originated from previous and ongoing unjustified land-use practices, argues that we must immediately change the methods we employ to manage our arable lands and produce agricultural and tree products [4]. However, at the very beginning of agricultural innovation, farmers maintained or vigorously included multipurpose trees in their agricultural landscapes [5]. Trees provided food, fodder, fuel, shelter, energy, and a variety of other services and functions that allowed farmland to thrive. So, the products and services provided by trees support the basic requirements and promote the livelihoods of millions of rural farmers in the developing world. In the tropics, the cultivation of crops in association with trees (i.e., agroforestry) is a common phenomenon, but scientific knowledge about the use of trees on farmland has not been fully discovered, and much remains to be learned about the relationship between agroforestry and the environment.

Agroforestry practices are very promising and popular with over 87% of small-scale farmers in Bangladesh [6,7]. Bangladesh is a densely populated country, having a lower per capita arable land of 0.048 ha and forest land of 0.02 ha [8]. Despite this, more than 21.8% of the population is impoverished and heavily reliant on natural resources for a living [9,10]. As a result, tree-crop-based production systems in the context of the limited land resources of Bangladesh would be a good practice to improve rural farmers' food security and livelihood while also protecting biodiversity [11–14]. More than 50,000 poor farmers living in the Madhupur tract are practicing tree-crop-based agroforestry practices in the government's own degraded Sal forestland, which is locally known as Madhupur Garh [15–17]. So, agroforestry practices in the Madhupur tract have been a good alternative for local communities and the environment [14].

Madhupur Garh was once a biodiversity hotspot with a broad range of flora and fauna, but it is now one of Bangladesh's most endangered ecosystems [13]. Before 1947, the *Zamindar* (Landlord) controlled the Madhupur Garh, and during the British Colonial period, the *Zamindar* paid land tax to the British government. Following the British Colonial period, the Bengal government passed the East Bengal State Acquisition and Tenancy Act (EBSATA) in 1950, abolishing the *Zamindars*' ownership and placing the Madhupur Sal forests under the Bangladesh Forest Department. In order to gain control of the Sal forest, the Forest Department implemented a variety of forest management strategies that included local people [16,17]. The Forest Department, with the help of the World Bank and the Asian Development Bank projects, began participatory agroforestry practices in the Madhupur Garh in the 1980s [14]. Simultaneously, local residents have illegally settled in Madhupur Garh and implemented agroforestry practices. Thus, Sal forest deforestation has been accelerated by a lot of associated factors in which illegal settlement by the rural people was considered the leading factor in Madhupur tract, Bangladesh [11]. Agroforestry practices, on the other hand, have spread throughout the Madhupur Garh, resulting in profitable land-use practices [14].

It turns out that the world's and Bangladesh's biodiversity is changing at an uncontrollable and frightening rate. These trends of declining biodiversity will continue with population growth. Additionally, the effects of climate change and other anthropogenic disturbances will contribute to further habitat decline and biodiversity loss [18–20]. As seen in recent trends, it is projected that the world has lost almost 25% of species. That accounts for the decline of 27,000 species per year [21]. Commercial agriculture is commonly blamed for declining biodiversity. However, agricultural lands can nourish biodiversity with better management plans and support for the survival of species [22,23]. Furthermore, agroforestry has huge potential for conserving biological diversity; the pathways that agroforestry can provide include supporting habitats, preserving the germplasm of sensitive species, providing connectivity by creating corridors, and providing ecosystem services that prevent the loss of surrounding species [24].

Agroforestry practices in the Madhupur tract in the completely deforested and degraded forestland were started through initiatives by the government and local farmers in the 1980s [13]. Local farmers are cultivating seasonal crops in association with native and fast-growing exotic tree species, and these agroforestry practices are already very productive and well-known all over Bangladesh. More than 59% of Bangladesh's total pineapple production comes from the agroforestry practices of the Madhupur tract, and farmers receive a substantial amount of cash income from their agroforestry practices [25,26]. However, the livelihood development of rural farmers and species conservation of those agroforestry practices have not been determined systematically. Previously, only a few sporadic studies were carried out on the income generation of those agroforestry practices [13,17]. So, the study found a gap in the development of human, social, physical, natural, and economic assets of rural people and as well as the biodiversity conservation potentiality of agroforestry practices in Bangladesh. Thus, the study analyzed the impacts of agroforestry practices on the development of livelihood assets of rural farmers and the biodiversity conservation ability of the Madhupur tract, Bangladesh.

2. Materials and Methods

2.1. Conceptual and Theoretical Framework

The agroforestry practices of the Madhupur tract provide a number of socio-ecological benefits from local to global levels. The study analyzed the livelihood improvement pathway of rural farmers through a sustainable livelihood framework [27] and biodiversity using common (e.g., Shannon–Weiner) species richness and diversity indexes. Livelihood denotes the capabilities, properties (such as social and material), and activities required for a way of living. A livelihood is considered sustainable when it can recover from sudden shock and stress, increase its capabilities and assets, and not deplete its natural resources [28,29]. Usually, livelihood models focus on households as an effective social group for assessing livelihood development. For this study, we used the Department of International Development (DFID) sustainable livelihood model, particularly the livelihood capitals pentagon, as a point of reference (DFID 2001). The DFID's model looks at the basic dynamics of livelihoods and how farmers are characterized on a set of capitals as a basis for their daily lives [30,31]. Nevertheless, that framework is effective for describing the interrelationship among various livelihood capitals and its utilization in diversifying livelihood approaches to achieve required outcomes like- income in the enabling environment. The DFID called these five capitals human, social, physical, economic, and natural (Figure 1). The sustainable livelihood approach emphasizes that people require a variety of livelihood capital to achieve positive livelihood outcomes; thus, no single type of capital is sufficient to produce all of the various and varied livelihood outcomes that people require [27]. Because of this, the livelihood capitals are connected and depend on each other in order for people to have a sustainable way of life.

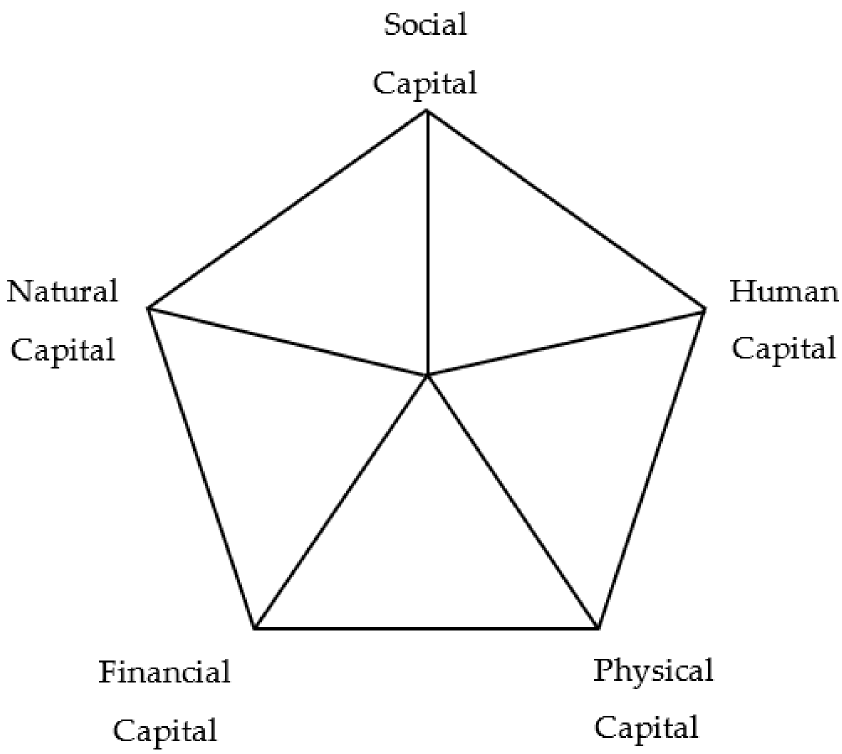

Figure 1. Dimensions, with sustainable livelihood capitals.

In the 1980s, the term "biodiversity" was commonly used as a synonym for biological diversity, and biodiversity is the traditional method of determining and separating species, in other words, including the variety and variability of living organisms [32,33]. In order to measure biodiversity, it is necessary to deconstruct some of the individual elements. However, biodiversity generally encompasses all kingdoms, including fungi, and there is no set definition of biodiversity, and often, it is re-defined according to the context and purpose of the scientists. Therefore, the study assessed the biodiversity of agroforestry in Bangladesh with the help of some common methods or formulas for species richness and diversity that are widely used in environmental science.

2.2. Study Area

The study was conducted in the Madhupur tract (45,565.2 acres), which is also called Madhupur Sal Forest or Madhupur Garh, situated across a major part of the Tangail and a small portion of Mymensingh (593 acres) districts of Bangladesh (Figure 1) [10,13]. Geographically, the Madhupur tract is located at 23′50° to 24′50° north latitude and 89′54° to 90′50° east longitudes, and the soil belongs to the bio-ecological zone of the Madhupur Sal Tract [11]. The soils on the top are better drained, friable clay loam to clay overlying the friable clay substratum across varying ravines. More than 50,000 farmers, including 20,000 ethnic people, are currently practicing tree-crop-based agroforestry practices in the Madhupur tract [13]. From statistics published in 2008, it was estimated that only one-third of the original Madhupur Sal forest coverage remained [34]. Accordingly, the agroforestry practices were implemented in the deforested forestland with the involvement of local people. Hence, the study selected five important villages, namely Jangolia, Makontinagar, Gaira, Auronkhol, and Joynagasa, for data collection (Figure 2).

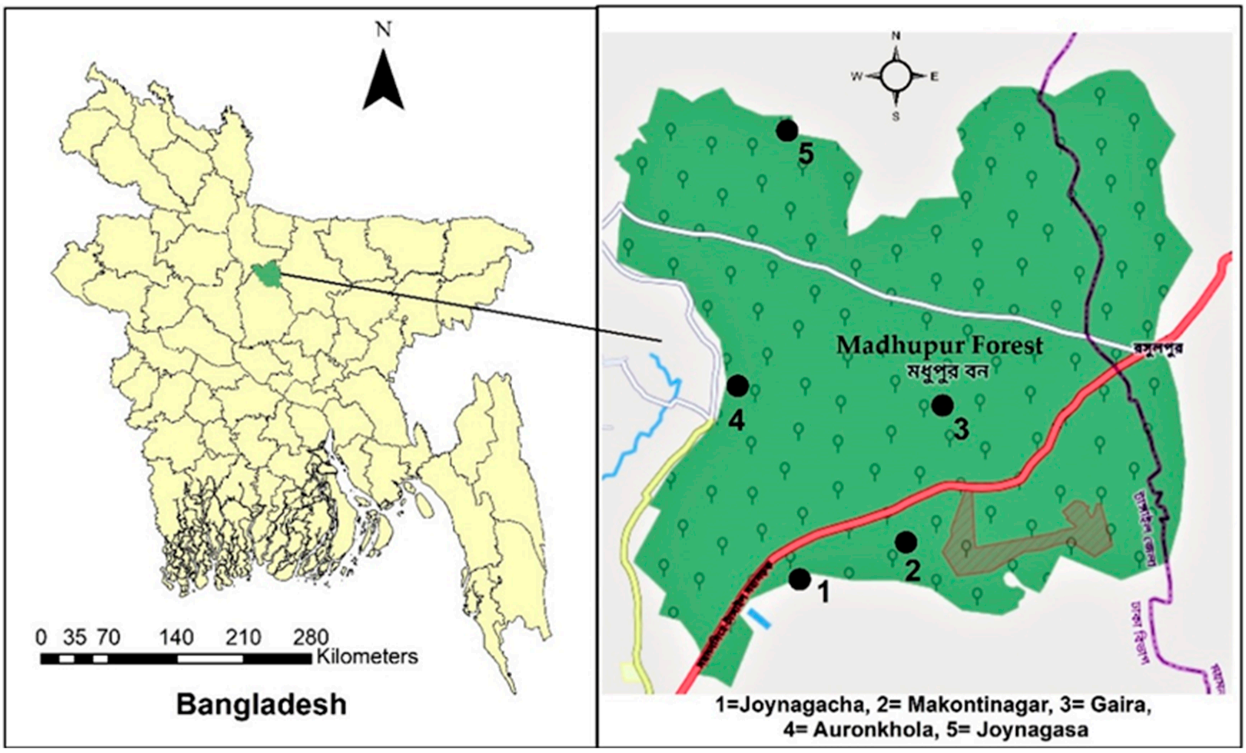

Figure 2. Study area map showing different villages of Madhupur tract and Bangladesh.

2.3. Data Collection

The study collected some basic information about agroforestry farmers and their practices through discussions with local farmers and forest officials in the Madhupur tract. The study followed a mix-method approach for data collection, i.e., for livelihood data, the study used face-to-face interviews, focus group discussions, practical observation techniques, and quadrat (size 20 m × 20 m) techniques for biodiversity assessment. A total of 100 agroforestry farmers were chosen at random from five different villages for an interview using a questionnaire, and for species richness and diversity, the study selected 50 quadrat sampling plots. We chose 50 quadrat plots at random to represent the full situation because the Madhupur Garh farmers' socioeconomic conditions and agroforestry methods were not significantly different. The face-to-face interviews were conducted with the help of a semi-structured questionnaire, which consisted of socioeconomic information, income from agroforestry components, input costs of all items, cost of total production of the agroforestry program, improvements of five livelihood capitals, sudden shocks, stress, food sufficiency, road infrastructure, marketing systems of agroforestry products, and other social information. Interviews were carried out in the daytime with the help of two MSc students from the Bangladesh Agricultural University. However, the five case studies were conducted in the village common places, where farmers gathered, gossiped, and shared their views. The farmers were informed about the focus group discussions, and their common perceptions, ideas, and problems related to agroforestry practices were recorded accordingly. For the general and common problems for all of the farmer-related decision-making questions, the study would repeat the question, and the collected data would be verified and cross-checked. The data collection was carried out from March to September 2021.

In parallel, the study obtained plant biodiversity data through 50 quadrat plot (size of 20 m × 20 m) techniques from the 50 agroforestry farmers' land. The size of each quadrat was set at 20 m × 20 m, with a mature tree having a dbh of 10 cm, a 10 m × 10 m sub-quadrat for measuring shrubs and climbers, and a 5 m × 5 m sub–sub-quadrat for measuring crop and seedling data, respectively (Figure 3).

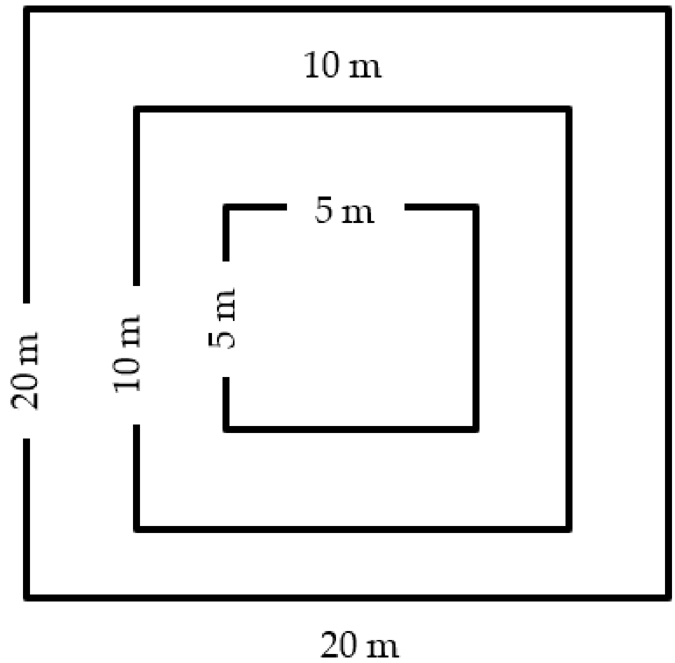

Figure 3. A sample quadrat plot (20 × 20 m^2) with sub and sub–sub plot.

The following equations were used to measure the species richness and diversity data from the agroforestry practices:

Species richness: the species richness denotes the number of different species in a specific area. It was calculated to measure the sensitivity of the agroforestry ecosystems and their resident species.

Species-area curve: It was designed from the total number of plant species found at different sample plots to capture the maximum number of plant species in the study area.

Shannon–Wiener Index: Also called the diversity index, which expresses the total number of species in a habitat (richness) and their relative abundance. The Shannon–Wiener index was measured using the following formula given by Magurran (1988) [35]. $H' = -\sum_{n=1}^{n}(pi \times \ln\ pi)$, where H′ = Shannon diversity index, pi = proportion of individual of ith species in an entire community, n = individual of a given species and N = total number of individuals in a community.

Evenness: Is the calculation of the relative abundance of the different species that constitute the richness of an area. The evenness is calculated following the formula given by Magurran (1988) [35]. E = $\frac{H'}{\ln S}$ where E = Evenness of the species in an ecosystem, H′ = Shannon index, S = number of species.
Similarity index: The similarity index, also known as the community coefficient, is calculated to find out how the species overlap, as well as their similarities and contrasting differences between ecosystems or forests. The similarity index was calculated using the Jaccard and Sorensen index [36,37]. Jaccard Index = $j/(a + b + c - j)$, Sorensen Index = $2S$ $(A + B + C)$, where j/S = number of species common along the three zones and a/A, b/B, c/C = number of species in zone A, B, and C, respectively.
Simpson index: Also called the Concentration of Dominance (CD), is often used to quantify the biodiversity of a habitat. The Simpson index takes the number of species present into account, as well as the abundance of each species, which is determined by the following formula [38], CD = $-\sum_{i=1}^{s}(Pi \times Pi)$, where pi = proportion of individual of ith species in a whole community.

2.4. Data Analysis

The agroforestry trees and crops provided different outputs at different times of the year, so the study calculated the outputs of agroforestry outputs on a yearly basis and converted them into a hectare. Therefore, the total productivity (tree and crops) of each agroforestry system was calculated and converted into the local currency of Taka (1 USD≈ 85 Taka); however, the study also determined all the production costs based on a year per hectare basis. The BCR (Benefit-Cost Ratio) of each agroforestry practice was determined, BCR $= \frac{\sum_{i=0}^{n} B_t(1+i)t}{\sum_{i=0}^{n} C_t(1+i)t'}$, here, B_t = total income in ith year, C_t = total cost in ith year, t = number of years, and i = interest (discount) rate (assuming 11% interest rate). Finally, the collected livelihood data were tabulated and analyzed using the Computer Microsoft Excel Software program.

3. Results

3.1. Description and Economic Outputs of Agroforestry Practices

The study found that fast-growing trees (e.g., *Acacia auriculiformis* (*Akashmoni*), *Eucalyptus cameldulensis* (*Eucalyptus*), *Melia azedarach* (*Gora Neem*), *Gmelina arborea* (Gamar), and *Azadirachta indica* (*Neem*)) in association with shade-loving (pineapple, aroid, turmeric, and ginger) crop-based agroforestry were the most common practices in the entire Madhupur tract. In addition, the local Sal (*Shorea robusta*), Mahogany (*Swietenia mahogoni*), Jarul (*Lagerstroemia speciosa*), Bohera (*Terminalia bellirica*), and Teak (*Tectona grandis*) trees alone with shade-loving crops-based agroforestry practices were also observed in the study area. The fast-growing tree species provided a quick economic return, and farmers could harvest timber after a 10-year cycle. Thus, the majority (over 97%) of the agroforestry practices were fast-growing trees with shade-loving crop-based systems. In these agroforestry practices, the farmers first planted fast-growing trees along the boundary and inside of the field (maintaining wide spacing) and then transplanted seasonal crops in line × row techniques. In this way, around 24,000 pineapple suckers, 600 kg of turmeric/ginger seed, and 200 trees would be able to fit in one hectare of agroforestry land. These agroforestry practices were followed to maximize the utilization of land resources with multiple crop outputs (e.g., pineapple with aroid or ginger or turmeric) at a time. The study observed that three types of agroforestry practices were the most common and dominated (over 97%) in the Madhupur tract of Bangladesh, which were fast-growing trees (mostly *Acacia* alone with a few *Eucalyptus*, *Neem*, and *Gora Neem*) with pineapple-aroid or pineapple-turmeric or pineapple-ginger crop-based agroforestry practices (Figure 4). A complete list of all agroforestry tree species and their relative abundance is presented in the biodiversity section.

Pineapple-Ginger crops based AF Pineapple-Turmeric crops based AF Pineapple-Aroid crops based AF

Figure 4. Three most common and profitable agroforestry practices in Madhupur tract, Bangladesh.

Economic outputs play the most significant role in cultivating and continuing tree-crop-based agroforestry practices in the world. The economic analysis of the most common agroforestry practices showed that the Madhupur tract agroforestry practices required a huge amount of agricultural labor, which was considered the major input cost for farmers (Table 1). The labor cost was calculated by the total man-days (a man-day is 8 h, and one man-day wage is around 6.9 USD) required to cultivate an agroforestry field. The acacia tree is highly suitable for the local climate and easy to propagate, so the cost of seedlings was low (around 20 Taka/seedling). However, the initial cost of buying seedlings and crop planting materials was quite high, and often farmers borrowed money or took out loans to purchase the planting materials. Additionally, the fertilizer, manure, weeding, and harvesting costs of agroforestry practices contributed to higher production costs (Table 1). On the contrary, farmers received a significant amount of income from the seasonal output of crops. The final income from the trees was higher, but the cycle of the fast-growing tree harvesting phase would be 10 to 12 years. The farmers in Bangladesh did not want to grow trees that took a long time to grow, so they did not want to use slow-growing tree-based agroforestry. The study looked at how much money trees make in the current market and expressed it in Taka per hectare per year. The result revealed that the cost of production for pineapple-aroid-based practice was low; therefore, the Benefit–Cost Ratio (BCR) of that agroforestry practice was the highest (2.81) (Table 1). The pineapple-turmeric-based agroforestry practice provided the lowest BCR value of 2.03 compared to the pineapple-aroid and pineapple-ginger-based practices. When compared to the total gross income, the pineapple-ginger-based agroforestry practices (674,900 Taka) were found to be the best practices in the Madhupur Table 1).

3.2. Livelihood Development of Agroforestry Farmers

Demographic characteristics of the agroforestry farmers: The farmers of Madhupur Garh were 36-years-old on average (Table 1). The male to female ratio in farmer households was 48:52. Farmers have a lower literacy rate (34%), which is lower than Tangail's entire civil district literacy rating of 47.8% [7]. Farmers in Madhupur Garh had larger families than the national average of 4.8 [7]. Agroforestry farmers owned 0.32 hectares of land on average (Table 2). Land ownership, on the other hand, is owned by the government, which means that farmers do not have proper land ownership rights. Agroforestry farmers' major sources of income were agriculture and day work (Table 2). The distribution of farmer households by origin provided the most significant demographic data, with 76 percent of agroforestry participants hailing from different districts (Table 2). In terms of religion, the farmers follow the Islamic faith (86%).

Table 1. Cost of production and income from fast-growing tree and shade-loving crops-based agroforestry practices.

Items	Agroforestry Practices		
	Pineapple-Turmeric Based AF	**Pineapple-Ginger Based AF**	**Pineapple-Aroid Based AF**
Cost (USD)			
Tree seedlings/saplings costs	232.56	191.86	215.12
Land preparation costs	180.47	165.12	98.84
crop seedlings/rhizomes/sucker buying costs	356.40	377.91	191.86
Labor costs	759.30	877.33	473.84
Fertilizer and manure costs	236.05	299.42	99.42
Insecticides and pesticide costs	239.53	87.79	40.70
Weeding and Irrigation costs	143.02	145.93	98.26
Harvesting costs	297.67	411.63	261.63
Sticks	98.84	66.28	58.14
Transport	8.02	9.88	14.53
Tree seedlings costs	144.19	190.70	145.35
Land Price (100 Decimal) *	87,209.3	87,209.3	87,209.3
Total Cost of Production	2486.74	2823.84	1697.67
Return (USD)			
Timber income	488.37	465.12	511.63
Thinning income	58.14	75.58	104.65
Firewood income	23.26	25.58	23.26
Fodder income	6.98	13.95	8.14
Crops income	4476.74	7267.44	4127.91
Total Gross Income (USD)	5053.49	7847.67	4775.58
Net Income (USD)	2566.74	5023.84	3077.91
BCR (Benefit–Cost Ratio)	2.03	2.78	2.81

* Land is owned by govt. so, we exclude land price to calculate BCR, 1 USD ≈ 86 Taka (BDT), AF = Agroforestry.

Table 2. Demographic characteristics of the agroforestry farmers living in Madhupur Garh.

Characteristics	Farmers
Age (Mean ± SD)	36.15 ± 8.80
Household size (Mean ± SD)	5.40 ± 1.20
Male: Female ratio	48:52
Per household landholding (ha) (Mean ± SD)	0.32 ± 1.30
Distribution of households by religion	
Muslim	86%
Christian	5%
Shangsarek	2%
Hindu	7%
Others	0
Households' main sources of income	
Agriculture/Jhum	39%
Wage labor	32%
Business	7%
Unemployment	11%
Fuelwood and NTFPs collection from forests	5%
Others	6%
Distribution of households as origin	
From same area/village	8%
From same district (not same village)	15%
From another district	76%
From another country	0

Regarding the farmers' human capital of skills, knowledge, health, and educational status, the study found out that the local forest department and NGOs offered several training sessions in order to raise the local farmers' awareness of forest conservation, agroforestry, and other aspects. Most of the training sessions lasted from 1 to 3 days, and these sessions played an important role in building the farmers' capabilities and skills. More than 90% of the agroforestry farmers received training either from the Forest Department (FD) or NGOs (Table 3). This training also raised the farmers' awareness of species conservation and community development. It was also observed that the farmers who had received training were able to manage their agroforestry practices in more effective ways than those who had not received training. However, two farmers mentioned that due to an antagonistic relationship with the local FD, they did not attend the training programs. The farmers mentioned that the training program conducted by the FD helped them to enhance their knowledge and skills in tree management, cultivation of multiple components together, and leadership development as well. The overall literacy rate of the agroforestry farmers (33%) was far below the national average of 74.9% (Table 3). The availability of family labor for agroforestry farmers was 1.75, but it was declining. The public health care systems of Bangladesh tend to have better coverage in urban areas when compared to rural areas. As the Madhupur tract is situated in rural and remote areas, the farmers' health care facilities were poor, and they had to rely on the nearest district hospital for treatment. The study observed that due to education and training programs, the awareness of agroforestry farmers has increased and has, in turn, improved the farmers' interest in modern medical systems compared to traditional herbal medicine.

Regarding the farmers' physical capital for housing, equipment, tools, infrastructures, etc., the study observed that the majority of the farmers' houses were made with tin walls and a tin roof (Table 3) and, in a few cases, brick walls and a tin-roof structures. Nearly all (97%) of the farmers had radios, black and white televisions, and some kitchen appliances. The presence of valuable household appliances indicated that the agroforestry farmers had improved living standards compared to 10 years prior. The study found out that the agroforestry farmers were living in a remote area, which was quite far from the main and only market (an average of 6.2 km) of the Madhupur tract. However, the farmers reported that the road structures were improving from muddy structures to the bitumen-sealed type (Table 3). Regarding livestock, the farmers had 7.25 small (chicken and duck) and 2.40 big (goat, pig, cow/bull) livestock, which could be sold to withstand a family crisis or sudden shock (Table 3). Almost 88% of the farmers stated that they purchased large animals after receiving crop income from agroforestry practices. The overall landholding of the farmers was low, and it was due to the fact that the Madhupur Sal forest belongs to public property.

At the same time, social networks, platforms, and community relationships are critical for farmer-livelihood development, and in developing countries such as Bangladesh, the government frequently combines the social and economic issues [39]. The study found that the agroforestry practices created a new social platform among the farmers. On a five-point Likert measurement scale of very good, good, neutral, bad, and very bad (5 points), the study revealed that the agroforestry farmers had very good relationships with other farmers in their communities, while they had a bad relationship with the local FD (Table 3). Social capital, particularly relationship and trust capital, acted as an active catalyst to protect rural farmers from family crises and hardship. However, the overall relationship between the agroforestry farmers and other stakeholders in the community has been increasing, which, in turn, has created a sense of collective action among the rural farmers in the community. Agroforestry farmers also mentioned that the year-round income of the agroforestry practices had increased their annual food sufficiency rate to 11 months out of a year (Table 3).

The tree stock of the farmers' agroforestry plot was considered one of the important natural capitals of the farmers, and the study found that, on average, there are 225 trees in the farmers' agroforestry land (Table 3). The average number of trees in a farmer's homestead was 14.45, and it was observed that most of the trees belong to fruit and timber-yielding species. Free access to Madhupur Sal forest was banned by the government, and thus, the farmers' dependency on natural forests was minimized. Nevertheless, the agroforestry practices provide an alternative source of timber/firewood supplies to rural farmers and also play a role in decreasing the farmers' dependency on natural forests for firewood/timber. The study did not find any common watershed facilities for local farmers, but some farmers have small ponds on their homestead premises, and the majority have hand tube wells for drinking water facilities.

Table 3. Status of major livelihood capitals of Agroforestry farmers.

Items	Agroforestry Farmers	Current Trends
Human		
-Agroforestry training received from		
Govt./FD	76%	increasing
NGOs	17%	
Others	2%	
-Literacy rate	33	increasing
-Children school attendance rate	92	sharpy increased
-Available family labor (18 to 60 years)	1.75	declining
-Health care facilities	Medium to low	improving
Physical		
-Household structure	Tin-wall with tin-roof	Improving
-Road structure	Mostly brick with bitumen sealant	Good
-Land holdings	0.138 ha	Low
-AF practice distance from market	6.2 km	Bit far
-Livestock (small and big)	7.25 and 2.40	Improving
Social		
-Social organizations involved	11	Improving
-Relationship with FD/Govt. officials	Neutral to bad	Decline
-New social platform	Created	Positive
-Annual food sufficiency (month/year)	11	Improving
Natural		
-Number of trees in agroforestry plot	225	declining
-Number of trees in homestead	14.45	improving
-Dependency on natural forest	Low to zero	improving
-Watershed availability	Nil	immediate need
Financial		
-Household getting micro credit	61%	increasing
-Sources of household income		
Agroforestry practices	64%	
Agriculture and Livestock	21%	improving
Labor/Wage	12%	
Remittance	2%	
Others	1%	
-Annual expenditure (% of total income)	93%	

Lastly, financial capital denotes the financial resources that farmers use to attain their livelihood objectives [27]. In the Madhupur area, most of the rural farmers (61%) were taking loans from NGOs or other private organizations with a higher interest rate (around 11%) in order to cultivate seasonal crops, buy livestock, and repair houses. Regarding the farmers' household income sources, the study found that agroforestry income was the main source (64%), followed by agriculture and livestock (21%), day labor (12%), remittance (2%), and other (1%, small businesses) (Table 3). The higher income from the agroforestry practices also had a positive impact on the farmers' annual savings, i.e., the agroforestry farmers' annual expenditure was about 93% of their total income. Although the farmers' annual savings was only about 7% of their total income, it showed a positive indication in terms of the agroforestry farmers' financial capabilities.

3.3. Biodiversity Conservation through Agroforestry Practices

Biodiversity is a vital basis for the development of an ecosystem and the whole landscape of a given area. It comprises everything that is visible and invisible required to sustain life on Earth. The study also discovered the species richness, dominance, and diversity of the homestead plants of the Madhupur tract of Bangladesh.

Species richness: In the Madhupur tract, 34 plant species were identified, of which 26 were trees, two were shrubs, and six were herbs species (Table 3). Among these species, acacia or locally called akashmoni (32.9%), pineapple (21.0%), turmeric (7.6%), ginger (6.9%), papaya (2.7%), gliricidia (2.7%), taro (2.7%), eucalyptus (2.4%), and guava (2.3%) were the dominant plant species (Figure 3). It was found that Akashmoni was the most dominant species in the Madhupur tract. These 34 plant species belong to 23 families and 33 genera. Among 23 families, Meliaceae has the highest species richness of five, followed by Fabaceae with a species richness of three, Zingiberaceae, Lamiaceae, Sapindaceae, Myrtaceae, and Rutaceae with a species richness of two, and the other 16 families with a species richness of one (Table 3). Among the 33 genera, Swietenia had the two highest species, followed by the rest of the 32 genera with a single species (Table 4).

Diversity Index: The diversity index of the Madhupur tract was recorded from 0.0078 to 0.3657. The highest diversity index was observed in the species akashmoni (0.3657), followed by pineapple (0.3279), turmeric (0.2317), ginger (0.1842), papaya (0.0969), gliricidia (0.0969), and the lowest (0.0138) in guava (Figure 5). This result indicates that the species of acacia widely was dispersed or spread all over this region, followed by pineapple, turmeric, and ginger.

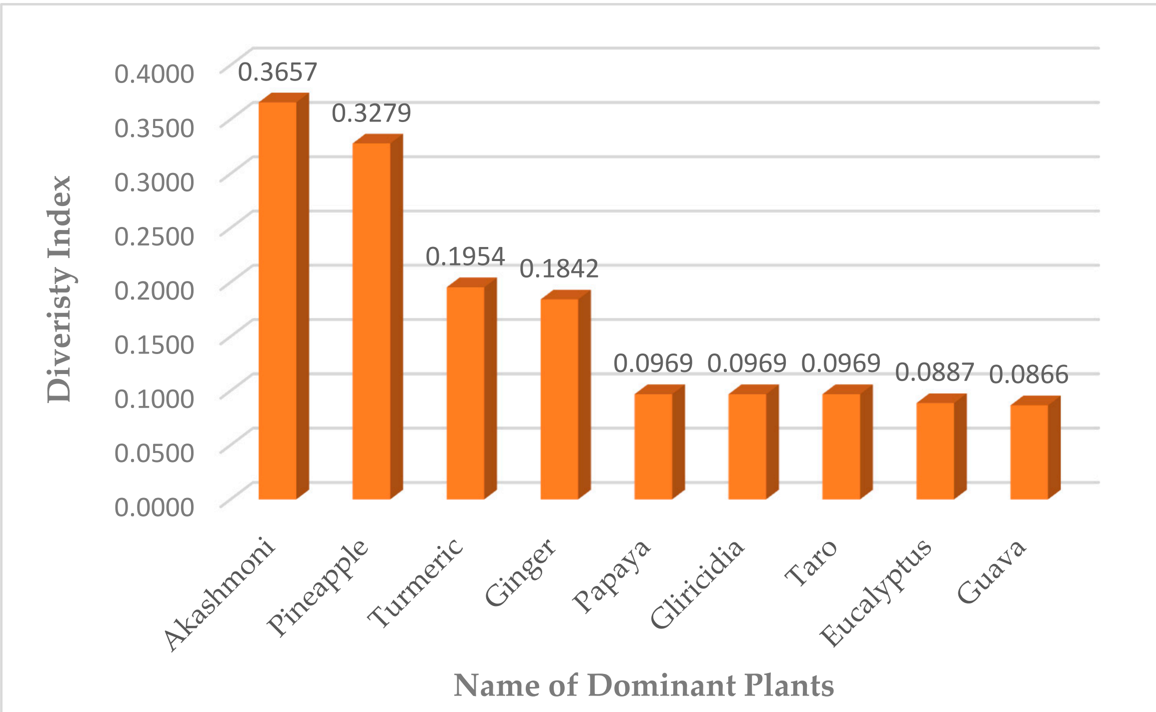

Figure 5. Diversity Index of the dominant plant species of Madhupur Area.

Table 4. Plant species observed in Madhupur tract, Bangladesh.

Sl No.	Local Name	Scientific Name	Family Name	Habit	Uses
01	Mango	*Mangifera indica*	Anacardiaceae	Tree	F, Fd, T
02	Taro	*Colocasia esculenta*	Araceae	Herb	Fd
03	Supari	*Areca catechu*	Arecaceae	Tree	M, Fd
04	Pineapple	*Ananas comosus*	Bromeliaceae	Herb	Fd
05	Jiga	*Lannea coromandelica*	Burseraceae	Tree	Fd, M, N, T
06	Papaya	*Carica papaya*	Caricaceae	Herb	Fd
07	Bohera	*Terminalia bellirica*	Combretaceae	Tree	Fd, M, T
08	Bon Chalta	*Dillenia pentagyna*	Dilleniaceae	Tree	Fd, M, T
09	Sal	*Shorea robusta*	Dipterocarpaceae	Tree	T
10	Gab	*Diospyros malabarica*	Ebenaceae	Tree	M, T
11	Akashmoni	*Acacia auriculiformis*	Fabaceae	Tree	F, N, T
12	Gliricidia	*Gliricidia sepium*	Fabaceae	Tree	M, N
13	Minjiri	*Senna siamea*	Fabaceae	Tree	Fd, T, M
14	Teak	*Tectona grandis*	Lamiaceae	Tree	M, T
15	Gamari	*Gmelina arborea*	Lamiaceae	Tree	T
16	Jarul	*Lagerstroemia speciosa*	Lythraceae	Tree	N, T
17	Shimul	*Bombax ceiba*	Malvaceae	Tree	M, T
18	Lambu	*Khaya anthotheca*	Meliaceae	Tree	T
19	Mahogany	*Swietenia macrophylla*	Meliaceae	Tree	T
20	Mahogany	*Swietenia mahagoni*	Meliaceae	Tree	T
21	Neem	*Azadirachta indica*	Meliaceae	Tree	M, T
22	Ghora Neem	*Melia azedarach*	Meliaceae	Tree	M, T
23	Jackfruit	*Artocarpus heterophyllus*	Moraceae	Tree	Fd, N, T
24	Joyfol	*Myristica fragrans*	Myristicaceae	Tree	Fd, M, T
25	Guava	*Psidium guajava*	Myrtaceae	Herb	F, Fd, M, N
26	Eucalyptus	*Eucalyptus camaldunensis*	Myrtaceae	Tree	F, N, T
27	Boroi	*Ziziphus mauritiana*	Rhamnaceae	Shrub	Fd
28	Lemon	*Citrus limon*	Rutaceae	Shrub	Fd, M
29	Bael	*Aegle marmelos*	Rutaceae	Tree	Fd, M, T
30	Litchi	*Litchi chinensis*	Sapindaceae	Tree	Fd, M, T
31	Joina	*Schleichera oleosa*	Sapindaceae	Tree	Fd, M, T
32	Agar	*Aquilaria agallocha*	Thymeliaceae	Tree	N
33	Ginger	*Zingiber officinale*	Zingiberaceae	Herb	Fd, M
34	Turmeric	*Curcuma longa*	Zingiberaceae	Herb	Fd, M

F = Fuelwood, Fd = Food and fodder, T = Timber, M = Medicinal, N = Miscellaneous uses.

The Concentration of Dominance: The concentration of dominance in the Madhupur tract was recorded from 0.0000 to 0.1082. The highest concentration of dominance was observed in akashmoni (0.1082), followed by pineapple (0.0442), turmeric (0.0057), ginger (0.0047), papaya (0.0007), gliricidia (0.0007), and the lowest (0.0005) in guava (Figure 6). This result defines that akashmoni is less stabilized and less active from a functional point of view.

Similarity Index: The similarity index of the Madhupur tract was recorded to be two in all plants. This means that the similarity index did not vary for the identified plant species in the Madhupur Garh.

The Evenness: The evenness of the Madhupur area was recorded from 0.3593 to 2.2098. The highest evenness was observed in the species Jiga (2.2098). For the dominant species, the evenness in the species Guava was (0.5929), Eucalyptus (0.5882), Papaya (0.5714), Gliricidia (0.5714), Taro (0.5714), and it was lowest (0.3593) in Akashmoni (Figure 7).

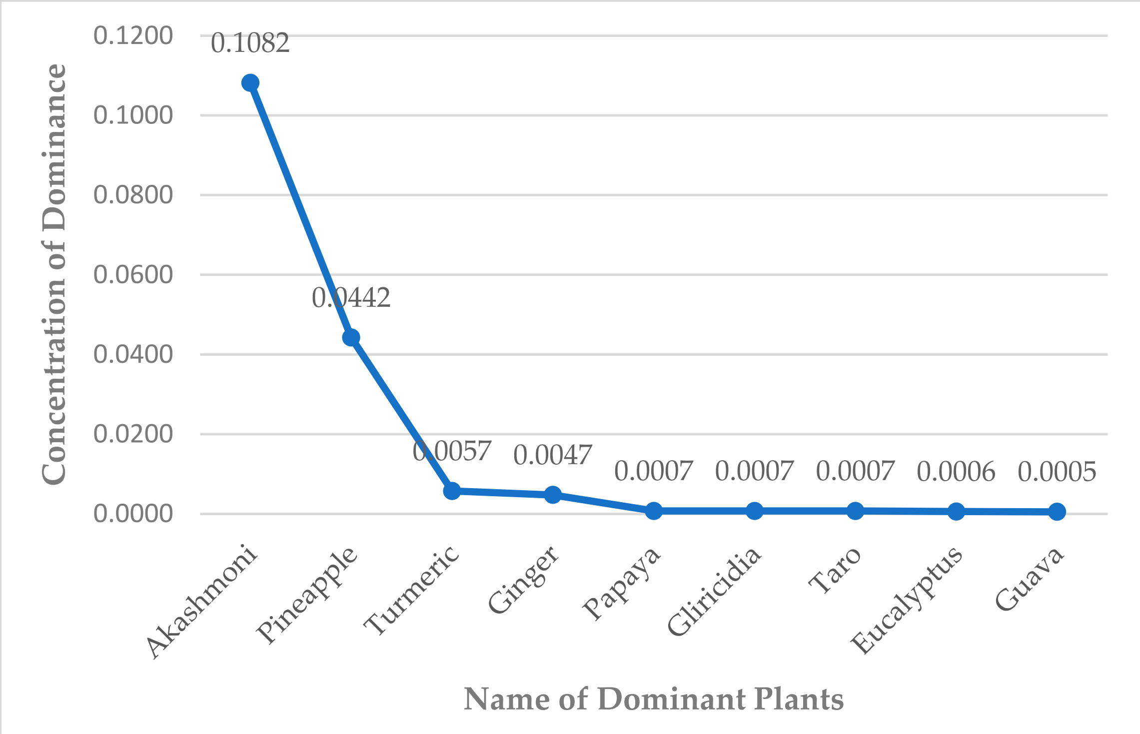

Figure 6. Concentration of Dominance of the dominant plant species in Madhupur.

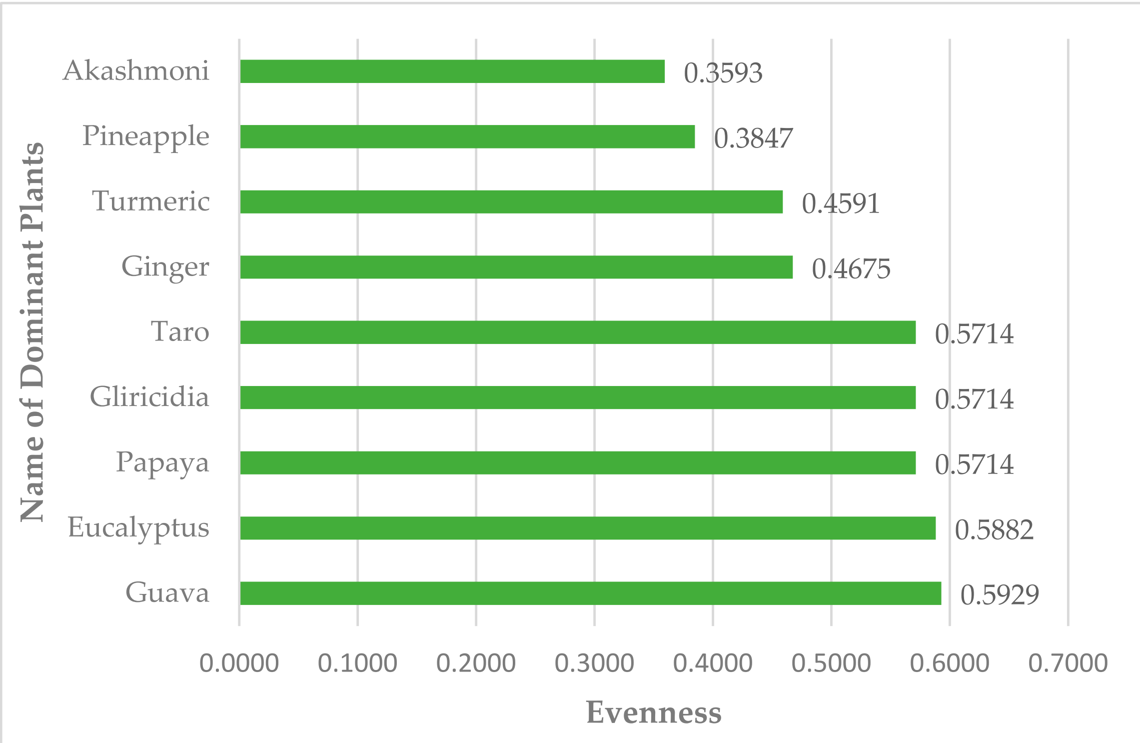

Figure 7. The Evenness of the dominant plant species in the Madhupur tract.

4. Discussion

Around 40% of the terrestrial land area is covered by crop and pasture lands, and around 43% of the world's cropland represents at least 10% of tree cover [40,41]. Thus, agroforestry has immense potential to conserve and enhance biodiversity. At the same time, agroforestry can increase farm productivity through crop and tree outputs for small-scale farmers around the world. The study measured the five livelihood capital development factors of agroforestry farmers through the DFID's livelihood framework. In the case of human capital development, the study evaluated farmers' training and workshops in which they gained knowledge and skills in agroforestry and also had a positive impact on the adoption of improved tree-crop-based technology in their agroforestry farms [29,42]. Nevertheless, these skills and knowledge have a direct link to the farmers' self-capacity and the building of social relationships within the community, which was also mentioned by Sobel (2002) [43]. Sal forest conservation has been negatively impacted by farmers' antagonistic relationships with local FD. That is, because of a bad relationship with the local FD, some agroforestry farmers did not have a positive attitude toward conserving and protecting Sal forest species. Studies on the Madhupur Sal forest by Islam et al. (2011) [29] and Gain (2002) [44] yielded similar findings. The number of total tree species in the agroforestry plot has been declining, and it is due to the fact that the farmers want more crop output than trees. However, the road infrastructure in the Madhupur tract has improved, and all of the farmers mentioned that the carrying cost of agroforestry products to the main market has also decreased due to better road infrastructure. In addition, a sense of collective action among the farmers was also observed when repairing and constructing the side/feeder road structures, which indicated the improvement of their social capital as well [29]. Agroforestry farmers bought big animals such as goats, cows, or bulls with the income from selling their agroforestry crops, but they mentioned that the grazing land and available cattle fodder have been decreasing in the study area. This decline is due to the fact that commercial agriculture has been drastically expanding in the Madhupur tract and has stopped the free access right to the Madhupur Sal forest [44,45]. Financial capital, in particular the ability to generate income from agroforestry programs, had a significant relationship with the farmers' children's education and family health care systems [29], and the study clearly pointed out that the trained and skilled farmers could manage their physical, human, and natural capital more profoundly than the less skilled and non-trained farmers. So, the farmer's income, human, social, physical, and natural capital all play a big role in sustaining their livelihoods, and when one of them declines, it puts more pressure on the other factors [46].

On the contrary, agroforestry practices naturally have higher biodiversity compared with monocropping systems because plant diversity plays a key role in increasing biodiversity in agroforestry systems [24,47–49]. At the same time, the species richness of agroforestry practices provides an understandable and immediate expression of diversity [50]. Agroforestry practices in the Madhupur tract were initiated in the deforested and degraded forest land, and the study found 34 types of plant species in Madhupur agroforestry practices. In a previous study of the Madhupur tract, Islam et al. (2021) [9] found that the natural Sal Forest had identified 109 plant species, while another main Sal Forest had only 53 plant species in Bangladesh. Therefore, the greater the number of species that appear, the greater the value of the diversity index in any ecosystem [50,51]. The Shannon–Wiener index is being used in several scientific papers to represent the species diversity in the ecosystem, and it assumes a zero value when there is only one species. The study found that the *Acacia* spp. had the highest diversity index, followed by pineapple, turmeric, and ginger crops. The local farmers and FD staff also reported that the majority of the agroforestry (more than 97%) practices were comprised of acacia trees and pineapple crops. The reason for cultivating fast-growing timber species in agroforestry plots was that the farmers were keen on growing timber trees for quick cash income. So, the highest species dominance indicates that the acacia species had the highest value of importance without assessing the input of other species [50]. The Simpson index ranges from 0 to 1, with 1 indicating greater dominance [50]. Thus, the Simpson index of the acacia and pineapple species clearly indicates that these two were the dominant species in the Madhupur tract. Nevertheless, the evenness index of the agroforestry practices clearly shows how evenly the individual species in an ecosystem are distributed. The evenness values near 1 mean that the species is abundant, and the results showed that the acacia species was the most abundant species in the agroforestry practices of the Madhupur tract. At the same time, environmentalists also argue that exotic trees, such as acacia, have a negative impact on the local ecosystem and also the environment [16,17,25,42]. So, the inclusion of acacia trees in the local ecosystem has both positive and negative aspects, and the study did not emphasize that issue.

The agroforestry farmers also mentioned that the tree species attract several birds to obtain their food and make nests. Some birds act as pollinators and help control insects that damage their crops. Agroforestry has already demonstrated that it reduces the use of synthetic fertilizers, soil disturbances, pesticides, herbicides, and other chemicals that have a significant impact on biodiversity conservation [52,53]. The study also observed that the agroforestry practices in the Madhupur tract act as a corridor for wild animals, in particular monkeys and deer, and thus serve as habitats outside of protected Sal forests. Therefore, agroforestry practices in the deforested Madhupur Sal forest areas are a viable land-use strategy for biodiversity conservation, ecosystem services, and the livelihood development of local farmers in Bangladesh.

5. Conclusions

In Bangladesh, rural farmers have been practicing various types of agroforestry by maintaining and planting a broad array of fast-growing trees in conjunction with crops for a variety of uses and benefits, including enhanced farm income and biodiversity conservation. The findings concluded that agroforestry approaches increased agricultural production by producing a wider range of crops while also enhancing farmers' human, social, physical, and natural capital. According to the research, more emphasis should be made on how agroforestry techniques can improve social networks and trust by fostering positive connections and resolving conflicting issues between agroforestry farmers and local governments. Nonetheless, agroforestry practices have introduced 34 plant species into the Madhupur tract's entirely deforested land, and the species richness and abundance demonstrate that farmers prefer to grow fast-growing tree species for immediate economic gain. At the same time, these agroforestry practices serve as wildlife corridors and attract birds, resulting in habitat conservation. As a result, the Madhupur tract's agroforestry practices are a sustainable land-use strategy for improving farmers' lives while also conserving biodiversity in Bangladesh. Finally, the study suggested that these potential agroforestry practices should be spread across the country, but more research is needed to achieve the full benefits of agroforestry for biodiversity conservation, livelihood development, and climate change mitigation.

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References

1. UN. *World Population Prospects: The 2017 Revision*; The Population Division of the United Nations, Department of Economic and Social Affairs, United Nations Secretariat: New York, NY, USA, 2017. Available online: https://www.unfpa.org/world-population-trends (accessed on 19 February 2022).
2. UN. *World Population Prospects 2019: Highlights*; The Population Division of the United Nations, Department of Economic and Social Affairs, United Nations Secretariat: New York, NY, USA, 2019. Available online: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf (accessed on 19 February 2022).
3. FAO. *How to Feed the World in 2050: Global Agriculture Towards 2050*; Economic and Social Development Department Report: Rome, Italy, 2019; pp. 1–2.
4. Dagar, J.C.; Gupta, S.R.; Teketay, D. (Eds.) *Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges*; Springer Publication: Berlin/Heidelberg, Germany, 2020; p. 4.
5. Mcneely, J.A.; Schroth, G. Agroforestry and biodiversity conservation: Traditional practices, present dynamics, and lessons for the future. *Biodivers. Conserv.* **2006**, *15*, 549–554. [CrossRef]
6. World Bank. *Agriculture, Forestry, and Fishing, Value Added (% of GDP) in Bangladesh*; World Bank National Accounts Data: Washington, DC, USA, 2020.
7. BBS. *Agriculture Census, Bangladesh Bureau of Statistics (BBS)*; Government of Bangladesh: Dhaka, Bangladesh, 2019.
8. World Bank. *Arable Land (Hectares per Person) in Bangladesh*; The World Bank Group: Washington, DC, USA, 2022. Available online: https://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?locations=BD (accessed on 18 February 2022).
9. Islam, K.K.; Hyakumura, K. The potential peril of Sal Forest land grabbing in Bangladesh: An analysis of economic, social, and ecological perspectives. *Environ. Dev. Sustain.* **2021**, *23*, 15368–15390. [CrossRef]
10. Islam, K.K.; Saifullah, M.; Hyakumura, K. Does Traditional Agroforestry a Sustainable Production System in Bangladesh? An Analysis of Socioeconomic and Ecological Perspectives. *Conservation* **2021**, *1*, 21–35. [CrossRef]
11. Islam, K.K.; Hyakumura, K. Forestland concession, land rights and livelihood of ethnic minorities: The case of the Madhupur Sal forest, Bangladesh. *Forests* **2019**, *10*, 288. [CrossRef]
12. Nair, P.K.R. *An Introduction to Agroforestry*; Springer: Dordrecht, The Netherlands, 1990.
13. Islam, K.K.; Jose, S.; Tani, M.; Hyakumura, K.; Krott, M.; Sato, N. Does actor power impede outcomes in participatory agroforestry approach? Evidence from Sal forests area, Bangladesh. *Agroforest. Syst.* **2015**, *89*, 885–899. [CrossRef]
14. Islam, K.K.; Rahman, G.M.; Fujiwara, T.; Sato, N. People's participation in forest conservation and livelihoods improvements: Experience from a forestry project in Bangladesh. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* **2013**, *9*, 30–43. [CrossRef]
15. Nair, P.K.; Kumar, B.M.; Nair, V.D. Agroforestry as a strategy for carbon sequestration. *J. Plant Nut. Soil Sci.* **2009**, *172*, 10–23. [CrossRef]
16. Gain, P. *The Last Forest of Bangladesh*; Society for Environmental and Human Development (SEHD): Dhaka, Bangladesh, 2002; pp. 101–179.
17. Muhammed, N.; Koike, M.; Haque, F.; Miah, M.D. Quantitative assessment of people oriented forestry in Bangladesh: A case study from Tangail Forest Division. *J. Environ. Manag.* **2008**, *88*, 83–92. [CrossRef]
18. Pimm, S.L.; Russell, G.J.; Gittleman, J.L.; Brooks, T.M. The future of biodiversity. *Science* **1995**, *269*, 269–350. [CrossRef]
19. Jose, S. Agroforestry for conserving and enhancing biodiversity. *Agrofor. Syst.* **2012**, *85*, 1–8. [CrossRef]
20. Rands, M.R.; Adams, W.M.; Bennun, L.; Butchart, S.H.; Clements, A.; Coomes, D.; Entwistle, A.; Hodge, I.; Kapos, V.; Scharlemann, J.P.; et al. Biodiversity conservation: Challenges beyond 2010. *Science* **2010**, *329*, 1298–1303. [CrossRef] [PubMed]
21. Nyaupane, G.; Poudel, S. Linkages among biodiversity, livelihood, and tourism. *Ann. Tour. Res.* **2011**, *38*, 1344–1366. [CrossRef]
22. Kleijn, D.; Sutherland, W.J. How effective are European agri-environment schemes in conserving and promoting biodiversity? *J. Appl. Ecol.* **2003**, *40*, 947–969. [CrossRef]
23. Opermmann, R.; Beaufoy, G.; Jones, G. *High Nature Value Farming in Europe: 35 European Countries—Experiences and Perspectives*; Verlag Regionanlkultur: Ubstadt-Weiher, Germany, 2012.
24. Udawatta, R.P.; Rankoth, L.K.; Jose, S. Agroforestry and biodiversity. *Sustainability* **2019**, *11*, 2879. [CrossRef]
25. Alam, M.S.; Sarker, M.A.; Hoque, M.J.; Khan, M.S.H. Use of Agrochemicals in Pineapple Farming: A case study from Madhupur Forest Areas of Bangladesh. *J. South Pac. Agric.* **2019**, *22*, 10–16.
26. Islam, K.K.; Sato, N. Protected Sal Forest and Livelihoods of Ethnic Minorities: Experiences from Bangladesh. *J. Sustain. For.* **2013**, *32*, 412–436. [CrossRef]
27. DFID. *Sustainable Livelihood Guidance Sheets-Comparing Development Approaches*; Department for International Development (DFID): London, UK, 2002. Available online: https://www.dfid.gov.uk/ (accessed on 22 February 2022).
28. Scoones, I. *Sustainable Rural Livelihood: A Framework for Analysis*; IDS Working Paper No. 72; Institute of Development Studies: Brighton, UK, 1998.
29. Islam, K.K.; Sato, N. Participatory forestry in Bangladesh: Has it helped to increase the livelihoods of Sal forests dependent people. *South. For.* **2012**, *74*, 89–101. [CrossRef]
30. Carney, D. *Sustainable Rural Livelihoods; What Contribution Can We Make?* Department for International Development: London, UK, 1998.
31. Hussein, K.; Nelson, J. *Sustainable Livelihood and Livelihood Diversification*; IDS Working Paper, No. 69; Institute of Development Studies: Brighton, UK, 1998.

32. Lovejoy, T.E. *The Global 2000 Report to the President*; The Technical Report, Penguin: New York, NY, USA, 1980; pp. 327–332.
33. Kareiva, P.; Marvier, M. What is conservation science? *BioScience* **2012**, *62*, 962–969. [CrossRef]
34. Alam, M.; Furukawa, Y.; Sarker, S.K.; Ahmed, R. Sustainability of Sal (*Shorea robusta*) forest in Bangladesh: Past, present and future actions. *Int. For. Rev.* **2008**, *10*, 29–37. [CrossRef]
35. Magurran, A.E. *Ecological Diversity and Its Measurement*; Springer Nature Publication: Gewerbestrasse, Switzerland, 1988.
36. Jaccard, P. The distribution of the flora in the alpine zone. *New Phytol.* **1912**, *11*, 37–50. [CrossRef]
37. Sorensen, T. A method of establishing groups of equal amplitude in plant sociology based on similarity of species context, and its application to analyses of the vegetation on Danish commons. *K. Dan. Vidensk. Selsk. Biol. Skr.* **1948**, *5*, 1–34.
38. Simpson, E.H. Measurement of Diversity. *Nature* **1949**, *163*, 688. [CrossRef]
39. Islam, K.K.; Hyakumura, K. Forestland grabbing by the foreigners in Hokkaido, Japan: Is it a big concern for sustainable forest development? *Appl. Sci.* **2018**, *8*, 1724. [CrossRef]
40. Foley, J.A.; Defries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K.; et al. Global consequences of land use. *Science* **2005**, *309*, 570–574. [CrossRef] [PubMed]
41. Zomer, R.J.; Neufeldt, H.; Xu, J.; Ahrends, A.; Bossio, D.; Trabucco, A.; Van Noordwijk, M.; Wang, M. Global Tree Cover and Biomass Carbon on Agricultural Land: The contribution of agroforestry to global and national carbon budgets. *Sci. Rep.* **2016**, *6*, 29987. [CrossRef]
42. Islam, K.K.; Hoogastra, M.; Ullah, M.O.; Noriko, S. Economic contribution of participatory agroforestry program to poverty alleviation: A case from Sal forests, Bangladesh. *J. Res.* **2012**, *23*, 323–332. [CrossRef]
43. Sobel, J. Can We Trust Social Capital? *J. Econ. Lit.* **2002**, *40*, 139–154. [CrossRef]
44. Gain, P. *Bangladesher Biponno Bon (In Bengali)*; SEHD: Dhaka, Bangladesh, 2005; p. 123.
45. Islam, K.K.; Fujiwara, T.; Noriko, S.; Hyakumura, K. Evolving and Strengthening the Cooperative Approach for Agroforestry Farmers in Bangladesh: Lessons Learned from the Shimogo Cooperative in Japan. *Sustainability* **2018**, *10*, 617. [CrossRef]
46. Rigg, J.D. Forests, marketization, livelihoods and the poor in the Lao PDR. *Land Degrad. Dev.* **2006**, *17*, 123–133. [CrossRef]
47. Torralba, M.; Fagerholm, N.; Burgess, P.J.; Moreno, G.; Plieninger, T. Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. *Agric. Ecosyst. Environ.* **2016**, *230*, 150–161. [CrossRef]
48. Bardhan, S.; Jose, S.; Biswas, S.; Kabir, K.; Rogers, W. Home garden agroforestry systems: An intermediary for biodiversity conservation in Bangladesh. *Agrofor. Syst.* **2012**, *85*, 29–34. [CrossRef]
49. Stamps, W.T.; Woods, T.W.; Linit, M.J.; Garrett, H.E. Arthropod diversity in alley cropped black walnut (*Juglans nigra* L.) stands in eastern Missouri, USA. *Agrofor. Syst.* **2002**, *56*, 167–175. [CrossRef]
50. Kanieski, M.R.; Longhi, S.J.; Soares, P.R.C. *Methods for Biodiversity Assessment: Case Study in an Area of Atlantic Forest in Southern Brazil*; IntechOpen Limited Publication: London, UK, 2018; p. 50.
51. Ludwig, J.A.; Reynolds, J.F. *Statistical Ecology: A Primer on Methods and Computing*; John Wiley & Sons: New York, NY, USA, 1988; p. 338.
52. Kleijn, D.; Kohler, F.; Báldi, A.; Batáry, P.; Concepción, E.D.; Clough, Y.; Díaz, M.; Gabriel, D.; Holzschuh, A.; Knop, E.; et al. On the relationship between farmland biodiversity and land-use intensity in Europe. *Proc. R. Soc. Lond. Biol. Sci.* **2008**, *276*, 903–909. [CrossRef] [PubMed]
53. Helgason, B.L.; Walley, F.L.; Germida, J.J. No-till and soil management increases microbial biomass and alters community profiles in soil aggregates. *App. Soil Ecol.* **2010**, *46*, 390–397. [CrossRef]