sustainability

MDPI

Article

Improvement of Farmers' Livelihood through Choi Jhal (*Piper chaba*)-Based Agroforestry System: Instance from the Northern Region of Bangladesh

Syed Aflatun Kabir Hemel [1,2,*], Mohammad Kamrul Hasan [1], Md. Abdul Wadud [1], Rojina Akter [1], Nasima Akther Roshni [1], Md. Tariqul Islam [1,3], Afsana Yasmin [4] and Keya Akter [5]

[1] Department of Agroforestry, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[2] Scientific Officer, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka 1207, Bangladesh
[3] Lecturer, Haor and Char Development Institute, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh
[4] Department of Horticulture, Faculty of Agriculture, Khulna Agricultural University, Khulna 9100, Bangladesh
[5] Department of Crop Botany, Faculty of Agriculture, Khulna Agricultural University, Khulna 9100, Bangladesh
* Correspondence: himelaflatun@gmail.com; Tel.: +880-1868361922

Abstract: One of the most significant linchpins of the socioeconomic and livelihood milieu for rural farmers around the world is agroforestry. Several agroforestry practices are being employed by farmers in Bangladesh's northern region, with Choi Jhal (*Piper chaba*)-based agroforestry being one of the most prevalent. Numerous researches have been conducted in different regions of Bangladesh to determine the potential livelihood for farmers who engage in diversified agroforestry, but hardly any comprehensive research has been carried out considering the aforementioned system as one of the most sustainable practices. To address this knowledge void, the present research was conducted in the Chinai union of Rajarhat Upazila in the Kurigram district of Bangladesh, surveying 105 *Piper chaba* farmers to assess the impact of this existing agroforestry system on their livelihood predicament. A mixed-method approach, including secondary data review, questionnaire survey, key informant interviews, focus group discussions and direct observations, were used for data collection and triangulation. To evaluate livelihoods and the problem severity, the Livelihood Improvement Index (LII) and the Problem Facing Index (FPI) were utilized, respectively. The findings demonstrate that the most suitable tree for *Piper chaba* cultivation is the betel nut (74.3%), and the majority (64.8%) of farmers have 41 to 90 *Piper chaba* plants. By strengthening farmers' constant availability of food, fruit, timber, fodder, and fuelwood, this agroforestry system has markedly increased the sustainability of their livelihoods. This practice is thought to boost farmers' livelihood capitals, with natural capital improving the most, while social capitals improve the least. However, eight major problems have been identified that farmers face while growing the crop and these must be remedied if different livelihood capitals are to be vastly improved. This research gives a full insight into the current *Piper chaba* production scenario and livelihood dynamics of local farmers, allowing some bold propositions to be formulated for further upgrading of their subsistence.

Keywords: agroforestry; *Piper chaba*; livelihood; Livelihood Improvement Index (LII); livelihood capitals; Problem Facing Index (PFI)

check for updates

Citation: Hemel, S.A.K.; Hasan, M.K.; Wadud, M.A.; Akter, R.; Roshni, N.A.; Islam, M.T.; Yasmin, A.; Akter, K. Improvement of Farmers' Livelihood through Choi Jhal (*Piper chaba*)-Based Agroforestry System: Instance from the Northern Region of Bangladesh. *Sustainability* **2022**, *14*, 16078. https://doi.org/10.3390/su142316078

Academic Editor: Waqas Ahmed

Received: 19 October 2022
Accepted: 14 November 2022
Published: 1 December 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Climate change, also known as global warming, is a term used for the observed century-scale rise in the average temperature of the earth's climate system and its related effects. It indicates how weather patterns change over decades or longer periods as a result of natural and human factors. Bangladesh's geophysical setting, geographic variability, and anticipated future climate change make it one of the nation's most susceptible to climate threats [1]. Bangladesh, which is ranked 22nd out of 191 countries by the 2019 Inform Risk Index, has some of the greatest levels of disaster risk in the whole world [2]. Agroforestry systems are well recognized as an integrated practice for sustainable land use besides their contribution to climate change mitigation and adaptation [3]. It is possible to progress concerns, such as soil health, resource allocation, carbon sequestration, biodiversity, water management, and food security by combining agroforestry with Climate Smart Agriculture (CSA) [4]. Both carbon sequestration and CSA are interrelated, and various CSA approaches, such as agroforestry, can increase soil and plant carbon stocks and improve food security [5].

To satisfy the rising demands of a population that is anticipated to exceed nine billion people by 2050, food production systems throughout the world are experiencing enormous problems [6]. Most of the spice crop-based agroforestry systems, for example the Choi Jhal (*Piper chaba*)-based agroforestry system, are mainly incorporated in home gardens. The spice-based agroforestry system is a great source of fuelwood and charcoal. Additionally, it is stated that agroforestry practitioners spend less money on fuelwood, depend less on natural fuelwood sources, and spend less time gathering fuelwood. For the most vulnerable food producers, agroforestry may increase farm income and crop resilience [7]. This offers a way to increase climate change resistance while also improving access to food, livelihood, health, and environmental stability [8].

Choi Jhal (*Piper chaba*) is a flowering creeper vine that can be grown around large fruit and timber trees. *Piper chaba* is considered to be a very expensive and lucrative plant because of its spicy, pungent flavor and high nutritional value. Various portions of this plant have been employed extensively in various traditional formulations, including ayurvedic medicine [9]. In the southern region of Bangladesh, it is a very popular spice but nowadays it is also cultivated in northern regions of Bangladesh, such as the Kurigram, Panchagarh, Nilphamari, etc. districts. In the Kurigram district, farmers have found *Piper chaba* to be very profitable and economical due to its high market value and low production cost [10]. The *Piper chaba* production can be combined with homestead forestry practices for additional benefit and earning extra money. Farmers can be economically more solvent by cultivating *Piper chaba* with some common forest and fruit tree species with the application of knowledge of agroforestry. The incorporation of timber, fruits, vegetables, spices, and some medicinal plants in a multistoried agroforestry system can be an effective and compatible element in the agroforestry system.

The sustainable livelihood approach places a strong emphasis on the need to take into account people's access to capital assets, how they combine these assets to make a living, and how they might increase their assets [11]. The primary indicators utilized in evaluating results are livelihood capital or assets, which take into account livelihood outcomes. Various studies have looked at how much and what kind of capital affects how people live in society. For millennia, Bangladesh's rural livelihood systems have included spice-based agroforestry as a key component which plays one of the key roles in supplying family food and energy, safety, generating cash and jobs, investment possibilities, and preserving the environment. An analysis of farmers' livelihood improvement through agroforestry practices was carried out by Akter et al. [12], Islam et al. [13], Islam [14], Islam and Hyakumura [15], Islam et al. [16] and Islam et al. [17] in the deciduous Sal Forest, Cox's Bazar and Jashore regions of Bangladesh. Rahman et al. analyzed the betel leaf-based agroforestry system in the Sylhet region [18], and several works on livelihood analysis of agroforestry practicing farmers have been carried out by Hanif et al. [19], Rahman et al. [20] and Ibrahim et al. [21] in the Mymensingh and Padma floodplain regions of Bangladesh. However, considering *Piper chaba* is a highly profitable and climate-friendly spice crop, hardly any research has been carried out addressing the livelihood status of *Piper chaba* farmers in Bangladesh. So, the research found a loophole in the progress of natural, human, physical, social, and financial capitals of rural people for *Piper chaba*-based agroforestry systems in Bangladesh. To reduce this gap, the objective of the research is to analyze the impacts of Choi Jhal (*Piper chaba*)-based agroforestry systems on livelihood assets development of rural people in the northern area of Bangladesh.

2. Theoretical Framework

Agroforestry systems (AFS) provide prospects for improving the livelihood of the underprivileged by ensuring their economic and environmental security [22]. The skills, resources (including material and social resources), and activities necessary for a living are together referred to as a livelihood. A livelihood is sustainable if it can withstand stress and shocks, recover from them, retain or improve its capacities and resources without depleting the natural resource base [23]. Usually, most of the livelihood models focus on the household as an appropriate social component for assessing livelihood improvement. For this study, we used the United Kingdom Department for International Development (DFID) Sustainable Livelihood (SL) framework for livelihood analysis. According to the framework, stakeholders operate in an environment of vulnerability where they have access to specific resources. Due to the current social, structural, and organizational environment (policies, institutions and processes), assets have gained significance and value. This setting has a profound impact on the livelihood alternatives people have while pursuing the beneficial livelihood outputs they define for themselves [24]. Moreover, the interrelationships between the livelihood capitals and their application in diversifying livelihood strategies to accomplish desired results (such as increased income, land productivity) in a particular environment may be explained using the SL framework. The five categories into which the capitals are divided in this SL framework are human capital (skill, knowledge, ability, labor capacity, better health etc.), social capital (relationships of mutual trust and reciprocity, networks, memberships of clusters), physical capital (basic infrastructure, transport, housing, communications etc.), natural capital (land, vegetation, water, wildlife, biodiversity etc.) and financial capital (monetary resources—savings, credit, remittances) (Figure 1). These capitals constitute the foundation of livelihoods, and a variety of assets are necessary to achieve successful livelihood outcomes. By making people's Sustainable Livelihood (SL) the ultimate aim of development for the poor, the SL approach based on this paradigm seeks to reduce poverty [25].

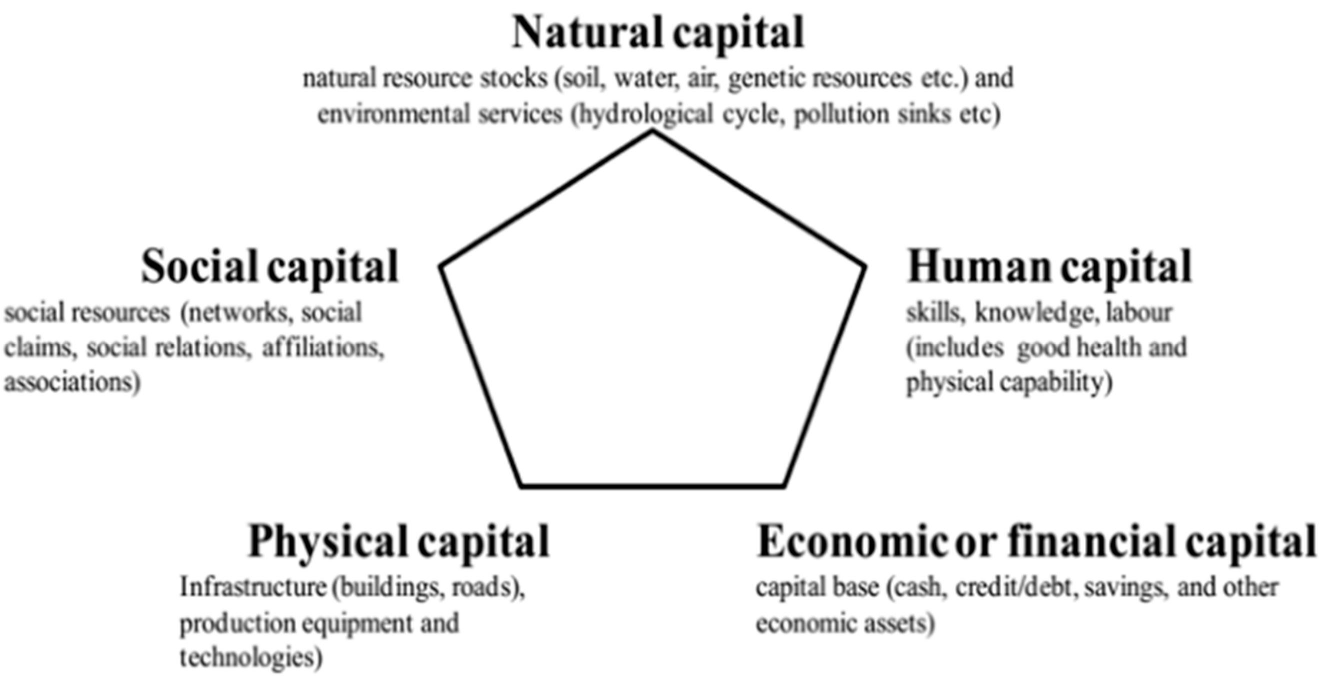

Figure 1. Pentagon showing the components of livelihood capitals (Adopted from Morse and McNamara) [26].

Since various *Piper chaba*-based agroforestry farming systems are being practiced widely in the research area, which has a direct and significant impact on rural people's livelihood, the research was designed and implemented as case studies to assess the contributions of this specific agroforestry system to various kinds of capital. It is based on an SL framework. Employing the sustainable livelihood approach (SLA) as a framework, Pandit et al. examined how the agroforestry system is altering its effects and motivators to enhance people's livelihoods [27]. The study by Sultana and Bari examined the most common agroforestry species and systems among char people in the Jamuna and Teesta River basins, as well as the socioeconomic effects of agroforestry technology on their livelihood [28]. Hanif et al. analyzed the present status, management practices and role of agroforestry in improving the livelihoods of farmers in Bangladesh with the help of the SL approach [19]. This paper extends its exploration by adding some important key indicators under different livelihood capitals and analyzing them based on the SL approach, which is directly impacted by the *Piper chaba*-based agroforestry system in the study area. The Sustainable Livelihood Approach (SLA) collects data on the elements that limit or increase livelihood chances and demonstrates how these aspects are related to the poor's way of life. It may be used to plan development initiatives and evaluate how well current endeavors have supported livelihoods. Therefore, a bold understanding of the change in the livelihood of rural people can be extracted in this paper using this analytical method.

3. Materials and Methods

3.1. Research Area

The research was conducted in the Chinai union of Rajarhat Upazila in the Kurigram district (Figure 2), belonging to the active Tista River floodplain Agroecological Zones (AEZ) of Bangladesh. The Chinai union is located at 25.60° to 25.80° north latitudes and 89.27° to 89.38° east longitudes. The area of the Chinai union is 24.36 km^2, including a population total of 28,280. The Chinai union comprises 18 villages, among them the research selected 5 important villages for data collection, namely Purba Deor char, Paik Para, Mekli, Chinai hat and King Chinai, where *Piper chaba* cultivation was comparatively high [29]. The surficial of the area is classified as recent floodplain deposits [30]. In comparison to other areas of Bangladesh, the research region has a warmer summer and a colder winter. The typical maximum temperature is between 32 °C and 33 °C, while the typical low is between 5 °C and 10 °C. Similar to other regions of Bangladesh, heavy rainfall is often experienced during the rainy season, with an average annual rainfall of roughly 3000 mm.

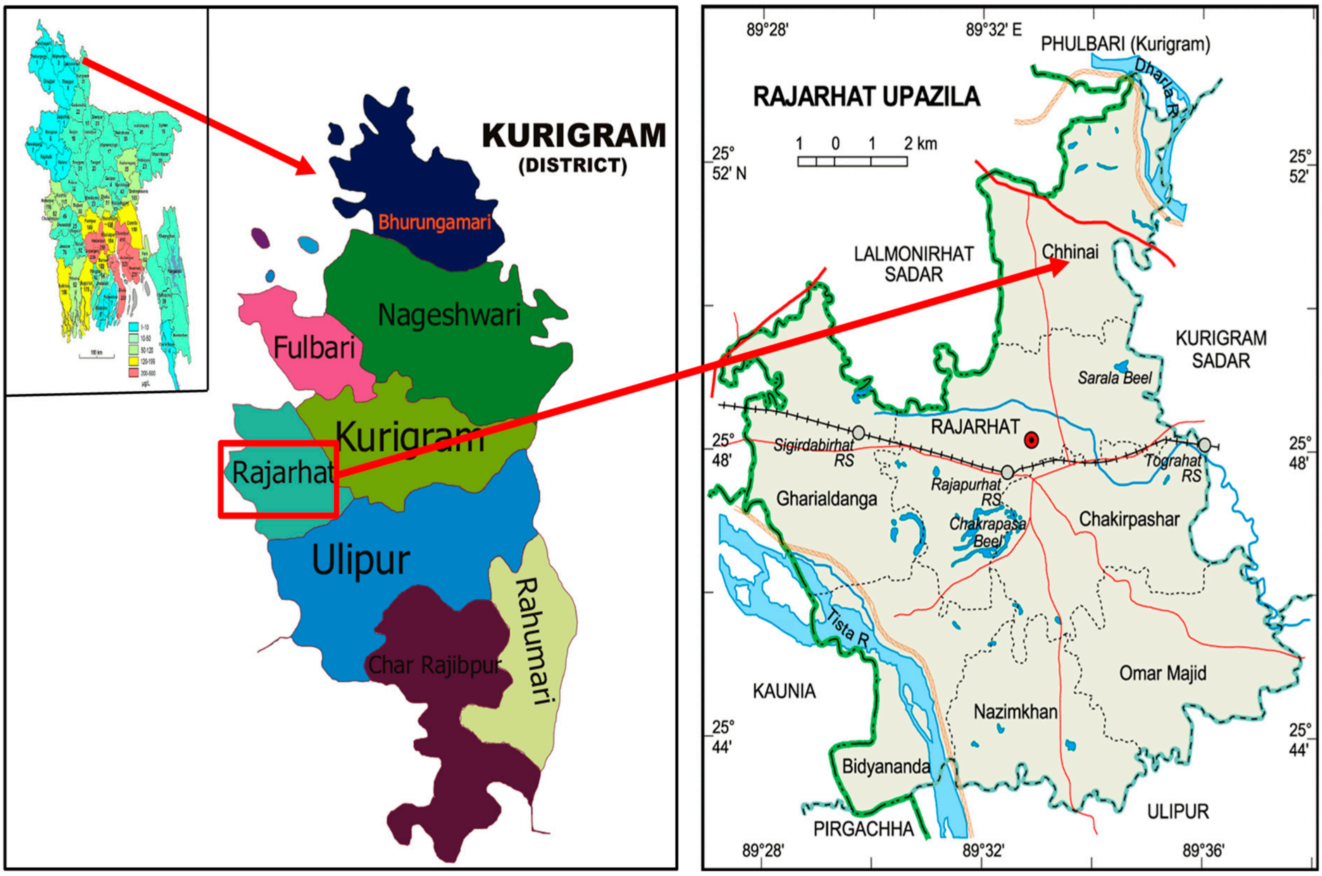

Figure 2. Area map showing the Kurigram district, Rajarhat Upazila and Chinai union in Rajarhat Upazila.

3.2. Data Collection

Multiple data collection methods (both primary and secondary) were used for collecting information from the research area from October to December 2020. The primary data was collected through observation, questionnaire survey, focus group discussions (FGDs) and key informant interviews (KIIs) using semi-structured questionnaires. The number of *Piper chaba* plants per farmer, *Piper chaba* cultivated area, and different problems related to *Piper chaba* cultivation were directly observed by the research team. Personal observation was also used to cross-check the data accumulated from the respondents. The corresponding data from the *Piper chaba* farmers was collected by a semi-structured questionnaire. A total of 105 Piper chaba farmers or producers were chosen with a stratified random sampling method from five different villages for an interview using a semi-structured questionnaire. Before the last interviews, the questionnaire underwent a pre-test. Some basic characteristics of the *Piper chaba* farmers such as age, education level, family size, land size, religion, annual income from agriculture, and number of income-earning members in the family were gathered. Each respondent to the survey was questioned regarding *Piper chaba*-based agroforestry systems, the reasons for planting trees, suitable tree species they planted for *Piper chaba* cultivation, cultivated area and number of *Piper chaba* plants for individual farmers, and enhancing their capital for their livelihoods, employing a questionnaire. The questions on livelihood were prepared according to the DFID livelihood framework and data was analyzed based on information found in the questionnaire. Key informant interviews were carried out by the research team where 15 key informant farmers, and 3 experts, including an Upazila Agriculture Officer, Agriculture Extension Officer and Sub Assistant Agriculture Officer, as well as an NGO worker, participated.

The study also conducted five FGDs in five different villages with 6–8 *Piper chaba* farmers in each group. Simple questions and/or statements focusing on the basic questionnaire were included in the FGD questions. The researchers created and pre-selected discussion subjects. Additionally, it was noted that certain unanimous conclusions were made by the respondents during focus group discussions relating to *Piper chaba* cultivation in that area, impacts on livelihood improvements, problems faced, and needs regarding the analysis and the putting into practice of probable solutions. The secondary data was collected from both published and unpublished sources including Department of Agricultural Extension (DAE) reports, journals, articles, books, and internet sources. These helped the research team to identify triangular relations among the other methods.

3.3. Data Analysis

Demographic characteristics of *Piper chaba* farmers were analyzed and categorized to identify range, mean and standard deviation, for improved explanatory power. Tree species, the reasons for planting trees, and suitable trees for *Piper chaba* cultivation were analyzed, by calculating the percentage of farmers giving each response, and then ranking them according to the findings. By computing a composite livelihood improvement score based on each of the five elements of the livelihood asset pentagon, the condition of *Piper chaba* farmers' livelihood improvement was determined: social, financial, physical, and natural capital along with human capital. Four indicators (assets) were set for each livelihood capital to analyze farmers' livelihoods (Table 1). Each indicator was rated on a four-point scale: highly increased, increased, slightly increased, and no change, with scores of 3, 2, 1 and 0 for positive assertions and inverted for negative assertions, respectively. The overall score for livelihood improvement was calculated by summing all of the capitals of the livelihood asset pentagon's scores. To determine the extent of problems faced by the *Piper chaba* farmers, several possible problems were identified through semi-structured interviews. Similarly, a four-point gradation (High = 3, Medium = 2, Low = 1, None = 0) was used to analyze the severity of problems faced by farmers. The farmers' individual and overall responses to livelihood capital and each statement of problems were then used to develop the Livelihood Improvement Index (LII) and Problem Facing Index (PFI). In the case of the LII, higher values indicate livelihood improvement and smaller values lower livelihood improvement. Conversely, for the PFI, higher values imply more problems, whereas lower values suggest fewer problems [19]. Statistical analyses of the data were performed with the aid of the Microsoft Excel program and SPSS computer software.

Table 1. Livelihood capitals along with corresponding indicators measured.

Livelihood Capitals	Corresponding Indicators
Natural capital	• Increase tree coverage • Conserve soil • Increase the overall productivity of land • Expand the availability of wood products
Human capital	• Increase the understanding of sustainable farming • Increase management skills of agroforestry • Increase children's education facilities • Increase health facilities
Physical capital	• Improve transport facilities • Increase basic infrastructures • Increase the utilization of different agricultural equipment or technology • Increase electricity use
Social capital	• Increase participation in community organizations • Increase the Upazila Agriculture Office's and community organizations' impact • Reduction of conflict with neighbors • Increase information availability

Table 1. *Cont.*

Livelihood Capitals	Corresponding Indicators
Financial capital	• Increase employment opportunity • Increase household income • Improve savings • Governmental and non-governmental entities' credit availability

4. Results

4.1. Respondents' Information on Demographics in the Research Area

Table 2 presents the findings of the selected demographics of the population sample. The demographic characteristics chosen are those that are thought to be pertinent to the research questions in light of the literature that has been written on the topics being evaluated. The age of the respondents ranges from 18 to 88 years with a mean of 42.24. The age is classified into three categories: young (<30 years), middle-aged (30 to 50 years), and old (>50 years). The majority of the respondents belong to the category of middle age (65.7%). Based on education level, respondents are categorized into four categories; illiterate, primary level (1–5), secondary level (6–10) and above secondary level (>10). The majority of farmers (39.1%) had secondary education (6–10 years of schooling) followed by 34.3% of primary level education, 13.3% were illiterate whereas 13.3% were above secondary level education in the research area (Table 2). Regarding the size of the family, the number of members observed ranged from 2 to 16 with a mean of 6.55. The family size was categorized into small (≤3), medium (4 to 7), and large (>7). Most of the families were categorized into medium sized (57.1%) (Table 2). The land category was created according to the model given by the Department of Agriculture Extension (DAE), Bangladesh. The land areas observed ranged from 0.08 ha to 0.3 ha, having a mean of 0.16. The majority (82.9%) of the respondents were in the landless category (<0.2 ha), and 17.1% were in the marginal category (0.21–0.5 ha). Small (0.51–1.0 ha), medium (1.01–2 ha), and large category farmers (>2 ha) were not found. Among the farmers surveyed, 63.8% were Muslim while 36.2% were Hindu. The observed annual income from agriculture ranged from BDT 20,000 to BDT 120,000 with a mean of 60,610. Of all the respondents, 1% earned up to BDT 25,000, 77.1% earned from BDT. 25,001 to BDT 75,000, and 21.9% earned above BDT 75,000 (Table 2). The families had 1 to 4 earning members with a mean of 1.3 (Table 2).

Table 2. Demographic features of the respondents **(n = 105)**.

Characters	Units	Range Observed	Category	Percentage	Mean	Standard Deviation
Age	Number of years	18–88	Young (Below 30)	15.2	42.24	13.18
			Middle age (30–50)	65.7		
			Old (over 50)	19.1		
Education level	Years of education	0–17	Illiterate (0)	13.3	6.99	4.54
			Primary education (1–5)	34.3		
			Secondary education (6–10)	39.1		
			Above secondary (>10)	13.3		
Size of family	Members in number	2–16	Small (≤3)	3.8	6.55	2.79
			Medium (4–7)	57.1		
			Large (>7)	39.0		

Table 2. *Cont.*

Characters	Units	Range Observed	Category	Percentage	Mean	Standard Deviation
Land size	Hectares	0.08–0.3	Landless (0.0–0.2)	82.9	0.16	0.05
			Marginal (0.21–0.5)	17.1		
			Small (0.51–1.0)	0		
			Medium (1.01–2.0)	0		
			Large (>2.0)	0		
Distribution of farmers by religion	Number of farmers	-	Muslim	63.8	-	-
			Hindu	36.2		
			Others	0		
Annual income from agriculture	Amount in taka	20,000–120,000	0–25,000	1	60,610	20,055.93
			25,001–75,000	77.1		
			>75,000	21.9		
Earning member	Number of persons	1–4	-	-	1.3	0.5

4.2. *Piper chaba*-Based Agroforestry Systems and Their Composition

The results reveal that the most important purpose of tree planting in cropland or homesteads was timber production, which was performed by 54.3% of the farmers. The next most important reason was food (34.3%) followed by fruits (31.4%), fodder (25.7%), and fuel (19%) (Table 3).

Table 3. Reasons for planting trees by *Piper chaba* farmers.

Reason	Percentage (%)	Ranking
Timber	54.3	1st
Food	34.3	2nd
Fruit	31.4	3rd
Fodder	25.7	4th
Fuel	19	5th
Others (Medicinal/Nonwood forest products, etc.)	13.3	6th

A total of 32 tree species were planted by farmers in cropland or homestead in the research area (Table 4). The tree *Eucalyptus camaldulensis* (88.6%) was the most common type of tree followed by *Areca catechu* (85.7%), *Borassus flabellifer* (37.1%), and *Neolamarckia cadamba* (27.6%) (Table 4). Among the fruit species, *Artocarpus heterophyllus* (79%) was the most prevalent followed by *Cocos nucifera* (40%) and *Citrus limon* (38.1%) (Table 4). The tree *Azadirachta indica* (31.4%) was the most dominant medicinal species, followed by *Saraca asoca* (11.4%), and *Terminalia arjuna* (9.5%) (Table 4).

Table 4. Percentage of *Piper chaba* farmers possessing different trees.

Tree Species	Scientific Name	Percentage (%)	Uses *
Eucalyptus	*Eucalyptus camaldulensis*	88.6	T, FW
Betel nut	*Areca catechu*	85.7	F
Jackfruit	*Artocarpus heterophyllus*	79.0	F, T, FW
Coconut	*Cocos nucifera*	40.0	FD
Sajna	*Moringa oleifera*	39.0	M, F
Lemon	*Citrus limon*	38.1	F
Date palm	*Phoenix dactylifera*	38.1	F, NFP
Palmyra palm	*Borassus flabellifer*	37.1	F, T
Mango	*Mangifera indica*	33.3	F, T, FW
Neem	*Azadirachta indica*	31.4	M, T
Kadamba	*Neolamarckia cadamba*	27.6	T
Olive	*Elaeocarpus floribundus*	26.7	F
Krishnachura	*Delonix regia*	25.7	T
Ipil ipil	*Leucaena leucocephala*	24.8	F
Pomelo	*Citrus maxima*	22.9	F
Jujube	*Ziziphus mauritiana*	21.9	F, T
Acacia	*Acacia auriculiformis*	21.0	T
Mahogany	*Swietenia macrophylla*	20	T, FW
Sal	*Shorea robusta*	17.1	T
Litchi	*Litchi chinensis*	14.3	F
Golden Shower tree	*Cassia fistula*	13.3	T, FW
Khair	*Acacia catechu*	12.4	FW
Asoka	*Saraca asoca*	11.4	M
Blackberry	*Syzygium cumini*	10.5	F, T
Arjun	*Terminalia arjuna*	9.5	M
Raintree	*Samanea saman*	6.7	T, FW
Babla	*Acacia nilotica*	6.7	FW
Hog Plum	*Spondias mombin*	6.7	F
Sissoo	*Dalbergia sissoo*	3.8	T, FW
Bot	*Ficus benghalensis*	2.9	F
Shimul	*Bombax ceiba*	2.9	NFP
Depol/Khoi	*Pithecellobium dulce*	1.9	FW

* T = Timber, F = Fruit/food, FW = Fuelwood, FD = Fodder, NFP = Non-timber forest products, M = Medicinal.

The trees that are most suitable for *Piper chaba* cultivation are shown in Table 5. From the results, it is revealed that betel nut (*Areca catechu*) is the species that was suggested by the highest number of farmers (78), a total of 74.3% of all respondents, as supportive plants for *Piper chaba* cultivation (Table 5). Coconut (*Cocos nucifera*) was second, suggested by 67.6%, with a frequency of 71, followed by jackfruit (*Artocarpus heterophyllus*) (41%, frequency 43), mango (*Mangifera indica*) (30.5%, frequency 32), hog plum (*Spondias mombin*) (13.3%, frequency 14), litchi (*Litchi chinensis*) (12.4%, frequency 13), and blackberry (6.7%, frequency 7) (Table 5). However, the farmers said that while fruit plants which have a good branching ability (for example jackfruit, mango) can give a higher yield of *Piper chaba*, they prefer betel nut and coconut the most due to their abundance.

Table 5. Trees suitable for *Piper chaba* cultivation preferred by farmers.

Species	Number of Farmers Suggested (n = 105)	Percentage (%)	Ranking
Betel nut	78	74.3	1st
Coconut	71	67.6	2nd
Jackfruit	43	41.0	3rd
Mango	32	30.5	4th
Hog plum	14	13.3	5th
Litchi	13	12.4	6th
Blackberry	7	6.7	7th

It was noted that 2.9% of the farmers cultivate *Piper chaba* in an area up to 0.004 hectares (ha). In the research area, 17.1% of the farmers had acquired an area between 0.0041 ha and 0.01 ha, 69.5% of the farmers had between 0.011 ha and 0.05 ha, 7.6% of the farmers had between 0.051 ha and 0.1 ha, and 2.9% of the farmers had a cultivated area of *Piper chaba* above 0.01 ha (Figure 3a). The average area for the cultivation of *Piper chaba* in the research area was 0.025 ha per farmer and the standard deviation was 0.026. Likewise, it was observed that 7.6% of the farmers had up to 40 *Piper chaba* plants while 64.8% of the farmers had 41 to 90 plants, 17.1% of the farmers had 91 to 140, and 8.6% of the farmers had *Piper chaba* plants ranging in number from 141 to 190. Only 1.9% of the farmers had above 190 *Piper chaba* plants (Figure 3b). The average number of *Piper chaba* plants for an individual farmer was 89.8 and the standard deviation was 36.31.

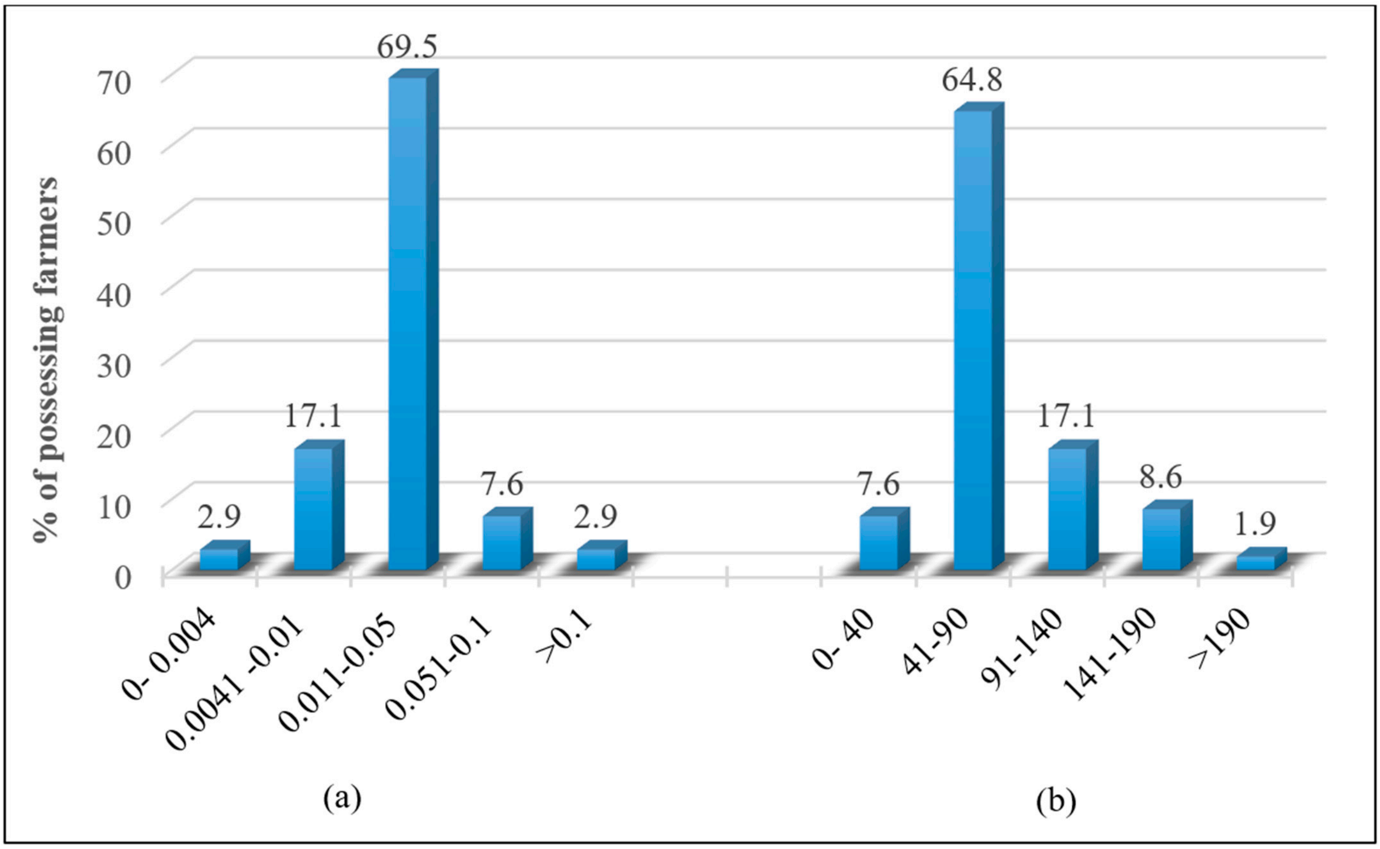

Figure 3. Showing *Piper chaba* cultivated areas in ha (**a**) and the number of *Piper chaba* plants for the individual farmer (**b**).

A *Piper chaba*-based agroforestry system can be classified as an agrisilvicultural system, or 'multispecies tree garden'. In an agrisilvicultural system, land is intentionally and consciously used to produce multiple agricultural products, including tree crops, at the same time. In a *Piper chaba*-based multispecies tree garden, several different tree species are included (Table 5) and the principal crop, *Piper chaba*, is grown therein. The primary purpose of this system is to produce food, fodder, and wood products for domestic use and commercial sale.

4.3. Livelihood Improvement

The Sustainable Livelihood framework, developed by the DFID, is frequently used to examine people's livelihoods using the five capitals for sustainable livelihood. Increasing the understanding of sustainable farming and management of agroforestry is important to improve human capital. Farmers must select suitable trees and crops while managing an agroforestry system, which is a difficult task. In this area, different agroforestry systems are not widely practiced, and this is limited to *Piper chaba*-based and sometimes *Piper betle*-based agroforestry in most cases. This is why there is moderate improvement in understanding of sustainable farming and management skills of agroforestry. By earning extra money, the farmers ensured their children's proper education (LII 191.3) but health facilities (LII 149.6) were not much improved despite extra income, due to the limited number of health complexes and the remoteness of the area (Table 6). Pondering physical capital, most of the respondents agreed that transport facilities (LII 174.3) and basic house infrastructure (LII 186.7) had increased considerably (Table 6). They improved with the utilization of different agricultural equipment or technologies due to the gradual increase and acceptability of *Piper chaba*-based agroforestry practices. The increase in electricity use was moderately good, as they use electricity for different purposes such as lighting, using different machines, and modern technology such as mobile phones, computers, television, etc.

Table 6. Farmer distribution based on the improvement of their subsistence livelihoods.

Capitals	Extent of Agreement (%)				LII *	Rank Order
	Highly Increased	Increased	Slightly Increased	No Change		
Human						
Increase the understanding of sustainable farming	21.0	25.7	33.3	20	147.7	15
Increase management skill of agroforestry	18.1	24.8	41.0	16.1	144.9	17
Increased child education facilities	37.1	30.5	19.0	13.4	191.3	4
Increase health facilities	22.9	33.3	14.3	29.5	149.6	13
Physical						
Improve transport facilities	27.6	24.8	41.9	5.7	174.3	9
Increase basic infrastructure	25.7	46.7	16.2	11.4	186.7	6
Increase the utilization of different agricultural equipment or technology	19.0	30.5	28.6	21.9	146.6	16
Increase electricity use	24.8	36.2	37.1	1.9	183.9	7

Table 6. *Cont.*

Capitals	Extent of Agreement (%)				LII *	Rank Order
	Highly Increased	Increased	Slightly Increased	No Change		
Social						
Increase participation in community organizations	15.2	9.5	74.3	1.0	138.9	19
Increase the Upazila Agriculture Office's and community organizations' impact	24.8	41.0	24.8	9.4	181.2	8
Reduce conflict with neighbors	20.0	21.0	39.0	20.0	141.0	18
Increase information availability	18.1	41.9	29.5	10.5	167.6	10
Financial						
Increase employment opportunity	30.5	21.0	20.0	28.5	153.5	12
Increase household income	38.0	41.0	20.0	1	216.0	3
Improve savings	25.7	15.2	30.5	28.6	138.0	20
Governmental and non-governmental entities' credit availability	36.2	30.5	18.1	15.2	187.7	5
Natural						
Increase tree coverage	55.2	37.1	3.9	3.8	243.7	1
Help in soil conservation	44.8	43.8	10.5	0.9	232.5	2
Increase overall productivity of land	14.3	35.2	41.0	9.5	154.3	11
Expand the availability of wood products	19.0	34.3	23.8	22.9	149.4	14

* LII = Livelihood Improvement Index.

Social capital is reflected in the culture and interpersonal connections that exist within people and communities. Compared to other sustainable livelihood capitals, the farmers' social capital in the research had improved only somewhat. Increased participation in community organizations was not much improved due to the insufficiency of different social groups. In the research area, most of the farmers belonged to a marginalized group who lacked sufficient land to cultivate. Growing trees along agricultural boundaries that shade adjoining fields caused tensions, preventing farmers from building confidence and making it more difficult for them to cooperate. The increase in the impact of the Upazila Agriculture Office (UAO) and community organizations (LII 181.2) was moderately satisfactory. The UAO tries to give advisory support to the farmers but is sometimes unable to give monetary support to the farmers due to unknown limitations and much the same thing applies to community organizations. Since they do not have access to larger institutions where they may learn about self-improvement activities, the farmers' ability to access information held by public bodies (LII 167.6) is not sufficient (Table 6). There was a significant improvement in increasing household income (LII 216.0) as 38% of farmers said it had significantly increased and 41% of farmers agreed with the statement that household income had increased. If properly cultivated and properly marketed, *Piper chaba* is a very much more beneficial crop than other indigenous crops in that area. The net benefit is comparatively higher (Table 6). The increase in employment opportunities scored on average LII 153.5. People were accessing education with the use of extra income from the farm, and this increased education level increases the chance of finding employment. Improving savings was the lowest among all the indicators (LII 138.0) as farmers used almost all of the extra income for household purposes and they had very little money to save (Table 6). Moreover, NGOs are not greatly interested in giving pecuniary support to farmers to cultivate *Piper chaba*.

From trees planted in fields, farmers acquire wood products for household use. The addition of litter and prunings to the soil increases soil conservation (LII 232.5), increasing natural capital (Table 6). The most important benefit of the *Piper chaba*-based agroforestry system was that farmers planted more trees suitable for *Piper chaba* cultivation which increased the overall tree coverage. Among all the livelihood indicators in this research, improvement of tree coverage was the greatest (LII 243.7). Those assets have cumulatively improved the overall natural capital of the particular area (Table 6).

Considering the comparative impact of *Piper chaba* cultivation on different livelihood capitals of farmers, it was found that overall, natural capital improvement was the highest, which scored 779.9, followed by financial capital (695.2), physical capital (691.5), and human capital (633.5). Among them, improvement of overall social capital was the lowest (628.7) (Figure 4). *Piper chaba*-based agroforestry aids the research region's rural sustainable livelihood by increasing farmers' livelihood capitals, where agriculture and rural subsistence farming are the major sources of income.

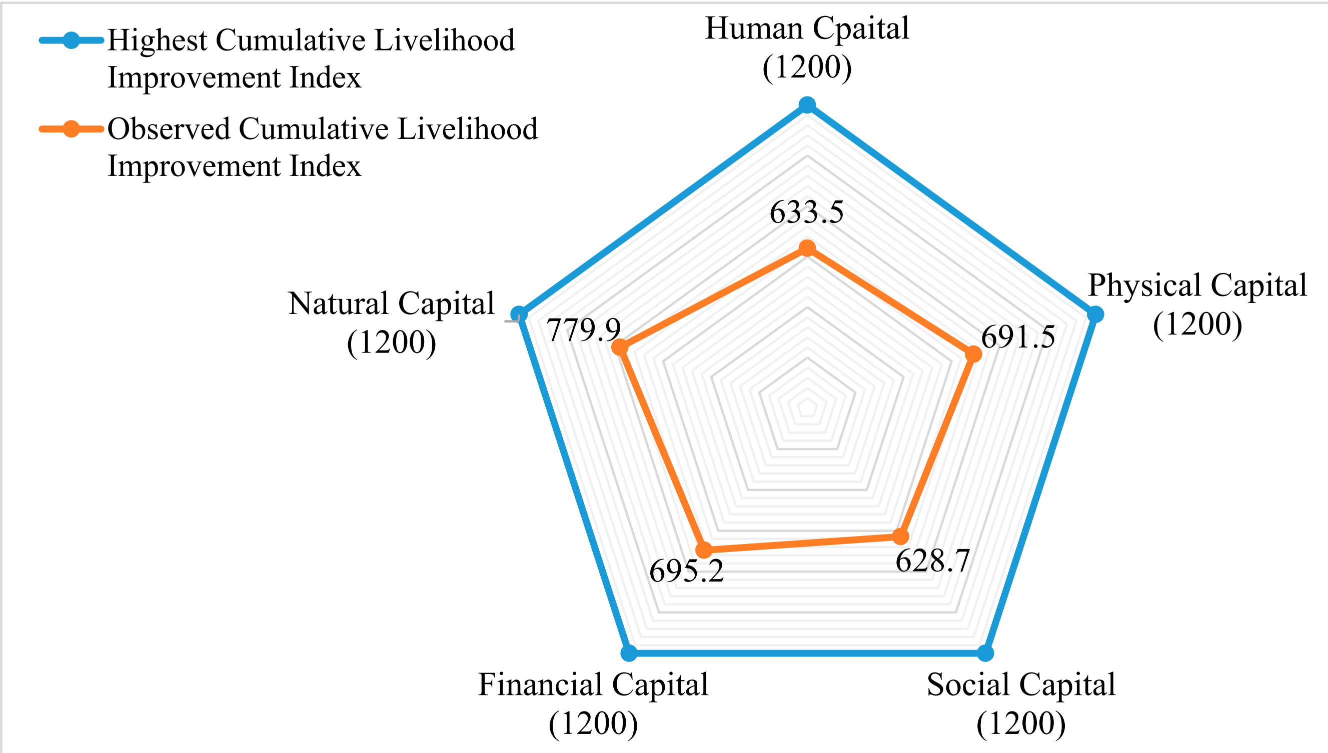

Figure 4. Comparative impact of *Piper chaba* cultivation on different livelihood capitals of farmers based on the Livelihood Improvement Index (LII) measures.

4.4. *Problems Faced by Farmers while Cultivating* Piper chaba *through Agroforestry*

The study identified eight major problems regarding *Piper chaba* cultivation through focus group discussions (FGD) using the Problem Facing Index (PFI) (Table 7). The results show that thieving of the plant was the most severe problem (PFI 284.9). Barkers frequently attempt to pay the farmers less while purchasing the crop because the mature plant (5–7 years old) is lucrative. They frequently intend to steal such plants from the garden if they are unable to reach an agreement with farmers regarding the payment. Farmers try to guard the orchard but most of the time it is not possible. Rotting of the plant, scoring PFI 279, was also predominant (Table 7). Farmers face severe losses due to the rotting of the whole plant. The disease responsible for this mainly occurs during moist and warm weather. Lack of help from the agriculture office was identified as the third most severe problem (PFI 267.6), followed by lack of market information (PFI 218.1), pest infestation (PFI 212.4), shortage of propagating material (PFI 210.5) and lastly, lack of capital (PFI 162.9) (Table 7). The researchers believe that by constructively resolving these problems, various livelihood indicators will eventually improve, resulting in a substantial increase in livelihood capitals.

Table 7. Distribution of farmers in the research area in accordance with the problems they encountered when implementing *Piper chaba*-based agroforestry systems.

Problems	Severity of the Problems				PFI *	Rank Order
	None	Low	Medium	High		
Thieving of the plant	1	0	12.4	86.7	284.9	1
Rot of the plant	0	2.9	15.2	81.9	279	2
Lack of help from agriculture office	0	5.7	21	73.3	267.6	3
Lack of market information	0	0	81.9	18.1	218.1	4
Pest infestation	0	11.4	64.8	23.8	212.4	5
Shortage of quality propagating material	0	13.3	62.9	23.8	210.5	6
Grazing of animals	0	34.3	38.1	27.6	193.3	7
Lack of capital	0	51.4	34.3	14.3	162.9	8

* PFI = Problem Facing Index.

5. Discussion

5.1. Piper chaba-Based Agroforestry Systems and Their Composition

In the research area, harvesting timber is the main goal of planting trees in agricultural or residential areas, followed by the harvest of food and fruit. The farmers are not sufficiently financially stable, and their focus is on making direct cash from the farm. The majority of them opt to plant trees for timber, food and sometimes fruit because these commodities have high economic worth. Farmers are interested in planting trees for the reasons outlined, as well as for the fact that obtaining fuelwood and fodder from planted trees lowers the cost of purchasing. This result supports the findings of Islam and Sarker, who found that farmers have chosen to grow trees on homesteads more often due to economic considerations than ecological ones. *Eucalyptus camaldulensis* was the most common timber species in the area [31]. Despite consuming huge amounts of water, affecting other trees and reducing crop production, farmers plant *Eucalyptus camaldulensis* due to its huge economic outcome through its timber value, which supports the findings of Tefera et al. [32]. The study of Hossain and Haque deduced that 18,900 acres, or 7% of Bangladesh's 113 plantations, are covered in Eucalyptus plantations [33]. Betel nut (*Areca catechu*) is the second most prevalent species in the research area which is similar to the findings of Nath et al. [34] and Nath and Inoue [35]. *Artocarpus heterophyllus* is the most prevalent fruit species in the research area, which supports the findings of Mannan [36].

For reducing production costs, different fruit and plantation trees such as betel nut, coconut, jackfruit, mango, hog plum, and litchi are very widely used by farmers as living supports for *Piper chaba* plants. Setting a unique example of agroforestry by trailing these types of vines on living standards may help increase the soil's quality. This is supported by Dinesh et al. and Kumar et al. who found this kind of favorable outcome while trailing black pepper on different kinds of living supports [37,38]. Reddy et al. found that in addition to betel leaf, other crops that can be successfully cultivated in the spaces between areca nuts include black pepper (*Piper nigrum* L.), bananas (*Musa sapientum* L.), cocoa (*Theobroma cacao* L.), and acid lime (*Citrus aurantium* L.) [39]. Analyzing the nature, objective, features and outputs, *Piper chaba*-based agroforestry is classified as an 'agrisilvicultural system' where *Piper chaba* is cultivated as a main crop. This finding is in line with Sinclair who classified different agroforestry systems in accordance with their properties and attributes [40]. The study has discovered that *Piper chaba*-based agroforestry has contributed to and raised annual farm earnings as a result of its demand and favorable market, which is ultimately one of the primary objectives of practicing agroforestry in the region. This result also conforms to the findings of Malekina et al. [41]. Along with the result, Feder et al. found that farmer income and contact with extension services were two factors that substantially correlated with farmers' adoption of agroforestry [42].

5.2. Impacts of *Piper chaba*-Based Agroforestry on Farmers' Livelihood Capitals

Researchers typically utilize the Sustainable Livelihood Framework to assess the sustainability of farmers' livelihoods, which looks at the five different types of capital needed. The Livelihood Improvement Index (LII) used in this research demonstrates that respondents recognized improvements in the assets that were taken into consideration. The study indicated that implementing *Piper chaba*-based agroforestry satisfactorily boosted human capital. The results showed that farmers' ignorance of the need to grow *Piper chaba* for commercial purposes somehow hindered an understanding of sustainable farming producing greater advantages. These findings are similar to the findings of Greiner et al. and Mzoughi, who found that adopting sustainable practices is adversely related to economic objectives, and related to lifestyle and conservation objectives [43,44]. Due to the lack of a new agroforestry approach being implemented in rural areas, farmers there are not well informed about the practices. Because of this, farmers have a low level of agroforestry management skills. Since farmers could educate their children and spend more on gaining access to healthcare facilities with the extra money they receive from *Piper chaba* farming, the improvement of the children's educational chances and access to better healthcare was gratifying. This result supports the findings of Rahman et al. who found that agroforestry income has a positive effect on contributing to healthcare and meeting educational expenses [20].

While questioning different indicators of physical capital, farmers thought that the upgrade of transportation facilities was mediocre. Local transportation infrastructure improves when farm incomes rise significantly. People now prefer driving cars over walking, so there are more new roads and vehicles overall. When the data from the interviews were compared, it was revealed that some of the farmers had built houses, cowsheds, sanitary latrines, roads, threshing floors, and other structures with the extra money. However, they typically spend the money solely on home expenses. As farmers cultivate *Piper chaba* using a traditional method, improvements in the usage of various agricultural equipment and technologies are subpar, and that is supported by the findings of Kiyani et al. [45]. The use of electricity has increased, which is generally positive. The farmers use it for a variety of things, including lighting, powering various machinery and contemporary technology such as televisions, mobile phones etc. This result supports the findings of Zada et al. [46]. Concerning the findings on farmers' physical capital, Ahmed et al. revealed that the agroforestry farmer's different physical capital, natural capital, and social capital were significantly improved compared to conventional farmers [47].

A crucial aspect of a community is its social capital, which is also one of the elements of the assessment pentagon in the sustainable livelihood framework. The feeling of trust inside more personal and restricted networks, where members are well-connected, is known as bonding social capital [48]. The research shows that farmers' social capital has not grown as much as other capital categories. Interview results revealed that participation in social insurance programs is hampered by rural populations' lack of secure and sufficient earnings. Particularly in low-income countries, agricultural income is often cyclical and weather-dependent, which makes regular social insurance contributions challenging. The researchers found that the increase in impact of the Upazila Agriculture Office and community organizations was moderately satisfactory. Agriculture offices always provide advice to farmers, but occasionally they are unable to provide financial or logistical support, which farmers are more interested in. Moreover, it was reported that there was an ongoing conflict between neighbors due to incomplete or ambiguous information flow, unsuitable environment, and clash of personal values. This supports the findings of Hanif et al. who concluded that in the northern region of Bangladesh there was persistent conflict between nearby farms over agroforestry approaches [19]. On the other hand, the farmers' access to information from a socio-economic perspective was moderately good among the indicators cited. The overall findings on the improvement of farmers' social capital support the results demonstrated by Sultana and Bari [28] and Hanif et al. [19], who found that the agroforestry approaches did not increase social capital as much as other capitals of livelihood for the farmers of the Teesta and Jamuna River Basins and Northern Bangladesh.

The research questioned the corresponding farmers about many indicators that directly affect the respondents' financial capital. By utilizing *Piper chaba*-based agroforestry, it has been shown that several financial concerns improved significantly. As people further their education with the assistance of additional money and benefits, the rise in career opportunities is only moderately satisfactory and these findings can be backed up by Hanif et al. [19]. One of the most notable aspects that have vastly improved is the surge in household income. If it is grown and marketed appropriately, *Piper chaba* is a very profitable crop in terms of net profit, market demand, and nutritional value, compared to other indigenous crops grown in the same region. Because it is grown with various trees and is in high demand in many areas of Bangladesh, the income from this agroforestry system is consistently quite high. This supports the findings of Kassie who observed that in Northwest Ethiopia, agroforestry diversified farm income when farmers converted from the cultivation of cereal crops to agroforestry [49]. Similar results were found by Pogutz and Winn, Bugayong, Regmi, Zerihun [50–53]. Results from Akter et al. showed that farmers in the Madhupur Sal Forest (MSF), Bangladesh, receive superior returns from using timber-based agroforestry techniques [54]. The study of Singh et al. argued that agroforestry is a sustainable method for raising farmers' income in the trans-Gangetic plains zone of India [55]. Access to loans from government and non-government organizations has markedly increased. The government is steadily concentrating on the improvement of the *Piper chaba*, betel leaf, and black pepper-based agroforestry system in that specific location, which finally results in a better level of support from the government to the stakeholder farmer. Among the livelihood assessment indicators, improving savings has the lowest measurement because some farmers are apprehensive about disclosing their savings. One of the primary challenges of subsistence farming is that people spend practically all of their surplus money on household expenses, leaving them with very little left over for savings.

The research has discovered that by adopting this agroforestry system, among all the other capitals, the maximum improvement occurs in natural capital. There is a substantial rise in tree coverage, which usually results in less pressure on the forest and more efficient nutrient recycling and transfer by deep-rooted trees to the crops on the site. Farmers frequently plant trees in their homestead or boundary that are appropriate for *Piper chaba* production, so indirectly increasing overall tree coverage. The leaf litter and prunings from trees fall to the ground, increasing organic matter and soil fertility while reducing soil erosion and leaching loss. There is also a trend among the farmers toward using less synthetic fertilizer in *Piper chaba* farming. These factors work together to efficiently conserve soil. These findings are supported by Atangana et al., Zomer et al., Negi, Kabala et al. who boldly concluded that agroforestry helps enormously to improve the ecosystem and increase tree coverage, with fruitful conservation of soil [56–59]. The supply of wood products and fuelwood from trees climbs considerably as tree coverage increases. The agricultural approach of *Piper chaba* cultivation has enhanced the farmland's total productivity. Betel nuts, mango, jackfruit, guava, and other plants are suited to *Piper chaba* cultivation. As a result of the production of *Piper chaba*, farmers receive a variety of fruits and nuts, increasing agricultural productivity overall. These findings are in line with Irshad et al. and Essa et al. [60,61]. Positive results on improving the overall productivity of the land have been found by Hasan et al. (a, b) in the case of mango- and lemon-based agroforestry systems, respectively [62,63].

Agroforestry increases the farm's perennial components (creating new long-term income sources) and develops a more diverse plant system that more closely resembles a natural ecosystem. That is why more farmers are gradually switching to this farming system. Incorporating trees, livestock, crops, and/or other lifeforms into an agroforestry system might lead to better water quality, soil fertility, biodiversity, and carbon sequestration. Agroforestry has a lot of potential to strengthen food production and farmers' economic conditions sustainably through the potential benefits on household income [49]. Agroforestry also has the potential to improve different livelihood options for rural farmers. According to Islam et al., agroforestry approaches can boost farmers' human, physical, social and natural capital while increasing agricultural output by allowing them to grow a larger assortment of crops [64]. Given the interdependence of these capitals, households that reinvest the financial capital they obtain from agroforestry into other types of livelihood capital (physical, human, social, and natural capital) may eventually establish more resilient livelihood strategies [65]. Likewise, by enhancing various capital types, households could safeguard their financial capital. For the shape of livelihood capabilities and the fulfilment of rural farmers' material and spiritual demands, the combination and interchangeability of various types of livelihood capitals are fundamental.

6. Conclusions

Agroforestry is a growing trend among farmers in Bangladesh's northern area for several reasons, including increased agricultural profitability and biodiversity preservation. The findings provide the insight that a total of 32 species in all are found to be planted by farmers in cropland or on their homesteads for a variety of purposes, most notably for timber and fuel. The most prevalent species are *Eucalyptus camaldulensis, Areca catechu, Artocarpus heterophyllus, Cocos nucifera, Moringa oleifera,* etc. Seven tree species with which *Piper chaba* can be cultivated are proven to be the most common, with a special emphasis on betel nut, coconut and jackfruit. Following the research findings, this agroforestry system enhances agricultural output by preserving species variety and strengthening farmers' human, social, physical, and natural capital. Farmers have concurred that *Piper Chaba*-based agroforestry increases financial capital by generating money from fuelwood, forest products apart from wood, and lumber, along with providing job opportunities. Physical capital, including transportation systems, basic infrastructure, and electricity use improves significantly once agroforestry is put into practice. The significant expansion of the tree cover, the enhancement of the soil, and the rise in total productivity may be responsible for the sharpest advance in natural capital in comparison to others. The explanation for the modest increase in human and social capital may be attributed to the farmers' lack of engagement and collaboration, as well as their incidental use of *Piper chaba* as a companion crop. The research also identifies eight major problems that arise when cultivating *Piper chaba*, which are the key obstacles preventing the advancement different livelihood capitals. If the severity of such problems can be mitigated, various indicators of the livelihood capitals could improve over time. Finally, the research recommends that this prospective *Piper chaba*-based agroforestry system be adopted nationwide, although further research is required to fully realize agroforestry's promise for biodiversity preservation, the creation of sustainable livelihoods, and climate change mitigation. Assuming the research's predictions are valid, it should offer a useful overview of how *Piper chaba*-based agroforestry systems affect farmers' livelihoods and, in fact, the ecology of Bangladesh's northern region. It should also serve as advice for future policy decisions. However, the researchers are also aware of the limitations of the study. Firstly, the samples surveyed could not fully portray the complete scenario of *Piper chaba* farming in this vast region, none-the-less, this study has some bearing on the great majority of research. Secondly, while the methodology was implemented at the micro-level, it did not rely on the macro-level to examine the capitals of livelihood and the power relationships of rural farmers. Finally, the quantitative data was calculated using a questionnaire that relied on recollection, potentially reducing data dependability. These potential flaws were addressed through group discussions and triangulation with key informants. Therefore, more research is necessary to more fully examine how agroforestry systems affect the environment and the living situations of farmers.

Author Contributions: Conceptualization, S.A.K.H. and M.K.H.; data curation, S.A.K.H.; methodology, S.A.K.H., M.K.H. and R.A.; formal analysis, S.A.K.H.; writing—original draft preparation, S.A.K.H. and M.K.H.; writing—review and editing, S.A.K.H., M.K.H., M.A.W., R.A., N.A.R., M.T.I. and A.Y.; validation, R.A. and N.A.R.; supervision, M.K.H. and M.A.W.; funding acquisition, S.A.K.H. and K.A. All authors have read and agreed to the published version of the manuscript.

Funding: S.A.K.H. was sponsored by a grant from the Ministry of Science and Technology (MoST), Government of the People's Republic of Bangladesh, which assisted in the authoring. The funders had no participation in the study's design, data gathering and analysis, publication decision, or manuscript preparation.

Data Availability Statement: The raw data given in this work are available upon request from the corresponding author.

Acknowledgments: We applaud the farmers who were interviewed and provided their valuable time to take part in the survey. We would also like to express our appreciation to the authority of National Science and Technology (NST) of Bangladesh, for providing financial assistance via the fellowship.

Conflicts of Interest: All the authors stated that they have no conflicting interests.

References

1. Ruane, A.C.; Major, D.C.; Yu, W.H.; Alam, M.; Hussain, S.G.; Khan, A.S.; Hassan, A.; Hossain, B.M.T.A.; Goldberg, R.; Horton, R.M.; et al. Multi-factor impact analysis of agricultural production in Bangladesh with climate change. *Glob. Environ. Change* **2013**, *23*, 338–350. [CrossRef]
2. European Commission. INFORM Index for Risk Management. Bangladesh Country Profile. 2019. Available online: https://drmkc.jrc.ec.europa.eu/inform-index/Countries/Country-Profile-Map (accessed on 31 March 2022).
3. Cubbage, F.; Balmelli, G.; Bussoni, A.; Noellemeyer, E.; Pachas, A.N.; Fassola, H.; Colcombet, L.; Rossner, B.; Frey, G.; Dube, F.; et al. Comparing silvopastoral systems and prospects in eight regions of the world. *Agrofor. Syst.* **2013**, *86*, 303–314. [CrossRef]
4. Newaj, R.; Chavan, S.B.; Prasad, R. Climate- smart agriculture with special reference to agroforestry. *Indian J. Agrofor.* **2015**, *17*, 96–108.
5. Raj, A.; Jhariya, M.K.; Bargali, S.S. Climate smart agriculture and carbon sequestration. In *Climate Change and Agroforestry*; Pandey, C.B., Gaur, M.K., Goyal, R.K., Eds.; New India Publishing Agency: New Delhi, India, 2018; pp. 1–19. ISBN 9789386546067.
6. Vinceti, B.; Ickowitz, A.; Powell, B.; Kehlenbeck, K.; Termote, C.; Cogill, B.; Hunter, D. The contributions of forest foods to sustainable diets. *Unasylva* **2013**, *64*, 54–64.
7. Waldron, A.; Garrity, D.; Malhi, Y.; Girardin, C.; Miller, D.C.; Seddon, N. Agroforestry can enhance food security while meeting other sustainable development goals. *Trop. Conserv. Sci.* **2017**, *10*, 1940082917720667. [CrossRef]
8. Duffy, C.; Toth, G.G.; Hagan, R.P.; McKewon, P.C.; Rahman, S.A.; Widyaningsih, Y.; Sunderland, T.C.; Spillane, C. Agroforestry contributes to smallholder farmer food security in Indonesia. *Agrofor. Syst.* **2021**, *95*, 1109–1124. [CrossRef]
9. Rahman, T.; Shilpi, J.A.; Ahmed, M.; Hossain, C. Preliminary pharmacological studies of Piper chaba stem bark. *J. Ethnopharmacol.* **2005**, *99*, 203–209. [CrossRef]
10. Piper Chaba Vines Lucrative for Kurigram Farmers. *The Daily Star*. 4 August 2017. Available online: https://www.thedailystar.net/country/piper-chaba-vines-lucrative-kurigram-farmers-1443340 (accessed on 24 August 2022).
11. Carney, D. *Sustainable Rural Livelihoods: What Contribution Can We Make?* Department of International Development: London, UK, 1998; ISBN 9781861920829.
12. Akter, R.; Hasan, M.K.; Kabir, K.H.; Darr, D.; Roshni, N.A. Agroforestry systems and their impact on livelihood improvement of tribal farmers in a tropical moist deciduous forest in Bangladesh. *Trees For. People* **2022**, *9*, 100315. [CrossRef]
13. Islam, K.K.; Saifullah, M.; Hyakumura, K. Does traditional agroforestry a austainable production system in Bangladesh? An analysis of socioeconomic and ecological perspectives. *Conservation* **2021**, *1*, 21–35. [CrossRef]
14. Islam, K.K. Participatory agroforestry for disadvantaged community development: Evidence from Madhupur Sal Forests. *J. Agrofor. Environ.* **2019**, *13*, 7–12.
15. Islam, K.K.; Hyakumura, K. Forestland concession, land rights, and livelihood changes of ethnic minorities: The case of the Madhupur Sal forest, Bangladesh. *Forests* **2019**, *10*, 288. [CrossRef]
16. Islam, K.K.; Tani, M.; Asahiro, K.; Rahman, M.Z.; Hyakumura, K.; Fujiwara, T.; Sato, N. Analysis of power dynamics and livelihood assets in participatory forest management: Experience from Bangladesh. *Intl. J. Nat. Res. Ecol. Man.* **2016**, *1*, 88–98. [CrossRef]
17. Islam, K.K.; Rahman, G.M.; Fujiwara, T.; Sato, N. People's Participation in forest conservation and livelihood improvements; Experience from a forestry project in Bangladesh. *Intl. J. Biodivers. Sci. Ecosyst. Sev. Manag* **2013**, *9*, 30–43. [CrossRef]

18. Rahman, M.; Rahman, M.M.; Islam, M. Financial viability and conservation role of betel leaf based agroforestry: An indigenous hill farming system of Khasia community in Bangladesh. *Bangladesh J. For. Res.* **2009**, *20*, 131–136. [CrossRef]
19. Hanif, M.A.; Roy, R.M.; Bari, M.S.; Ray, P.C.; Rahman, M.S.; Hasan, M.F. Livelihood improvement through agroforestry: Evidence from Northern Bangladesh. *Small-Scale For.* **2018**, *17*, 505–522. [CrossRef]
20. Rahman, S.A.; Imam, M.H.; Snelder, D.J.; Sunderland, T. Agroforestry for livelihood security in agrarian landscapes of the Padma Floodplain in Bangladesh. *Small-Scale For.* **2012**, *11*, 529–538. [CrossRef]
21. Ibrahim, K.; Wadud, M.A.; Mondol, M.A.; Alam, Z.; Rahman, G.M.M. Impact of agroforestry practices on livelihood improvement of the farmers of Char Kalibari area of Mymensingh. *J. Agrofor. Environ.* **2011**, *5*, 77–80.
22. Basu, J.P. Agroforestry, climate change mitigation and livelihood security in India. *N. Z. J. For. Sci.* **2014**, *44*, S11. [CrossRef]
23. Scoones, I. *Sustainable Rural Livelihoods: A Framework for Analysis*; IDS Working Paper no. 72; Institute of Development Studies: Brighton, UK, 1998.
24. Kollmair, M.; Gamper, S.T. *The Sustainable Livelihoods Approach—Input Paper for the Integrated Training Course of NCCR North-South Aeschiried, Switzerland*; Development Study Group Zurich, University of Zurich: Zurich, Switzerland, 2002; p. 11.
25. Farrington, J.; Carney, D.; Ashley, C.; Turton, C. *Sustainable Livelihoods in Practice: Early Applications of Concepts in Rural Areas, Natural Resource Perspectives*; Overseas Development Institute: London, UK, 1999; pp. 1–4.
26. Morse, S.; McNamara, N. *Sustainable Livelihood Approach: A critical analysis of Theory and Practice*; Springer: Reading, UK, 2013; ISBN 978-94-007-6267-1.
27. Pandit, B.; Srestha, K.; Bhattarai, S. Sustainable local livelihoods through enhancing agroforestry systems in Nepal. *J. For. Livelihood.* **2014**, *12*, 47–63.
28. Sultana, R.; Bari, M.S. Livelihood improvement of farmers through agroforestry practices in Teesta and Jamuna River Basins. *AJRAF* **2021**, *7*, 10–27. [CrossRef]
29. National Portal of Bangladesh. Available online: http://chinaiup.kurigram.gov.bd/site/page/8add1898-18fd-11e7-9461-286ed488c766/front (accessed on 30 July 2022).
30. Islam, S.; Sarker, S. Assessing bio geomorphological state of the Teesta River Floodplain: A Study on Gangachara Upazila, Rangpur, Bangladesh. *Intl. J. Geosci.* **2017**, *8*, 265–275. [CrossRef]
31. Salam, M.A.; Noguchi, T.; Koike, M. Understanding why farmer plant trees in the homestead agroforestry in Bangladesh. *Agrof. Syst.* **2000**, *50*, 77–93. [CrossRef]
32. Tefera, S.A.; Mulatu, D.; Lerra, M.D. Determinants of farmers decision making for plant Eucalyptus trees in market district, North Willow, Ethiopia. *Res. Hum. Social Sci.* **2016**, *6*, 62–70.
33. Hossain, M.K.; Haque, A.T.M. *Eucalyptus Dilemma in Bangladesh*; Institute of Forestry and Environmental Science, University of Chittagong: Chittagong, Bangladesh, 2013; p. 148. ISBN 978-984-33-8056-2.
34. Nath, T.K.; Inoue, M.; Islam, M.J.; Kabir, M.A. The Khasia tribe of northeastern Bangladesh: Their socio-economic status, hill farming practices and and impacts on forest conservation. *For. Trees. Livelihoods* **2003**, *13*, 297–311. [CrossRef]
35. Nath, T.K.; Inoue, M. Sustainability attributes of a small-scale betel leaf agroforestry system: A case study in North-eastern Hill Forests of Bangladesh. *Small-Scale For.* **2009**, *8*, 289–304. [CrossRef]
36. Mannan, M.A. Plant Biodiversity in the Homesteads of Bangladesh and Its Utilization in Crop Improvement. Ph.D. Thesis, Institute of Postgraduate Studies in Agriculture, Gazipur, Bangladesh, 2000. Available online: https://bsmrau.edu.bd/library/thesis/ (accessed on 23 July 2022).
37. Dinesh, R.; Srinivasan, V.; Hamza, S.; Parthasarathy, V.A.; Aipe, K.C. Physio-chemical biochemical and microbial properties of rhizospheric soils of tree species used as supports for black pepper cultivation in humid tropics. *Geoderma* **2010**, *158*, 252–258. [CrossRef]
38. Kumar, B.M.; Sasikumar, B.; Kunhamu, T.K. Agroecological aspects of black pepper (*Piper nigrum* L.) cultivation in Kerala: A Review. *AGRIVITA J. Agric. Sci.* **2021**, *43*, 648–664. [CrossRef]
39. Reddy, V.M.; Baranwal, V.K.; Singh, R.K. Areca nut (*Areca catechu* L.) based high density multispecies cropping system in West Bengal. *J. Plant. Crops* **1993**, *21*, 15–21.
40. Sinclair, F.L. A general classification of agroforestry practice. *Agrofor. Syst.* **1999**, *46*, 161–180. [CrossRef]
41. Malekina, R.; Beyranvand, Z.; Sosani, J.; Adeli, K. Factors affecting agroforestry acceptance level by farmers. *Agric. Sci. Dev.* **2013**, *2*, 102–105.
42. Feder, G.; Just, R.E.; Zilberman, D. Adoption of agricultural innovations in developing countries: A survey. *Econ. Dev. Cult. Change* **1985**, *33*, 255–298. [CrossRef]
43. Greiner, R.; Patterson, L.; Miller, O. Motivations, risk perceptions, and adoption of conservation practices by farmers. *Agric. Syst.* **2009**, *99*, 86–104. [CrossRef]
44. Mzoughi, N. Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? *Ecol. Econ.* **2011**, *70*, 1536–1545. [CrossRef]
45. Kiyani, P.; Andoh, J.; Lee, Y.; Lee, D.K. Benefits and challenges of agroforestry adoption: A case of Musebeya sector, Nyamagabe District in southern province of Rwanda. *Forest. Sci. Technol.* **2017**, *13*, 174–180. [CrossRef]
46. Zada, M.; Zada, S.; Ali, M.; Zhang, Y.; Begum, A.; Han, H.; Ariza-Montes, A.; Araya-Castillo, L. Contribution of small-scale agroforestry to local economic development and livelihood resilience: Evidence from Khybar Pakhtunkhwa Province (KPK), Pakistan. *Land* **2022**, *11*, 71. [CrossRef]

47. Ahmed, S.; Caihong, Z.; Ekanayake, E.M.B.P. Livelihood improvement through agroforestry compared to conventional farming system: Evidence from North Irrigated Plain, Pakistan. *Land* **2021**, *10*, 645. [CrossRef]
48. Guillen, L.A.; Wallin, I.; Brukas, V. Social capital in small-scale forestry: A local case study in Southern Sweden. *For. Pol. Econ.* **2015**, *53*, 21–28. [CrossRef]
49. Kassie, G.W. Agroforestry and farm income diversification: Synergy or trade-off? The case of Ethiopia. *Environ. Syst. Res.* **2018**, *6*, 8. [CrossRef]
50. Pogutz, S.; Winn, M.I. Cultivating ecological knowledge for corporate sustainability: Barilla's innovative approach to sustainable farming. *Bus. Strategy Environ.* **2016**, *25*, 435–448. [CrossRef]
51. Bugayong, L.A. Socioeconomic and environmental benefit of agroforestry practices in a community-based forest management site in Philippines. In Proceedings of the International Conference on Rural Livelihoods, Forests and Biodiversity, Bonn, Germany, 19–23 May 2003; pp. 1–21.
52. Regmi, B.N. Contribution of agroforestry for rural livelihoods: A case of Dhading District, Nepal. In Proceedings of the International Conference on Rural Livelihoods, Forests and Biodiversity, Bonn, Germany, 19–23 May 2003; pp. 1–19.
53. Zerihun, M.F. Agroforestry practices in livelihood improvement in the Eastern Cape Province of South Africa. *Sustainability* **2021**, *13*, 8477. [CrossRef]
54. Akter, R.; Hasan, M.K.; Rahman, G.M.M. Productivity analysis of timber and fruit tree-based agroforestry practices in Madhupur Sal forest, Bangladesh. *J. Bangladesh Agril. Univ.* **2020**, *18*, 68–75. [CrossRef]
55. Singh, M.; Sridhar, K.B.; Kumar, D.; Dwivedi, R.P.; Dev, I.; Tewari, R.K.; Chaturvedi, O.P. Agroforestry for doubling farmers' income: A proven technology for trans-gangetic plains zone of India. *Indian Farming* **2018**, *68*, 33–34.
56. Atangana, A.; Khasa, D.; Chang, S.; Dagrande, A. *Tropical Agroforestry*; Agroforestry for Soil Conservation; Springer: Dordrecht, The Netherlands, 2013; pp. 203–216. ISBN 978-94-007-7723-1. [CrossRef]
57. Zomer, R.; Neufeldt, H.; Xu, J.; Ahrendz, 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]
58. Negi, S.P. Agroforestry potential for increasing forest and tree cover in Himachal Pradesh—An analysis. *J. Non-Timber. Forest. Prod.* **2017**, *24*, 185–190. [CrossRef]
59. Kabala, K.F.; Chirwa, P.; Syampungani, S.; Ajayi, C.O. Contribution of agroforestry to biodiversity and livelihoods improvement in rural communities of Southern African regions. In *Tropical Rainforests and Agroforests under Global Change*; Tscharntke, T., Leuschner, C., Veldkamp, E., Faust, H., Guhardja, E., Bidin, A., Eds.; Springer: New York, NY, USA, 2010; pp. 461–476, ISBN 978-3-642-00493-3. [CrossRef]
60. Irshad, M.; Khan, A.; Inoue, M.; Ashraf, M.; Sher, H. Identifying factors affecting agroforestry system in Swat, Pakistan. *Afr. J. Agric. Res.* **2011**, *6*, 2586–2593.
61. Essa, M.; Nizami, S.M.; Mirza, S.N.; Khan, I.A.; Athar, M. Contribution of agroforestry in farmers' livelihood and its impact on natural forest in northern areas of Pakistan. *Afr. J. Biotechnol.* **2011**, *10*, 15529–15537. [CrossRef]
62. Hasan, M.K.; Roshni, N.A.; Hemel, S.A.K.; Hossain, M.B. Economic evaluation of five years aged mango-based agroforestry practices established in the deforested land in the Madhupur Sal forest of Bangladesh. *J. Bangladesh Agric. Univ.* **2020**, *18*, 388–394. [CrossRef]
63. Hasan, M.K.; Rahman, G.M.M.; Akter, R.; Hemel, S.A.K.; Islam, M.T. Economic assessment of lemon-based agroforestry systems established in Madhupur Sal forest area of Bangladesh. *Progress. Agric.* **2020**, *31*, 45–55. [CrossRef]
64. Islam, K.K.; Fujiwara, T.; Hyakumura, K. Agroforestry, livelihood and biodiversity nexus: The case of Madhupur Tract, Bangladesh. *Conservation* **2022**, *2*, 305–321. [CrossRef]
65. Quandt, A.; Neufeldt, H.; McCabe, J.T. Building livelihood resilience: What role does agroforestry play? *Clim. Dev.* **2018**, *11*, 485–500. [CrossRef]