Forest and Society
Vol. 8(1): 195-217, June 2024
doi: 10.24259/fs.v8i1.26769

REGULAR RESEARCH ARTICLE

Potential of Agroforestry Practices in Multifunctional Landscapes for Enhancing the Livelihoods of Local Dwellers in the North-Western Charlands of Bangladesh

Md. Shafiqul Bari [1,*], James M. Roshetko [2], Md. Manik Ali [1], and Md. Faruq Hasan [3]

AFFILIATIONS

1. Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.
2. World Agroforestry (ICRAF), Bogor, Indonesia.
3. Department of Agricultural Extension, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

*Corresponding author: barimdshafiqul@gmail.com

RECEIVED 2023-05-19
ACCEPTED 2024-03-07

ABSTRACT

Char is any accretion in a river course that extends or establishes new land. A well-planned integrated land-use system combining woody perennials (agroforestry) can ensure sustainable, environmentally friendly climate resilience land-use systems and livelihood options on charland. To date, no systemic investigation of charland land agroforestry has been undertaken. A comprehensive study of the potential of agroforestry systems in charland areas was conducted using qualitative and quantitative methodologies. Two methods were employed: structured questionnaire interviews and botanical surveys. Findings revealed that considerable variation exists in both charland and mainland areas in terms of socio-demographic characteristics. Both tree and agroforestry knowledge of mainland farmers is greater than that of charland farmers. Charland dwellers sell almost all their farm products, while most mainland farmers consume their products. Agroforestry-related communication between extension workers and farmers is limited in both ecosystems. However, farmer interaction with extension workers is far less common in charland areas. Mainland farmers are satisfied with their homestead production systems, whereas cha land farmers face huge problems with the free grazing of cattle and goats. Mainland farmers think quality planting materials and fencing systems are key issues. Leafy short-rotation vegetables and climbing vegetables are more common in charlands. Other common marketable vegetables are tomato, brinjal, carrot, cauliflower, and cabbage. All fruit trees common on charland are more frequently found in the mainland areas. In the case of timber, eucalyptus (*Eucalyptus camaldulensis*) is more common on charland, whereas mahogany (*Swietenia macrophylla*) frequency is higher in the mainland. Medicinal trees are uncommon in both ecosystems except for neem (*Azadirachta indica*). Through proper training and motivation of farmers, there is a vast scope to increase tree and vegetable diversity in charland farms.

KEYWORDS
Agroforestry; Charland; Sustainable livelihood; Multifunctional landscape; Climate resilience.

1. INTRODUCTION

The most important sector in Bangladesh remains agriculture, which has a significant economic impact on the nation. Approximately 45.6% of the labor force is employed in agriculture, accounting for 13.6% of GDP. In addition, 65% of the population depends on the agricultural sector for their livelihood (Rahman, 2017). It is not possible to overstate how vital agriculture is to Bangladesh's GDP. Because of various factors, primarily infrastructure development (the building of roads, highways, buildings, industries, and markets) cultivable land in Bangladesh is declining by 1% annually (BBS, 2022). Furthermore, Bangladesh increasingly faces the effects of climate change, which include erratic rainfall, altered rain patterns, and temperature fluctuations that can have an adverse impact on agricultural productivity. An additional climate risk to the agriculture industry is the emergence of extremely cold periods. A looming food crisis caused by decreased agricultural production could result from these issues. As a result, it is crucial to explore untapped land resources like char areas (Chen et al., 2021).

According to Ullah et al. (2010), "charland" refers to the accumulations along riverbanks or estuaries, which include various types like point bars and braid bars. Due to their expansion over time, these areas, which are created through erosion and accretion processes in river courses, offer opportunities for settlement and agriculture (Islam, 2003). These islands and attached chars have greater productivity potential than the mainland i.e. the land where the normal plain terrestrial ecosystems prevailed. On some chars, cattle are grazed on extensive natural grasslands.

Significant char deposits are created along the courses of major rivers like the Jamuna, Padma, and Meghna (Arifur & Munsur, 2011). These deposits are a valuable natural resource (Baqee, 1993) with unique hydro-geological characteristics (Sarker, 2008). The need for creative approaches to unlock the agricultural potential of charlands is highlighted by their ongoing expansion. A promising method for improving soil stability and quality while ensuring sustainable, climate-resilient land use is to implement mixed tree-annual crop agroforestry practices on charland.

In Bangladesh, agroforestry has become increasingly popular, especially in the northern regions, where 18–20 million primarily rural households are adherents (Khan et al., 2009). In addition to providing food, fuel, timber, and other necessities for families, these homesteading systems frequently rely on family labor. Homestead systems have developed to meet market demands, much like homegarden systems have (Michon & Mary 1994; Roshetko et al., 2002 Alam, 2012; Hossain & Khan, 2023).

The Village and Farm Forestry (VFFP) project was started in 1986 by the Swiss Agency for Development and Cooperation (SDC) to advance agroforestry techniques in northern Bangladesh. However, charland agroforestry was not included in these initiatives, which were mainly focused on the mainland. Charland residents face difficulties because of their geographic isolation, which restricts their access to services and markets. Low agricultural productivity is linked to limited extension activities and high transaction costs, which are experienced by both char dwellers and service providers. The poverty rate on charland is higher than the national average (35%), which is exacerbated by context-specific vulnerabilities brought on by floods, droughts, river erosion, and other natural calamities (Lein, 2000). Despite these difficulties, charlands are home to a wide variety of valuable resources, including arable land, lush fields, natural vegetation, grazing areas, and aquatic resources (Chowdhury, 2000).

Charland agroforestry systems contain obvious potential and socioeconomic advantages. Currently, however, there is insufficient technical support and empirical data regarding these systems. Comprehensive programs for charland development and sustainability should be supported by policymakers. While agroforestry practices in mainland Bangladesh have been extensively studied over the years, there remains a significant knowledge gap regarding charland agroforestry. The present study aims to identify, document, and contrast the current agroforestry systems in mainland and charland regions of Bangladesh. It was motivated by the need to fill the existing gap and to develop recommendations for improving charland agroforestry practices.

2. STUDY AREA

The research was carried out in the districts of Dinajpur, Nilphamary, and Rangpur, which are all in the Rangpur division. Among the three districts, Dinajpur characterize the mainland regions, while Nilphamary and Rangpur, represent charland regions. Dinajpur District, which has an extensive and varied population and an economy largely centered on agriculture, is located between 25°10' and 26°04' north latitude and 88°23' and 89°18' east longitude (fig. 1). The total cultivated land area is 349,387 hectares, and it is divided into four different agro - ecological zones (AEZ), numbered 1, 3, 25, and 27. The main crops grown in the area are fruits, jute, wheat, and rice. In terms of geography, the region is characterized by fertile plains, a tropical monsoon climate, and river borders. Nilphamary District is located roughly 400 kilometers northwest of the capital Dhaka with a total size of 1,547 square kilometers; and situated at 25°57' north and 88°57' east latitudes which has a diverse population. It is primarily dependent on agriculture, growing crops like rice, wheat, jute, and vegetables. The district is characterized by fertile plains and low-lying areas, a tropical monsoon climate, and rivers such as the Teesta that flow through it. Rangpur District is located at 25°36' north and 89°15' east longitudes with two Agro Ecological Zones (AEZ) 3 and 27 having a subtropical monsoon climate, fertile soil where paddy, wheat, maize, mustard, pulses, vegetables, groundnuts, and tobacco are grown on more than 70,000 hectares of land.

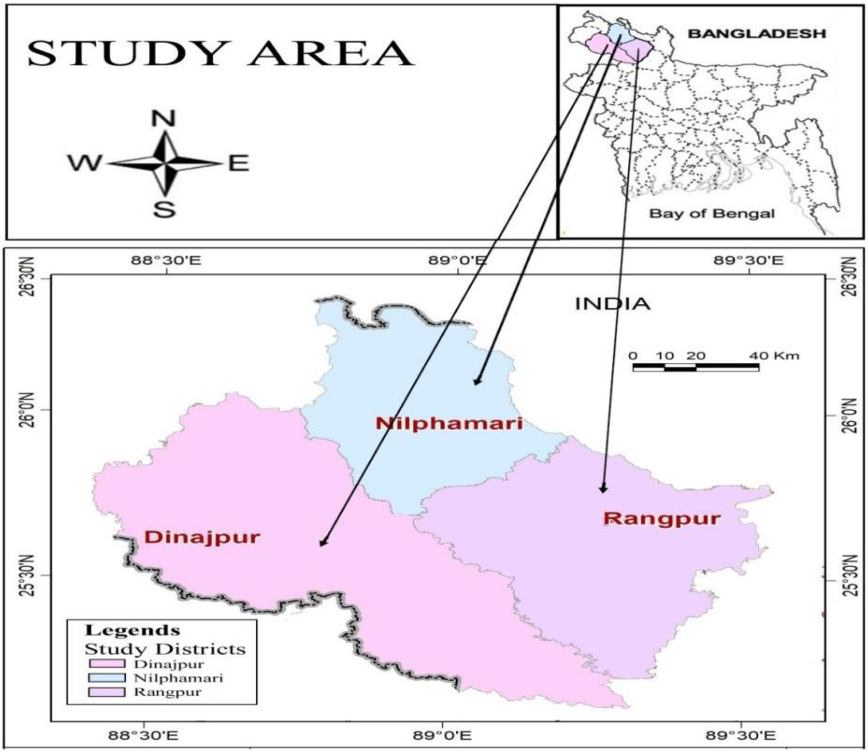

Figure 1. Map of the Study Area Districts.

3. METHODS

3.1 Sampling procedure

The study was conducted from March to August 2018. The Dinajpur District has 13 sub-districts (Upazila), of which four sub-districts (Dinajpur Sadar, Parbatipur, Biral, and Birganj) were selected randomly as mainland ecosystems for the study. In the case of Nilphamari District, there are six sub-districts: Nilphamari Sadar, Jaldhaka, Saidpur, Kishoreganj, Domar, and Dimla. As Jaldhaka and Dimla contain large areas of charland, these two sub-districts were selected as charland ecosystems for the study. Rangpur district has eight sub-districts: Badarganj, Mithapukur, Gangachara, Kaunia, Rangpur Sadar, Pirgachha, Pirganj and Taraganj, Gangachara and Kaunia were selected for the study as charland ecosystems, as they contain large areas of charland. In total 8 sub-districts were selected for the study, four representing mainland ecosystems and four representing the charland ecosystems. Two unions from each of the eight sub-districts were selected randomly as sampling sites. Following Cochran's formula (Cochran, 1977) a sample size of 385 households was calculated using the total number of households in the 16 unions with a 95% confidence level and 5% margins of errors. After that 24.125 ≅ 25 respondents were selected by proportional allocation technique from each union and purposive random sampling technique were used to select those 25 participants.

3.2 Data collection

A questionnaire was prepared to collect demographics and technical information from respondents in the study area and pretested before implementation. Besides demographic details, the survey used open-ended questions to collect information regarding farmers' knowledge of tree crops, agroforestry practices, problems of agroforestry, tree management, and related topics. Household heads were designated as survey respondents. Additionally, focus group discussions (FGD) and interviews with key respondents were conducted to triangulate information, fill information gaps, and develop a comprehensive understanding. In the three districts of the study area, one focus group discussion (FGD) was held in each sub-district with six to ten model farmers. Participants in the FGD were chosen based on traits such as their agricultural profiles, farm experiences, past use of extension services, and farm data from important extension service providers. Model farmers were chosen for this study primarily because of their role as a tool for mobilizing other farmers and because of the frequent communication they had with important extension service providers (Hailemichael & Haug, 2020). Nine extension agents were specifically chosen as key informants based on their years of experience, educational background, engagement with the agricultural communities and grasp of critical agroforestry issues. Some secondary data were collected from the statistical yearbook of Bangladesh, FAO reports, DAE (Department of Agricultural Extensions, Bangladesh) reports, and other published sources.

3.3 Data analysis

First, all data were organized in Excel spreadsheets. Means of demographic and socioeconomic characteristics of the farmers like age, education, occupation, family size, homestead area, and annual income, were determined based on a distribution of the data. Farmers' responses to questions regarding knowledge of agroforestry systems and trees were categorized as poor, moderate, and excellent. Responses regarding the uses of homestead products and labor distribution in the agroforestry were expressed as a percentage. DFID's sustainable livelihoods (SL) framework measures livelihood improvements through agroforestry (DFID, 2000). Farmers' feedback was assessed on a Likert scale based on their responses to the framework. To measure the extent of problems farmers face when practicing agroforestry, several possible problems were listed. Communication frequency between farmers and extension services was recorded on a four-point rating scale. Based on the individual and overall responses to each statement of problems and livelihood capital, the Livelihood Improvement Index (LII) (Subedi, 2016; Jannat & Uddin, 2016 and Hanif et al., 2018). A four-point rating scale was used for the measurement of livelihood improvement. In measuring the extent of livelihood improvement considering each capital, scores were separately assigned as: 0 for no change, 1 for slightly increased, 2 for increased and 3 for highly increased. The livelihood improvement index (LII) was calculated following Hanif et al., (2018) for the ranking of livelihood capitals, which aid in understanding the extent of livelihood improvement.

$$LII = (hi \times 3) + (i \times 2) + (si \times 1) + (n \times 0) \quad \text{(i)}$$

Where,
hi= Percentage of the respondents with 'highly increased' response
i= Percentage of the respondents with 'increased' response
si= Percentage of the respondents with a 'slightly increased' response
n= Percentage of the respondents with 'no change' response

A Problem Facing Index (PFI) score was calculated using a five-point scoring system (Sarmin & Hasan, 2020; Hanif et al., 2018). Each farmer was asked to rate the complexity of each challenge by selecting one of five options: “Very high”, "High," "Medium," "Low," or "Not at all." These replies were given weights of 3, 2, 1 and 0 accordingly. As a result, the problem facing score was calculated by multiplying the weighted sum of the problems' responses. The issues were ordered in order of their PFI ratings following the computation of the PFI scores. According to Saha et al. (2022), the following formula was used to calculate the PFI.

$$PFI = Pvh \times 4 + Ph \times 3 + Pm \times 2 + Pl \times 1 + Pn \times 0 \quad \text{(ii)}$$

where,
Pvh = Total number of farmers expressed problem as very high;
Ph = Total number of farmers expressed problem as high;
Pm = Total number of farmers expressed problem as medium;
Pl = Total number of farmers expressed problem as low and
Pn = Total number of farmers expressed problem as not at all

Communication Frequency Index (CFI) was calculated through the computation of scores of those attributes. The Communication Frequency Index (CFI) was determined using four-point scale as never (not at all), Low (somewhat), Medium (often) and High (regularly) and score was assigned as 0, 1, 2 and 3, respectively (Rahman et al., 2018; Hanif et al., 2018). In the case of the PFI, fewer problems are typified by lower values, while higher values typify more problems. Conversely, a higher LII value indicates a more considerable livelihood improvement, whereas lower LII value indicates a lower livelihood improvement (Hanif et al., 2018). On the other hand, lower CFI means low communication between farmers and extension agents and higher CFI means better communication. Statistical analysis was carried out with SPSS (19.0).

4. RESULTS

4.1 Current practices of Agroforestry

Current agroforestry systems are well established production systems embraced by farmers to improve living conditions. Diverse fruits and vegetables were grown in agroforestry system under varying cropping patterns across different locations. Four main systems were identified, i.e. multistoried agroforestry, crop field plantation, alley cropping, and aqua forestry (table 1). Both mainland and charland farmers cultivate a mix of fruits, vegetables, and grain alongside various tree species leading to the emergence of agroforestry practices. The most frequent strategy of agroforestry practices was the boundary tree planting followed by the scattered tree plantation technique, composite planting system, and the alley of cropland, respectively.

Table 1. Current agroforestry practices in mainland and charland.

Land Type	Major Agroforestry practices found	Major Species planted	Major crops and vegetables grown
Mainland	Multistoried Homestead Agroforestry Boundary/Scattered tree plantation in crop field Alley cropping Aqua forestry	*Artocarpus heterophyllus, Mangifera indica, Litchi chinensis, Citrus sinensis, Cocos nucifera, Swietenia mahagoni, Eucalyptus camaldulensis, Leucaena leucocephala, Dalbergia sissoo, Acacia* spp, *Albizia* spp,	Rice, Wheat, Jute, Cotton, Sweat gourd, Sweet potato, Brinjal, Amaranth, Red amaranth, Onion, Tomato, Okra, Ginger, Cauliflower, Mashkalai, Bean, Chili
Charland	Multistoried Homestead Agroforestry Boundary/Scattered tree plantation in crop field Aquaforestry	*Mangifera indica, Citrus sinensis, Swietenia mahagoni, Eucalyptus camaldulensis, Acacia* spp, *Ziziphus mauritiana, Psidium guajava, Laurus nobilis*	Jute, Maize, Aman rice, Sweat gourd, Potato, Chili, Red amaranth, Bottle gourd, Onion, garlic, Kangkong

4.2 Demographic and socioeconomic characteristics

The overall mean age of the farmer respondents was 44.8 years (fig. 2). However, mainland farmers had an average age of 48.0, whereas charland farmers were 30.0. Young farmers (< 36 years old) comprise 45.0% of charland farmers, and old farmers (> 50 years old) comprise 37.0% of mainland farmers. There were five categories of educational level. The predominant proportion (32.0%) of the farmers were never enrolled in any formal educational institute and could only sign their names. Illiterate farmers represent 10.5% of charland farmers but only 4.5% mainland farmers. Charland farmers have a lower level of education than mainland farmers, 4.9 years compared to 6.7 years. Regarding family size, overall, 61.5% of the farmers had a medium-sized family (4–6 family members), followed by 26.5% with a large family (> six family members), and 12.0% had a small family (≤3 members). Between the two farm ecosystems, medium-sized families are more common in mainland ecosystems (65.5% of respondents) than in charland ecosystems (57.5%). Interestingly, charland areas had more small families (≤3 members) than mainland areas. Most respondents (43.3%) had marginal farm sizes (0.02 to 0.20 ha), whereas minimum respondents (3.3%) had large land sizes (above 3 ha). Between the two ecosystems, more mainland farmers (4.0%) had large farms compared to charland farmers (2.5%). Overall, 9.3% of farmers had medium farms (1.01 to 3.0) and 17.0% of farmers were landless (less than 0.02 ha). Regarding annual income from agricultural products, most charland farmers (92.5%) had meager income (1.5 lacks Tk.). Only 1.5% of farmers of charland had high income (>4.5 lacks Tk.), whereas 40.5% of mainland farmers had a high income. Individuals with a medium income (>3-5 lakh Tk.) represent 24.5% of mainland farmers but only 1.0% of charland farmers. Overall, most respondents (68.8%) report their primary occupation as farming, with a minimum (4.8%) report day laboring (Fig. 2). Between the two ecosystems, 53.0% of mainland farmers have the main occupation of farming, whereas 84.5% of charland farmers belong to this occupation category. There was no service holder (0.0%) in charland, whereas 15.0% of mainland respondents were service holders. The businessman was the main occupation of 14.5% of mainland respondents, compared to 7.0% of charland respondents, slightly more than double.

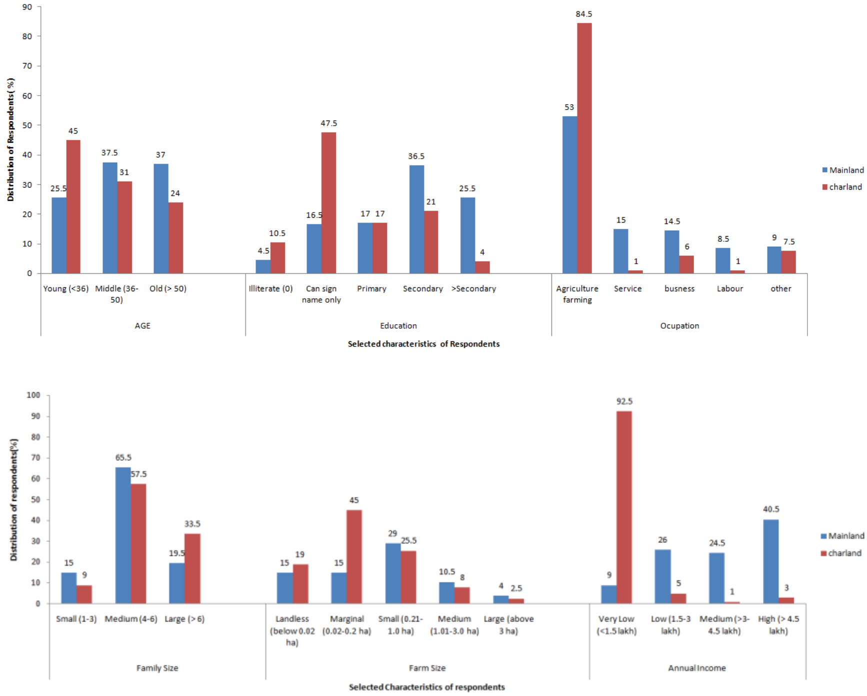

Figure 2. Demographic profile of the respondents.

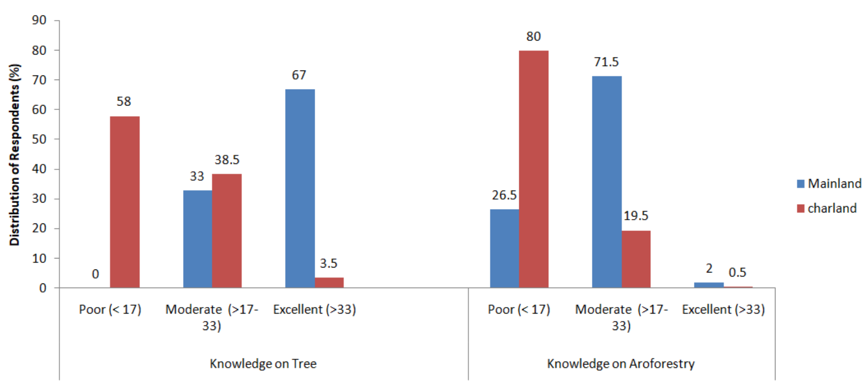

Figure 3. Distribution of farmers according to their knowledge on trees and agroforestry

4.3 Farmers' knowledge on trees and agroforestry

Farmers' knowledge of trees and agroforestry was categorized as poor (just aware), moderate (aware and have experience with cultivating) and excellent (aware, have experience with cultivating and use the crop as a source of income) (fig.3). Most farmers (35.8%) have moderate knowledge about trees, with a similar number (35.3%) having excellent knowledge. The proportion of farmers with poor knowledge of trees was high in the charland ecosystem (58.0%), with no mainland farmers reporting poor knowledge regarding trees. Most mainland farmers (67.0%) reported excellent knowledge of trees. Similarly, most charland farmers (80.0%) expressed poor knowledge of agroforestry, while most mainland farmers (71.5%) reported having moderate knowledge of agroforestry. Across the two ecosystems only a few farmers (1.3%) reported having an excellent knowledge of agroforestry.

4.4 Homestead products (fruits and vegetables) usage

The use of fruit and vegetable products produced on homesteads differs greatly between ecosystems. In charlands, 99.0% and 97.0% of farmers sell fruit and vegetable products, respectively. Among mainland farmers only 13.0% and 7.5% sell fruit and vegetable products respectively. The primary use of fruits and vegetables in mainland areas is for household consumption. Overall, 4.0% and 3.0% of farmers also distribute fruits and vegetables, respectively, to neighbors (fig. 4).

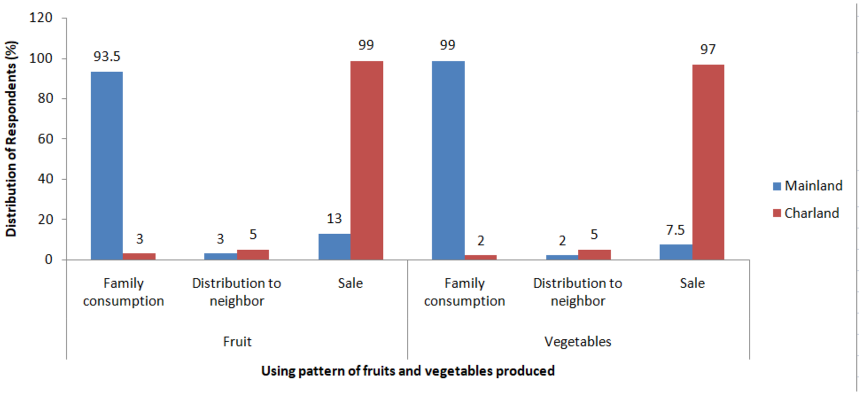

Figure 4. Using pattern of fruits and vegetables produced in agroforestry.

4.5 Communication with extension agencies

Table 2 provides a detailed overview of respondents' information sources and their corresponding Community Forest Index (CFI) rankings in both mainland and charland regions. The information sources are categorized into two areas: "Mainland" and "Charland," with columns indicating the percentage of respondents falling into categories of "Never," "Low," "Medium," and "High" for each source. In the mainland, "UAO" (85.5% never, 2.5% low, 6% medium, 6% high) and "AEO" (66.5% never, 18.5% low, 13% medium, 2% high) are the most prevalent sources, with relatively lower CFI ranks. On the other hand, "SAAO" (49.5% never, 38.5% low, 9% medium, 3% high) has a higher CFI rank. "NGO staff" (89.5% never, 8% low, 2% medium, 0.5% high) has the highest CFI ranking in the mainland, indicating its effectiveness as an information source. In charland, "NGO staff" (164.5% never, 1% low, 35% medium, 39% high) stands out as the dominant and most impactful source with the highest CFI rank. "TV/Radio" (166% never, 1.5% low, 44.5% medium, 42% high) is the second most significant source, also with a high CFI ranking. "Group Discussion" (91.5% never, 7.5% low, 1% medium, 0% high) is another noteworthy source. It's evident that the sources and their effectiveness in conveying information vary significantly between mainland and charland, with NGO staff and TV/Radio playing crucial roles in the latter's case.

Table 2. Farmers' communication with extension services/agent

Information Sources	Mainland						Charland					
	% Respondents				CFI	Rank	% Respondents				CFI	Rank
	Never	Low	Medium	High			Never	Low	Medium	High		
UAO	85.5	2.5	6	6	32.5	6	60.5	35.5	3.5	0.5	44	5
AEO	66.5	18.5	13	2	50.5	4	44	52.5	3.5	0	59.5	4
SAAO	49.5	38.5	9	3	65.5	3	16.5	43.5	39	0.5	123	2
NGO staff	89.5	8	2	.5	13.5	8	35	4.5	21.5	39	164.5	1
Group Discussion	74.5	11.5	4	10	49.5	5	91.5	7.5	1	0	9.5	8
Participation in Field Day	85.5	3.5	5	6	31.5	7	71.5	26.5	1.5	0.5	31	6
TV/ Radio	19	8	61	12	166	1	44.5	42	12	1.5	70.5	3
Newspaper, Leaflet, Bulletin	55	17	16	12	85	2	92	5	2	1	12	7

Notes: UAO = Upazilla Agriculture Officer; AEO= Agricultural Extension Officer; SAAO= Sub-Assistant Agriculture Officer, CFI = communication Frequency index.

Table 3. Distribution of farmers according to livelihood improvement

Component	Livelihood statements	Charland						Mainland					
		Extent of agreement (%)						Extent of agreement					
		None	Slight	Increase	High	LII*	Rank order	None	Slight	Increase	High	LII*	Rank order
Human	Increased vegetation knowledge	2.0	51.0	41.5	5.5	150.5	11	0.0	13.5	75.0	11.4	197.7	1
	Increased nutrition knowledge	4.5	34.5	60.0	1.0	157.5	10	0.0	22.5	69.0	8.5	186.0	3
	Increased homestead management knowledge	0.0	36.0	63.0	1.0	165.0	7	0.0	27.5	66.5	6.0	178.5	6
Social	Increased social relation with nearby communities	6.5	71.0	21.0	1.5	117.5	14	1.0	62.5	32.0	4.5	140.0	13
	Increased participation in social organization	11.0	53.5	32.0	3.5	128.0	12	29.0	66.0	5.0	0.0	76.0	15
	Conflict with neighbor	0.0	39.0	58.0	3.0	164.0	8	3.5	28.5	55.0	13.0	177.5	7
Natural	Increased nutritious food	0.0	19.5	71.0	9.5	190.0	4	0.0	31.5	65.5	3.0	171.5	8
	Increased fresh air	0.0	11.0	78.0	11.0	200.0	3	0.0	55.0	41.0	4.0	149.0	12
	Increased land utilization	11.5	56.5	31.0	1.0	121.5	13	0.0	44.0	48.5	7.5	163.5	10
Physical	Increased total agricultural production	0.0	17.5	81.5	1.0	183.5	5	0.0	6.0	91.5	2.5	196.5	2
	Increased fuel wood and timber supply	0.0	9.5	80.5	10.0	200.5	2	0.0	44.0	53.0	3.0	159.0	11
	Increased home infrastructure	4.0	34.0	62.0	0.0	158.0	9	0.0	19.5	79.5	1.0	181.5	4.5
Financial	Increased household income	0.0	3.5	90.5	6.0	202.5	1	0.0	37.0	59.0	4.0	167.0	9
	Increased household expenditure	3.0	17.0	79.5	0.5	177.5	6	1.0	16.5	82.5	0.0	181.5	4.5
	Increased savings	36.0	63.0	1.0	0.0	65.0	15	27.5	66.5	6.0	0.0	78.5	14

Notes: LII=Livelihood Improvement Index. Data in columns 'none', 'slight', 'increased' and 'highly' are %.

Table 4. Distribution of farmers according to the problems they faced in practicing agroforestry.

Sl	Problems	Charland						Mainland					
		Respondents (%)						Respondents (%)					
		None	Low	Medium	High	PFI	Rank	None	Low	Medium	High	PFI*	Rank
1	Damage by livestock	19.5	12	20	48.5	197.5	2	22	4.5	19.5	54	205.5	1
2	Social conflict	35.5	13.5	29.5	21.5	137	7	26.5	11	32.5	30	166	4
3	Lack of quality planting material	14.0	13.5	36.5	36	194.5	3	21	14	22	43	187	2
4	Lack of knowledge on agroforestry	28.0	21.5	27.5	23	145.5	6	23.5	25	16	35.5	163.5	5
5	Lack of suitable land for agroforestry	22.0	10	33.5	34.5	180.5	4	15.5	17	35.5	32	184	3
6	Risk of river erosion	21.0	5	18.5	55.5	208.5	1	0	0	0	0	0	-
7	Lack of enough credit facilities	21.5	24	17.5	37	170	5	29.5	26	23	21.5	136.5	6

Data in columns 'none', 'Low', 'medium' and 'high' are % of respondents.

Table 5. Distribution of vegetables and tress in homestead (% homestead containing the species).

Distribution of vegetables					Distribution of trees				
Common name	Scientific name	Charland (N=200)	Main-land (N=200)	All (N=400)	Common name	Scientific name	Charland (N=200)	Main-land (N=200)	All (N=400)
Jute leaf	*Corchorus olitorius*	10.5	6.5	8.5	Jackfruit	*Artocarpus heterophyllus*	68.0	76.0	72.0
Napa shak	*Malva verticillata*	6.0	9.0	7.5	Mango	*Mangifera indica*	86.5	96.0	91.3
Red amaranth	*Amaranthus tricolor*	47.0	21.0	34.0	Betel nut	*Areca catechu*	31.0	43.0	37.0
Kalmishak	*Ipomoea aquatica*	16.5	10.0	13.3	Coconut	*Cocus nucifera*	6.5	41.0	23.8
Data shak	*Amaranthas oleraceus*	4.0	9.5	6.8	Guava	*Psidium guajava*	26.5	47.0	36.8
County bean	*Lablab niger*	14.5	44.5	29.5	Olive	*Olea europeus*	6.0	16.0	11.0
Bottle gourd	*Lagenariascleraria*	49.5	9.5	29.5	Blackberry	*Randia formosa*	16.0	12.0	14.0
Pumpkin	*Cucurbitamuschata*	42.5	27.5	34.75	Litchi	*Litchi chinensis*	20.5	33.0	26.8
Cucumber	*Cucumissativus*	44.5	47.5	46.0	Ata	*Annona reticulate*	2.5	11.5	7.0
Indian spinach	*Basella alba*	31.5	36.0	33.8	Dalim	*Punica granatum*	4.5	13.0	8.8
Taro	*Colocasiaesculenta*	0.5	26.0	13.3	Boroi	*Zizyphus jujube*	10.0	15.0	12.5
Snake gourd	*Trichosanthesanguina*	2.5	2,0	2.3	Tentul	*Tamarindus indica*	1.0	5.0	3.0
Bitter gourd	*Momordicacharantia*	0.5	5.5	3.0	Bel	*Aegel mermelos*	5.0	13.0	9.0

Distribution of vegetables					Distribution of trees				
Common name	Scientific name	Charland (N=200)	Main-land (N=200)	All (N=400)	Common name	Scientific name	Charland (N=200)	Main-land (N=200)	All (N=400)
Pointed gourd	*Trichosanthesdioica*	25.5	1.0	13.3	Hog pium	*Sponditas pinnata*	5.0	11.0	8.0
Chilli	*Capsicum frutiscens*	1.5	16.0	8.8	Banana	*Musa domestica*	9.5	5.0	7.3
Brinjal	*Solanummelongena*	2.0	4.0	3.0	Lemon	*Citrus* sp.	10.0	26.5	18.3
Tomato	*Lycopersiconesculentum*	4.0	14.5	9.3	Palm	*Borassusflabellifer*	3.0	9.5	6.3
Drum stick	*Moringa oleifera*	5.5	25.0	15.3	Wax apple	*Syzygiessamarangense*	1.5	3.0	2.3
Ridge gourd	*Luffa acutangular*	7.0	5.5	6.3	Amloki	*Phyllanthusemblica*	2.0	3.5	2.8
Okra	*Hibiscus esculentus*	3.0	7.0	5.0	Chalta	*Dilleniaindica*	0.5	1.5	1.0
Carrot	*Daucus carota*	1.5	6.5	4.0	Papaya	*Carica papaya*	3.5	17.5	10.5
Cauliflower	*Brassica oleracea*var. *botrytis*	1.0	9.5	5.3	Date palm	*Phoenix dactylifera*	3.5	7.5	5.5
Cabbage	*Brassica oleracea*var. *capitata*	2.0	12.0	7.0	Kadam	*Anthocephalus chinenesis*	0.5	12.0	6.3
					Eucalyptus	*Eucalyptus camaldulensis*	44.0	17.5	30.8
					Mahogani	*Swietenia macrophylla*	9.5	34.0	21.8
					Sissoo	*Dalbergia sissoo*	1.0	1.5	1.3
					Koroi	*Acacia* spp	2.0	5.0	3.5
					Mangium	*Acacia mangium*	0.0	1.5	0.8
					Akasmoni	*Acacia auriculiformis*	3.5	11.0	7.3
					Lombu	*Switenia hybrida*	3.0	9.0	6.0
					Gamar	*Gmelina arborea*	1.0	2.5	1.8
					Bokain	*Melia azedirach*	5.5	14.5	10.0
					Arjun	*Terminalia arjuna*	1.0	1.5	1.3
					Deshi Neem	*Azadirachta indica*	10.5	31.0	20.8

4.6 Livelihood improvement

Livelihood improvement patterns differ between the mainland and char ecosystems due to the variations in agroforestry practices (Table 3). The human capital of the farmers improved substantially on mainland farms by practicing agroforestry, whereas financial and physical capital was increased dramatically in charland (Table 3). Mainland farmers stated that their knowledge of agroforestry improved considerably, while most charland farmers have not gained knowledge about agroforestry and its impact on human nutrition. As a result, mainland farmers have developed strong tree knowledge and management skills, while charland farmers still lack basic knowledge and skills.

In both ecosystems, the social capital of the farmers improved little because of practicing agroforestry. To the contrary, increased, or high levels of conflict with neighboring farmers related to practicing agroforestry was reported by 61.0% of charland farmers and 68.0% of mainland farmers. Moreover, 29.0% mainland farmers and 11.0% charland farmers stated that there is no change regarding their participation in social organizations like NGOs, while 53.5% and 66.0% of mainland and charland farmers, respectively, mentioned slight increases in social organization participation (Table 3). Regarding physical capital, 91.5% of mainland and 81.5% of charland farmers agreed that total agricultural productivity has increased because of practicing agroforestry. Similarly, 53.0% of mainland and 80.5% of charland farmers report increases fuelwood and timber supplies. Most mainland farmers (79.5%) and charland farmers (62.0%) mentioned that household infrastructure has also improved (Table 3). In the case of natural capital, most respondents from both ecosystems report that because of practicing agroforestry, the availability of fresh air and nutritious foods have increased substantially.

4.7 Problems faced by farmers practicing agroforestry

Farmers in both ecosystems identified problems faced when practicing agroforestry (Table 4). There was a difference in the severity of problems based on ecosystem. River erosion was the major problem (PFI 208.5) in charland areas, but unreported in mainland areas (PFI 0.0). Crop damage by livestock was the major problem in mainland areas (PFI 205.5) and the second major problem for charland farmers (PFI 197.5). A lack of quality planting material and limited land suitable for agroforestry were also identified as problems in both mainland (PFI 187.0) and charland areas (PFI 194.5). Farmers of both ecosystems acknowledged that agricultural credit facilities from GO and NGO sources are now more widely available to support agroforestry development and knowledge on agroforestry is becoming more readily available.

4.8 Plant biodiversity in agroforestry

Almost all the homesteads cultivate diverse species of various trees and seasonal crops. A total of 23 vegetable species and 34 tree species (Table 5) were identified in the homesteads overall. Native vegetables were more common in the charland whereas fruits and commercial vegetables were more prevalent in the mainland. Specifically, the commercial vegetables tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*), okra (*Hibiscus esculentus*), carrot (*Daucus carota*), cauliflower (*Brassica oleracea* var. *botrytis*) and cabbage (*Brassica oleracea* var. *capitata*) were more common in mainland areas, but as reported above, are mainly used for household consumption. In the case of tree species, fruit species were more common (22 species representing 59.5% of all tree species) followed by timber species (11 species, 29.7%). Medicinal tree species were few (4 species, 10.8 %). In the case of fruit tree frequency, jackfruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*) and betel nut (*Areca* *catechu*) are most common in both ecosystems. The frequency of fruit species is lower in charland compared to mainland areas, except for blackberries (*Randia formosa*). In case of timber tree frequency, eucalyptus (*Eucalyptus camaldulensis*) is very common on charland whereas mahogany (*Swietenia macrophylla*) is most common on the mainland. The only medicinal tree common in both ecosystems is neem (*Azadirachta indica*).

Table 6. Farmers' and expert's perceptions and aspirations for practicing agroforestry.

Comments	Mainland	Charland
Farmers	Benefits: • Anticipated increase in income and/or animal feed through the practice of agroforestry. • Multistrata agroforestry has the potential to mitigate certain drought impacts. • The homestead is deemed a suitable venue for promoting agroforestry.	Benefits: • Transitioning from monocropping to agroforestry minimizes the likelihood of crop failure. • Enhances opportunities for diverse agricultural production and livelihood improvement.
	Risks: • Reduction of land available for annual staple crops, posing a potential threat to food security.	Risks: • Accessing the market poses challenges.
Expert	Benefits: • Utilizing agroforestry for crop zoning can establish effective land use systems. • Adopting integrated farming within agroforestry, incorporating fish, ducks, poultry, dairy, goats, fruit trees, and forest trees, presents significant potential as a multistrata landscaping approach.	Benefits: • Implementing site-specific agroforestry, considering the local hydrogeological situation, can establish effective land use systems. • Utilizing large, stable attached charland provides an ideal environment for promoting agroforestry. • Agroforestry integrated with animal components holds substantial potential.
	Risks: • Escalating labor costs are affecting overall production. • The lack of longer-term investment capital, technical expertise, equipment, and high-quality tree seedlings is constraining adoption opportunities of agroforestry.	Risks: • The development of agroforestry may face hindrances due to the frequency and duration of natural hazards. • Government acquisition of charland for various development projects, such as export processing zones, resorts, power plants, etc., poses a risk. • Farmers perceive labor inputs for such endeavors as higher than the economic return.

4.9 Farmer and expert perceptions on agroforestry adoptions

Farmers on the mainland agreed that engaging in agroforestry could increase income and provide valuable animal feed (Table 6). They shared the belief that on the one hand homesteads were a good place to promote multistrata agroforestry because it could help mitigate the effects of drought Farmers on charlands. On the other hand, they contended that switching from monocropping to agroforestry could reduce the chance of crop failure. They realized that agroforestry could improve food and feed habits by increasing the potential for diverse production and enhancing livelihoods. Furthermore, they noted that integrating fruit trees and grass, along with implementing better management practices such as thinning and pruning, had enabled some farmers to reduce storm damage. Certain households even envisioned new business opportunities.

In discussions with experts, it was suggested that, for mainland agroforestry, combining crop zoning with agroforestry might establish effective land-use systems. The combination of fish, ducks, poultry, dairy, goats, fruit trees, and forest trees was considered a promising method for multifunctional landscaping in the context of integrated farming-based agroforestry. However, experts stressed that agroforestry specific to the site and the local hydrogeological conditions could be a useful land-use system for charlands. They emphasized that big, stable charlands offered a favorable setting for agroforestry, especially when adding animal elements. Several challenges to agroforestry adoption on the mainland of Bangladesh were identified, including scarcities of cultivable land, high input costs, and a shortage of quality planting materials. However, high investment costs, the difficulty of managing pests and diseases, an unstable market, low product prices, weather events, and a lack of awareness were blamed for the risks connected with agroforestry on charlands.

5. DISCUSSION

5.1 Demography of charlands

Charland dwellers are younger than their mainland counterparts. With land options limited, active and energetic young families establish settlements on charland. Due to their remote location and lack of infrastructure charland dwellers have lower levels of formal education. Family size in charland areas is smaller compared to mainland areas; this is likely due to families being younger. The younger generations generally want to keep their family small and use birth control measures. Similarly, the land area of charland farmers is smaller. Being new settlers, charland farmers start with small areas of land. Yet, farmers may have the option of purchasing more land to expand their farms. In our study, consistent with reports by Islam (2000), charland dwellers' main occupation is farming. Results confirm that off farm jobs are plentiful in mainland areas, while non-existent in charlands. There is no industry or non-farm income generation activities on charland.

5.2 Agroforestry knowledge and extension service providers on charland

It is a paradox that knowledge about trees and agroforestry is lower among charland farmers compared to mainland farmers. The communication link between agricultural extension services and charland farmers is poor due to isolation. Government extension offices are located in mainland areas. Therefore, mainland farmers have frequent visits and strong connections with government agencies. A few NGOs, while also located in mainland areas, do provide extension services to charland areas. The main source of agroforestry extension information for charland farmers is from NGO workers. Our results agree with those of Rahman et al. (2021) that while charland farmers may successfully manage agroforestry systems, they have limited training and knowledge of agroforestry practices and techniques.

5.3 Impacts of agroforestry on charland livelihoods

The SL framework tool developed by DFID assesses people's livelihoods by identifying their access to the five capitals (DFID, 2000). Improving skills and knowledge is an indication of improvement in human capital (Islam et al. 2011). It is a challenge to manage agroforestry, where farmers must select the right combination of tree species and crops that are appropriate for cultivation under specific agroecological conditions. Since most mainland farmers have been practicing agroforestry for a long time, they have developed knowledge and skill regarding homestead farming. Agroforestry practices in charland are less sophisticated, as they are new settlements and farmers are younger with less education and experience. Social capital is mirrored through the culture and relationships within individuals and groups. In our study, social capital of the farmers has not improved substantially in either ecosystem as compared to the other four capitals. In Bangladesh most farmers have small homesteads, with land division to smaller parcels persisting. Farmers plant trees on the boundary of their homesteads for demarcation, protection, and production. These trees may shade neighboring crops, causing conflicts. These conflicts prevent the farmers from creating a situation of communal trust and hamper their ability to work together. Hence, they are not able to create a viable association or local co-operative organization for mutual benefit. In remote areas with limited infrastructure, farmer-to-farmer communication is an effective means of cooperation to disseminate agroforestry information and technology (Martini et al., 2017). In many areas, farmers who practice agroforestry create local learning groups to discuss system management, innovations, and benefits. NGOs can play a crucial role in motivating people to practice agroforestry and developing learning groups to share knowledge and promote collaboration (Islam et al., 2014). Both NGOs and government extension offices can promote the dissemination of agroforestry information through farmer-to-farmer communication by training farmer leaders and farmer extensionists (Martini et al., 2017). Replicating this process would improve social capital in the study areas.

Household income can influence participation in social groups and farmers ability to adopt agroforestry technology (Rahman et al., 2017; Sabastian et al., 2014; Kallio et al., 2012). A diverse combination of trees and crops in agroforestry systems increases farm productivity in this study on both char and mainland farms. The production of food and forest products enhances the physical capital of households. By harvesting and selling timber, households gain income to access education, health, and sanitation services. Without such income sources most rural households would not be able to access those basic services due to limited cash resources and related opportunity costs. In this study, several farmers reported using vans (three-wheeled bicycles or bicycles with carrying capacity) to bring their products to markets. This innovation enabled farmers to increase or maximize sales potential of their products, securing higher income (financial capital), by accessing market facilities where prices are more lucrative.

The practice of agroforestry on homestead boosts the cultivation of valuable tree species, increasing agrobiodiversity. Consequently, rural landscapes are covered with many tree assets, which generate income for poor farmers (Rahman et al., 2012). As reported by both charland and mainland farmers in this study, the adoption of agroforestry can meet their demand for fuel wood and timber. When species match objectives and site conditions, it is recommended to plant leguminous and deciduous species in homesteads. Many leguminous species fix atmospheric nitrogen which is added to the soil through the application and decomposition of plant biomass (Roshetko, 2001). As a result of decomposition, soil nutrients are added, improving soil properties, and increasing plant productivity (Hasanuzzaman & Hossain, 2015; Rajendren & Mohan, 2014). Moreover, trees planted in homesteads can protect homes, soil and understory vegetables or other agricultural crops from high temperatures, severe wind, and storms (Tscharntke et al., 2011; Rice & Greenberg, 2000). The benefit of this natural capital has a greater impact on charlands than the mainland, as there is limited infrastructure in charland, making fertilizers difficult and costly to access. Moreover, charland is comparatively open with limited 'natural infrastructure' (Islam et al., 2011). Agroforestry systems are considered a foundation of resource-based farming, which is crucial in the context of climate change and environmental restoration for charland. Agroforestry increases farmers' household incomes and improves their socioeconomic condition in charland to a greater extent than on the mainland. Because homesteads are most often the only resource in which charland farmers can invest their money and labor, long-term economic improvement is effectively achieved by enhancing their agroforestry systems (Rahman et al., 2016). The development of those natural capitals often triggers broader household and community socioeconomic development (Chakraborty et al., 2015). Thus, well-planned expansion of agroforestry is a suitable option to facilitate socioeconomic development of charland areas.

5.4 Uses of vegetable and trees and its frequencies on charland

The main reason for mainland farmers to cultivate trees and vegetables is to for household consumption. The second reason is income generation by selling products in nearby markets, with 7.5% to 13.0% of mainland farmers marketing fruits and vegetables, respectively. However, mainland farmers cultivate seed-bearing vegetables more in their homesteads, whereas charland farmers cultivate short rotation leafy vegetable more in their homesteads. Charland farmers have restricted access to quality planting material (seed or seedlings) of seed-bearing vegetables compared to mainland farmers. Because charland farmers are comparatively poorer, they use their limited capital to invest in short rotation crops. In our study, farmers of both ecosystems prefer fruit tree species. *Mangifera Indica* was the most common tree species, cultivated by 91.3% of farmers. Similarly, Chowdhury (1997) reports *Mangifera indica* as the most dominant tree species in agroforestry. In southwest Bangladesh, 62.9% farmers plant fruit trees and 46.6% plant timber trees in their agroforestry systems (Hasanuzzaman et al., 2014). *Eucalyptus camaldulensis* is widely adaptable in Bangladesh due to its fast-growing nature, cylindrical stem, short crown, high yield (69 m3 ha−1year−1) and ready for market. *Swietenia mahogany* and *Melia azedarach* are other abundant species planted in homesteads of northern Bangladesh (Yasmin et al., 2010). Similarly, our study identifies *Eucalyptus camaldulensis*, *Swietenia mahagoni* and *Melia azedarach* as predominant species in the research area. Medicinal tree species are less frequent on charland as compared to the mainland. Our results specify that charland farmers have limited experience and knowledge of medicinal tree species and cultivation. A likely reason for this is that due to their economic condition, charland farmers often focus on short-term cash returns.

5.5 Charland farmer challenges and solutions relative to agroforestry practices

The quality of production inputs is an important issue to increase yields on homesteads. Farmers in the study area do not have access to good quality planting materials of annual or perennial crops and rely on the materials which are easily available. Farmers usually cultivate local variety of vegetables. When possible, they also plant grafted fruit seedlings of mature vegetative material with the intention of hastening fruit production. Sometimes the trees originating from those seedlings are uprooted by strong storms or cyclones during the monsoon due to poor development of root systems. Similarly, seeking quick returns, farmers often plant 2-year-old timber seedlings with deformed root systems. Suboptimal tree performance caused by poor root development is common in farmer systems across Africa and Asia (Nyoka et al., 2015; Carandang et al., 2006). Fruit trees are planted at wider spacing (6-8 m) while timber trees are planted at closer spacing (2-4 m). Farmers face challenges from free grazing cows, goats, and poultry which damage perennial and annual crops (Bari, 2019). This is a major problem in both ecosystems of the study areas. The issue is more severe in charland areas because households are poor and cannot build adequate fences to protect against livestock. In mainland areas, even moderately affluent farmers can build fences to protect their agroforestry groves. Riverine erosion is the most serious problem on charlands. For sustainable charland homesteads, a hydrological framework to protect the settled charland is needed (Islam, 2000). Hydro-engineering embankments or dams could be constructed to reduce the char erosion and settlement displacement. Moreover, nonstructural means could be included as an alternative solution of charland problems in the Tista River basin.

5.6 Farmer and expert perceptions on agroforestry adoption

The study's findings show that mainland farmers are in complete agreement about the possible advantages of agroforestry, highlighting its ability to increase revenue and supply valuable animal feed (Sollen-Norrlin, 2020). These farmers see homesteads as ideal settings for advancing multistrata agroforestry because they think it has the potential to lessen the effects of drought (Kewessa, 2020). Conversely, farmers on charlands argue that transitioning from monocropping to agroforestry could effectively reduce the risk of crop failure, acknowledging the potential for diverse production and improved livelihoods, thus enhancing food and feed habits. For some farmers of charlands, integrating grass and fruit trees with improved management techniques like thinning and pruning has reduced storm damage, which has given some households hope for new business prospects (Wanjira et al., 2020).

Combining crop zoning and agroforestry is suggested by expert discussions as an efficient way to manage land use on the mainland (Rahman et al., 2016). In addition, a promising method for multifunctional landscaping is highlighted: integrated farming-based agroforestry, which incorporates fish, ducks, poultry, dairy, goats, fruit trees, and forest trees. Experts stress the significance of site-specific agroforestry for charlands that are adapted to the local hydrogeological conditions, especially in the favorable environments of large, stable charlands (Sanz et al., 2017). The adoption of agroforestry on Bangladesh faces several obstacles, such as limited arable land, exorbitant input costs, and a lack of high-quality planting materials. On the other hand, there are several risks connected to agroforestry on charlands, such as high investment costs, difficulty managing pests and diseases, unstable market conditions, low product prices, vulnerability to weather events, and a lack of knowledge among stakeholders. The results highlight the necessity of targeted actions and education programs to tackle obstacles and hazards, enabling extensive implementation of agroforestry techniques in both main land and charland environments.

5.7 Policy implications for sustainable development in charland

Charlands, as fertile riverine deltas, will always be a valuable resource for food security and agricultural production. It is important to enhance the management and usage of this resource, particularly in the context of climate change and natural disasters. Government studies report that the impact of environmental concerns on income, employment, infrastructure, and migration will probably be more severe on charland (Bangladesh Planning Commission, 2022; GOB, 2018). The char dwellers will undoubtedly suffer if the proper steps are not taken to help them prepare to address the effects of climate change on their environments. Proper strategies for sustainable water management, agriculture, forest, rural roads, land policy, and disaster management are required to facilitate pro-poor growth. To increase sustainable agricultural productivity and profitability of charland, Bangladesh's National Agricultural Policy 2018 emphasizes the use of research and extension services for inclusive and integration in charland development (Ministry of Agriculture of Bangladesh, 2018). To make this goal actionable, the government should set aside dedicated resources in the development plans, preferably within a new institutional framework. By coordinating current GO and NGO activities and services in char regions, the government agencies and other relevant organizations could create the conditions necessary for the delivery of fundamental services, support, and new economic prospects. The government should also work alongside the international community to improve capacity and obtain resources for charland development and management. This type of coordination between government agencies with other stakeholders is a key recommendation of the recent FAO roadmap to enhance the use of technologies in the Asia-Pacific region (Roshetko et al., 2022).

6. CONCLUSIONS

Our study documents that agroforestry helps to ensure sustainable enhanced livelihoods through the production of commodities for home use and market sale, thus increasing farmers' food resources and income, while also protecting and improving soil quality, ensuring maximum utilization of natural resources, and reducing the risks associated with vulnerable livelihoods. However, in charland areas, while agroforestry benefits farmers and the environment, its potential remains unrealized due to their remote locations, low levels of farmer knowledge and limited access to resources, including information. Efforts are required to provide charland dwellers the information, resources, and market access necessary to further develop agroforestry systems to enhance local income and livelihoods, contribute to national food security, meet market demands, and promote sustainable resource management.

7. RECOMMENDATIONS

By implementing the following recommendations and suggestions, Bangladesh could make progress towards efficient planning and management of charland agroforestry, reducing poverty, stabilizing rural livelihoods, and advancing the Sustainable Development Goals.

- Use Geographical Information Systems (GIS) to plan and manage charland agroforestry by conducting in-depth analyses, visualizations, mapping, and modelling of land data. To ensure that local viewpoints are considered, encourage active community participation in charland agroforestry initiatives.
- Launch capacity-building initiatives to equip regional communities with better agroforestry knowledge and abilities.
- Prioritize tactics that are in line with regional circumstances, making sure that agroforestry techniques are tailored to the particulars of charlands.
- Incorporate applied research into the national development agenda to comprehend the dynamics of erosion and charland agroforestry.
- Apply research findings to support sustainable charland management through evidence-based decision-making.

- Acquire political will and commitment to implement agroforestry-based sustainable management and conservation efforts for charlands.
- Align the management of charland with broader national goals of ending poverty and stabilizing rural livelihoods.
- Acknowledge the importance of charland agroforestry for achieving the country's Sustainable Development Goals.
- Utilize the Bangladesh Delta Plan 2100's inclusion of multifunctional landscaping techniques for charland development.
- Put a focus on governmental policymaking to support and facilitate initiatives aimed at improving livelihoods through enhanced agricultural and agroforestry systems on charlands.
- Ensure that agroforestry methods and sustainable land use practices are promoted in policy frameworks.

Author Contributions: MSB: Conceptualization, funding acquisition, investigation, methodology, project administration, resources, supervision, writing—original draft, writing—review and editing; JMR: Data curation, formal analysis, methodology, writing—original draft, writing—review and editing; MMA: Data collection, investigation, data validation, visualization, writing—review and editing; MFH: Data curation, formal analysis, software, and visualization.

Competing Interests: The authors declare no conflicts of interest.

Acknowledgments: The authors gratefully acknowledge the support of World Agroforestry (ICRAF) in Bogor, Indonesia. We would also like to extend our thanks to the Rural Development Academy (RDA) in Bogura, Bangladesh for their logistical support during the study. Our sincere appreciation goes to the farmers in Dinajpur, Rangpur, and Nilphamary districts for their willingness to participate and their continued support throughout the research. Finally, we thank the Krishi Gobeshona Foundation (KGF) for providing the funding that made this study possible.

REFERENCES

Alam, M. (2012). Valuation of tangible benefits of a homestead agroforestry system: a case study from Bangladesh. *Human Ecology, 40*(4), 639–645. https://doi.org/10.1007/s10745-012-9512-5

Arifur, R. M., & Munsur, M. R. (2011). Resource and livelihood practices of Char Dwellers: A case study of an attached char. In Proceedings of the 3rd International conference on water and flood management, ICWFM-2011, Dhaka, Swasti Printers Nilkhet (Vol. 1, pp. 207-213).

Bangladesh Bureau of Statistics (BBS). (2022). *Statistical yearbook of Bangladesh 2007.* Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Bangladesh Planning Commission. (2022*). Overview of BDP 2100.* Bangladesh Planning Commission. Retrieved from https://bdp2100kp.gov.bd/BDP2100/Overview

Baqee, M. A. (1993). *The settlement process in the char-lands* [Doctoral Dissertation (Unpublished)]. University of Dhaka.

Bari, S. Md. (2019). *Agroforestry as a multifunctional landscaping tool in the charland area of Bangladesh.* AgriFoSe2030 Brief. Swedish University of Agricultural Sciences (SLU).

Carandang, W. M., Tolentino Jr, E. L., & Roshetko, J. M. (2006). Smallholder tree nursery operations in southern Philippines—supporting mechanisms for timber tree domestication. *Forests, Trees and Livelihoods, 16*(1), 71-83. https://doi.org/10.1080/14728028.2006.9752546

Chakraborty, M., Haider, M. Z., & Rahaman, M. M. (2015). Socio-economic impact of cropland agroforestry: evidence from Jessore district of Bangladesh. *International Journal of Research in Agriculture and Forestry, 2*(1), 11-20.

Chen, M., Atiqul Haq, S. M., Ahmed, K. J., Hussain, A. B., & Ahmed, M. N. Q. (2021). The link between climate change, food security and fertility: The case of Bangladesh. *PLoS One, 16*(10), e0258196. https://doi.org/10.1371/journal.pone.0258196

Chowdhury, M. (2000). An assessment of flood forecasting in Bangladesh: The experience of the 1998 flood. *Natural Hazards, 22,* 139-136. https://doi.org/10.1023/A:1008151023157

Chowdhury, M. K. (1997). Agroforestry in homesteads and croplands: existing practices and potentials. In M. K. Alam, F. U. Ahmed, & S. M. R. Amin (Eds.), *Agroforestry: Bangladesh perspectives* (pp. 68–84). Bangladesh Agricultural Research Council.

Cochran, W. G. (1977). *Sampling Techniques (3rd Edition)*. John Wiley & Sons.

DFID (Department for International Development). (2000). *Sustainable rural livelihood*. DFID (Department for International Development).

Government of Bangladesh (GOB). (2017). *Bangladesh Delta Plan 2100 (Draft)*. General Economics Division, Bangladesh Planning Commission. Retrieved from http://www.lged.gov.bd/UploadedDocument/UnitPublication/17/624/Bangladesh%20Delta%20Plan%202100%20Draft%20Report.pdf

Government of Bangladesh (GOB). 2018). Bangladesh Delta Plan 2100 (abridged version). General Economics Division, Bangladesh Planning Commission.

Hailemichael, S., & Haug, R. (2020). The use and abuse of the 'model farmer'approach in agricultural extension in Ethiopia. *The Journal of Agricultural Education and Extension, 26*(5), 465-484. https://doi.org/10.1080/1389224X.2020.1757475

Hanif, M. A., Roy, R. M., Bari, M. S., Ray, P. C., Rahman, M. S., & Hasan, M. F. (2018). Livelihood improvements through agroforestry: Evidence from Northern Bangladesh. *Small-scale Forestry, 17,* 505-522. https://doi.org/10.1007/s11842-018-9400-y

Hasanuzzaman, M., & Hossain, M. (2015). Leaf litter decomposition and nutrient dynamics associated with common cropland agroforest timber tree species of Bangladesh. *International Journal of Forest Research, 61*(2), 125–139. https://doi.org/10.1155/2014/805940

Hasanuzzaman, M., Hossain, M., & Saroar, M. (2014). Floristic composition and management of cropland agroforest in southwestern Bangladesh. *Journal of forestry research, 25*(3), 597-604. https://doi.org/10.1007/s11676-014-0451-4

Hossain, M. R., & Khan, M. A. (2023). Impact of Household Interventions on Homestead Biodiversity Management and Household Livelihood Resilience: An Intertemporal Analysis from Bangladesh. *Small-scale Forestry, 22,* 481-510. https://doi.org/10.1007/s11842-023-09540-4

Islam, M. S., Sultana, S., & Miah, M. A. (2014). Adaptation of char livelihood in flood and river erosion areas through indigenous practice: a study on Bhuapur Riverine Area in Tangail. *Journal of Environmental Science and Natural Resources, 7*(1), 13-19. http://dx.doi.org/10.3329/jesnr.v7i1.22138

Islam, S. N. (2000). *Char people, living with the Padma River and fragile environment: char study report March 2000* (Unpublished report). Gono Unnayan Prochesta (GUP).

Islam, S. N. (2003). *Banglapedia: National Encyclopedia of Bangladesh*. Asiatic Society of Bangladesh.

Islam, S. N., Roh, E., & Ashraf, D. (2011). Char-lands Development Policy for Livelihoods Sustainability in the Padma River Basin in Ganges Delta in Bangladesh. *KAPS*

International Conference, pp. 349-3969.

Jannat, A., & Uddin, M. T. (2016). Farmers perception about one house one farm project and its impact on enterprise profitability in selected areas of Mymensingh district. *The Agriculturists, 14*(1), 43-53. https://doi.org/10.3329/agric.v14i1.29099

Kallio, M. H., Kanninen, M., & Krisnawati, H. (2012). Smallholder teak plantations in two villages in Central Java: silvicultural activity and stand performance. *Forests, Trees and Livelihoods, 21*(3), 158–175. https://doi.org/10.1080/14728028.2012.734127

Kewessa, G. (2020). Homegarden agroforestry as a tool for sustainable production unit in Ethiopia. *Journal of Resources Development and Management, 67,* 14-19. http://dx.doi.org/10.7176/JRDM/67-02

Khan, M. A. H., Ali, M. Y., Quayyum, M. A., Nazrul, M. I., & Hossain, M. J. (2009). Year round homestead vegetable production: a means of reducing poverty and nutritional deficiency for small farm. *Bangladesh Journal of Agricultural Research, 34*(1), 169-174. http://dx.doi.org/10.3329/bjar.v34i1.5767

Lein, H. (2000). Hazards and 'forced' migration in Bangladesh. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography, 54*(3), 122-127. https://doi.org/10.1080/002919500423735

Martini, E., Roshetko, J. M., & Paramita, E. (2017). Can farmer-to-farmer communication boost the dissemination of agroforestry innovations? A case study from Sulawesi, Indonesia. *Agroforestry Systems, 91,* 811-824. https://doi.org/10.1007/s10457-016-0011-3

Michon, G., & Mary, F. (1994). Conversion of traditional village gardens and new economic strategies of rural households in the area of Bogor, Indonesia. *Agroforestry Systems, 25,* 31-58. https://doi.org/10.1007/BF00705705

Ministry of Agriculture of Bangladesh. (2018). National Agriculture Policy 2018. Ministry of Agriculture of Bangladesh, English version. Retrieved from https://moa.gov.bd/site/view/policies/Policies

Nyoka, B. I., Roshetko, J., Jamnadass, R., Muriuki, J., Kalinganire, A., Lillesø, J. P. B., ... & Cornelius, J. (2015). Tree seed and seedling supply systems: a review of the Asia, Africa and Latin America models. *Small-scale Forestry, 14,* 171-191. https://doi.org/10.1007/s11842-014-9280-8

Rahman, M. H., Uddin, M. N., & Khan, M. (2018). Communication Behaviour of Farmers with the Agricultural Extension Agents Using Cell Phone: A Case of Bangladesh. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems (IJASRT in EES), 8*(3), 121-127.

Rahman, M. S., Rahman, J., Saifullah, M., Jewel, K. N. A., & Yasmine, M. (2021). Exploring improved agroforestry practiced farmer's socio-demographic characteristics and their livelihood in selective charlands of Bangladesh. *Social Values and Society (SVS), 3*(2), 54-57. http://doi.org/10.26480/svs.02.2021.54.57

Rahman, M. T. (2017). Role of agriculture in Bangladesh economy: uncovering the problems and challenges*. International Journal of Business and Management Invention, 6*(7), 36-46.

Rahman, S. A., Imam, M. H., Snelder, D. J., & Sunderland, T. (2012). Agroforestry for livelihood security in Agrarian landscapes of the Padma floodplain in Bangladesh. *Small-scale Forestry, 11,* 529-538. https://doi.org/10.1007/s11842-012-9198-y

Rahman, S. A., Sunderland, T., Kshatriya, M., Roshetko, J. M., Pagella, T., & Healey, J. R. (2016). Towards productive landscapes: Trade-offs in tree-cover and income across a matrix of smallholder agricultural land-use systems. *Land Use Policy, 58,* 152-164. https://doi.org/10.1080/14728028.2008.9752629

Rahman, S. A., Sunderland, T., Roshetko, J. M., & Healey, J. R. (2017). Facilitating smallholder tree farming in fragmented tropical landscapes: Challenges and potentials for sustainable land management. *Journal of environmental management, 198,* 110-121. https://doi.org/10.1016/j.jenvman.2017.04.047

Rajendren, K., & Mohan, E. (2014). Tree species with potential of nitrogen fixation in agroforestry system adopted by farmers in semi-arid region of Southern India. *Biological Research Bulletin, 3,* 1-4.

Rice, R. A., & Greenberg, R. (2000). Cacao cultivation and the conservation of biological diversity. *AMBIO: A Journal of the Human Environment, 29*(3), 167-173. https://doi.org/10.1579/0044-7447-29.3.167

Roshetko, J. M. (2001). Agroforestry species and technologies: a compilation of the highlights and factsheets published by NFTA and FACT Net 1985-1999. Taiwan Forestry Research Institute and Council of Agriculture, Taiwan, Republic of China and Winrock International, Morrilton, Arkansas, USA.232 p.

Roshetko, J. M., M Delaney, K Hairiah, and P Purnomosidhi. (2002). Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage? American Journal of Alternative Agriculture, 17, 138-148.

Roshetko, J. M., Pingault, N., Quang Tan, N., Meybeck, A., Matta, R., & Gitz, V. (2022). *Asia-Pacific roadmap for innovative technologies in the forest sector.* Food and Agriculture Organization of the United Nations (FAO), Center for International Forestry Research (CIFOR), CGIAR Research Program on Forests, Trees and Agroforestry (FTA). https://doi.org/10.17528/cifor/008515

Sabastian, G., Kanowski, P., Race, D., Williams, E., & Roshetko, J. M. (2014). Household and farm attributes affecting adoption of smallholder timber management practices by tree growers in Gunungkidul region, Indonesia. *Agroforestry Systems, 88,* 257-268. https://doi.org/10.1007/s10457-014-9673-x

Sanz, M. J., De Vente, J. L., Chotte, J.-L., Bernoux, M., Kust, G., Ruiz, I., Almagro, M., Alloza, J. A., Vallejo, R., Castillo, V., Hebel, A., & Akhtar-Schuster, M. (2017). Sustainable land management contribution to successful land-based climate change adaptation and mitigation: A report of the Science-Policy Interface. Bonn: UNCCD. ISBN 978-92-9511-095-3.

Saha, S. M., Pranty, S. A., Rana, M. J., Islam, M. J., & Hossain, M. E. (2022). Teaching during a pandemic: do university teachers prefer online teaching? *Heliyon, 8*(1), e08663. https://doi.org/10.1016/j.heliyon.2021.e08663

Sanz, M. J., De Vente, J., Chotte, J. L., Bernoux, M., Kust, G., Ruiz, I., ... & Akhtar-Schuster, M. (2017). *Sustainable land management contribution to successful land-based climate change adaptation and mitigation: A report of the science-policy interface.* United Nations Convention to Combat Desertification (UNCCD).

Sarker, M. H. (2008). *Morphological response of the Brahmaputra-Padma-lower Meghna River system to the Assam Earthquake of 1950* [Doctoral Dissertation (Unpublished)]. University of Nottingham.

Sarmin, S., & Hasan, M. F. (2020). Constraints faced by the small-scale farmers in achieving household food security: A case from Dinajpur district, Bangladesh. Bangladesh Journal of Extension Education, 32(1), 63-72. http://dx.doi.org/10.5281/ZENODO.7229679

Sollen-Norrlin, M., Ghaley, B. B., & Rintoul, N. L. J. (2020). Agroforestry Benefits and Challenges for Adoption in Europe and Beyond. *Sustainability, 12*(17), 7001. https://doi.org/10.3390/su12177001

Subedi, B. P. (2016). Using Likert type data in social science research: Confusion, issues and challenges. *International Journal of Contemporary Applied Sciences, 3*(2), 36–49.

Tscharntke, T., Clough, Y., Bhagwat, S. A., Buchori, D., Faust, H., Hertel, D., ... & Wanger, T. C. (2011). Multifunctional shade-tree management in tropical agroforestry landscapes–a review. *Journal of Applied Ecology, 48*(3), 619-629. https://doi.org/10.1111/j.1365-2664.2010.01939.x

Ullah, H., Islam, M. N., & Malak, M. A. (2010). Charland dynamics of the Brahmaputra-Jamuna river in Bangladesh. Jahangirnagar Review Part II: Social Science, 167-184. http://dx.doi.org/10.13140/RG.2.1.3324.3282

Wanjira, E. O., Muriuki, J., & Ojuok, I. (2020). *Farmer Managed Natural Regeneration in Kenya: A primer for development practitioners.* CGIAR. Retrieved from http://apps.worldagroforestry.org/downloads/Publications/PDFS/B20069.pdf

Yasmin, R., Wadud, M. A., Mandol, M. M. A., & Sharif, M. O. (2010). Tree diversity in the homestead and cropland areas of Madhupur Upazila under Tangail District. *Journal of Agroforestry and Environment, 4*(1), 89-92.