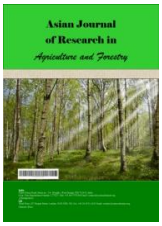

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Livelihood Improvement of Farmers through Agroforestry Practices in Teesta and Jamuna River Basins

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Authors' contributions

This work was carried out in collaboration between both authors. Author RS designed the study, managed the literature searches and wrote the first draft of the manuscript. Author MSB wrote the protocol, performed the statistical analysis and finalize the draft manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Agroforestry is one of the most sustainable land management systems practiced around the world due to the socioeconomic benefits to farmers. In Bangladesh, farmers practice agroforestry, applying indigenous knowledge. The objectives of the study are to explore the dominant agroforestry systems and species preferred by and to assess the socio-economic impact of agroforestry technologies on their livelihoods of farmers of the Char dwellers in Jamuna and Teesta river basins. The study was conducted at four Char Upazillas such as Kazipur, Shariakandi, Kaunia and Dimla. A total 120 farmers were surveyed during the research period using structured questionnaire with both open and closed ended questions. The majority of the respondents (56.67%) having low score in adoption of traditional agroforestry practices. Most of the farmers (94.17%) in Teesta and Jamuna river basins are practicing traditional homestead agroforestry system. The most frequent strategy was boundary tree plantation (44.17%) followed by scattered tree plantation technique on composite planting system, and the alley of cropland. A total of 41 tree species are abundant in Char areas of Teesta and Januna basins. Eucalyptus (*Eucalyptus camaldulensis)* is widely adaptable in Bangladesh including Char areas followed by Mango (*Mangifera indica)* in homestead besides, Mahagony (*Swietenia mahagoni)* is another abundant

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species planted in croplands boundaries of Char areas along with Akashmoni (*Acacia auriculiformis)*. The farmers mentioned different problems they were facing in practicing agroforestry but 'shade cast by trees' was the major problem. Majority farmers of Char areas plant trees in homestead for fruits (63.33%) and in cropland for fuel wood (95.83%) and timber production (82.50%). Farmers' livelihoods improved enormously by practicing agroforestry as they have more access to food, fodder and fuel wood which is reflected by greater access to livelihood capitals except social capital. However, the farmers have experienced increased incidences of pests and diseases to annual crops and trees. Agroforestry practices increases species diversity, ensure economic return and sustain farmers' livelihoods. The respondents, local leaders and experts suggested the constrains of adopting agroforestry in Char areas are lack of awareness, education, technical skills, capital, technical assistance, interest, marketing and transportation facilities at the study areas . The government should initiate some agroforestry focused projects, especially in the Char areas for the capacity building of the farmers and equip them with the new farming techniques through trainings and orientation workshops. The farmers should be provided scientific guidance about suitable tree species grown on agricultural land with field crops, their silvicultural operations and tree management practices along with free services and inputs including seeds, seedlings and loan schemes for promoting agroforestry.

Keywords: Agroforestry; livelihood and river basins.

1. INTRODUCTION

Agroforestry comprises of land use systems and technologies in which the woody perennials are deliberately integrated on the same land management unit with herbaceous crops and or animals in either some forms of spatial arrangement or temporal sequence [1]. In AGROFORESTRY systems there are both ecological and economical interactions between the woody and non-woody components in agroforestry [2,3]. ICR AGROFORESTRY's current definition is a collective name for land-use systems and practices in which woody perennials are deliberately integrated withcrops and/or animals on the same land-management unit. The integration can be either in a spatial mixture or in a temporal sequence. Agroforestry is a system in which different components are benefiting from each other in several different ways. The trees can give fodder to animals and fix nitrogen for the crops and providing different biological pesticides and an improved micro-climate [4]. Agroforestry also ranges from very simple and sparse to very complex and dense systems and it holds a wide range of practices. The aim of Agroforestry lies in optimizing production based on interactions between various systems` components and their physical environments leading to higher sum total and a more diversified and sustainable production [5]. The most common Agroforestry systems in the tropics and subtropics include; Agrosilviculture, Silvopasture and Agrosilvopasture [1]. Others are Aquosilvicultural and Aposilvicultural systems [6]. Agroforestry technologies (AGROFORESTRYTs) on the other hand, refer to the various way of arrangement of the components in an agroforestry system [3]. Examples of AGROFORESTRYTs are like Home gardens, mixed intercropping, integrated tree/pasture management, alley farming, windbreak, etc. [7]. Agroforestry focuses on the growing of annual crops sequentially or alongside perennial trees [8,9] and is a system that can be sustainable and eco-friendly [10], and satisfies the socio-economic needs of the people [11,12]. The products (food crops and tree resources) harvested from the agroforestry practices fulfil the multidimensional needs of rural people [13]. Agroforestry practices have the potential to improve soil fertility; control soil erosion; improve water quality and enhance biodiversity [14]. It also alleviates poverty by increasing income and engages women's in production activities [15,16]. Agroforestry practices can also reduce the negative effect of climate change through carbon sequestration [17,18].

Bangladesh is the eighth most densely populated country in the world, 65% of the population lives in rural areas and their livelihood largely depends on agricultural activities [19]. Due to rapid urbanization and industrialization, the land area for agriculture has decreased sharply. The cultivable land has decreased 0.14% from 1976 to 2000 and 0.73% from 2000 to 2010; this trend is anticipated to worsen in the future [20]. Moreover, the present land use system with separate allocation to agriculture and forestry wasnot be sufficient to satisfy the demands of the people living in the rural communities [21].

Agroforestry has the potential to help offset the loss of agricultural and forest land. Agroforestry involves the simultaneous production of perennial trees and annual crops in cropland [22]. In a composite plantation system, both fruit and woody species are planted to generate more income. Fast-growing, deciduous, nitrogen-fixing, small crowned trees are often chosen for planting [9]. Cereal crops, vegetables, spices, pulses and cash crops are grown in agroforestry [8].

Horticultural-tree based agroforestry is more common than forest-tree (timber-yielding trees) based agroforestry in Bangladesh [23]. Mango-based agroforestry has been reported to improve the livelihood of farmers of the Padma flood plain region of Bangladesh [12]. Research conducted in southern Bangladesh reported that agroforestry not only improves the socioeconomic condition [11] and livelihood [12] of the farmers but also ensures environmental services even in degraded ecosystems such as sandbars [24]. Previous studies in northern Bangladesh highlighted the structure and diversity [25], biodiversity conservation [26,27], economic benefits [28], livelihood improvement and economic services provided by homestead agroforestry [29,30]. Other research focused only on the species diversity [22] or annual crop diversity [31] of cropland. Farmer's livelihoods improved enormously by practicing agroforestry as they have more access to food, fodder and fuel wood which is reflected by greater access to livelihood capitals (except social capital). However, farmers have experienced increased incidences of pests and diseases to the annual crops and trees. Agroforestry practices increases species diversity, ensure economic return and sustain farmer's livelihoods [32].

Generally, Char areas have been created along the bed or basin of the large rivers. Char lands are the sandbars that emerge as islands within the river channel or as attached land to the river banks. Simply, the riverine sand and silt landmasses known as Char in Bengali. On an average, 5% of Bangladeshi population as well as 6.5 million people live on the Chars covering almost 5% of the total land area of the country and miserably it is narrowed as 7200 square kilometer [33]. Most of the Char dwellers are involved in various kinds of farming systems that represent production of crops, livestock, poultry, fisheries, etc. Generally the production practices are different from the main land due to different soil and land topography. The Char dwellers invest their available resource base to enhance farm productivity.

The livelihood patterns of the people in Char areas are much more harsh and full of uncertainties. The livelihood of Char people is described by Schumuck-Widmann [34] and Sarker et al. [35]. According to them there are very limited and seasonal work opportunities in the Char areas. People living in Char lands endure insecure livelihoods. Geographical, social, immoral and political instability and insecurity pushed the Char dwellers to a vicious cycle of poverty. The major issues that the Char dwellers face are poor access to essential services, inadequate saving and credit options, poor access to income enhancing opportunities and services, and so on [36]. However, the Char dwellers always fight against the hunger, poverty, illiteracy, less farm productivity, climatic disasters, etc.

1.1 Statement of Problem

The production and livelihood scenarios of Char dwellers have been picturized in a number of literatures. According to Islam et al., (2014) explored indigenous survival techniques and variation in peoples' ability to adopt with flood and river erosion in Char areas of Tangail district and showed that the people in the Char lands with high flood proneness and low socioeconomic circumstances were more likely to fail to adopt with the conditions compared to the people in areas with high and sudden flooding. According to Ibrahim [37] conducted a study on impact of agroforestry practices on livelihood improvement of the farmers of Char Kalibari area of Mymensingh district and found that, by the proper implementation of agroforestry practices with proper tree-crop combination, the people could improve their livelihood and socioeconomic status. According to Saifullah [36] identified the perception of Char dwellers under Kazipur Upazilla in Sirajganj district regarding their livelihood option and their capacity to cope with climate change and prioritize the adaptation option for reducing their vulnerability and found that the people changed cropping patterns with seasons and selected time of cultivation agroforestryter prediction of natural disasters to overcome the impact of natural disasters. To the best of our knowledge, no cohesive statistics are available on recent practices of agroforestry along with the management and its impact on the livelihood of the farmers from Char areas of Bangladesh.

Most of the farmers of the areas are marginal farmers getting a lower yield of crop due to the adverse effect of drought and flood. Hence farmers are planting trees in their cropland to derive production from trees to improve their livelihood [38]. The Char land of Bangladesh has vast opportunities for the extension of agroforestry. Therefore, it is important to find out the extent of livelihood improvement through agroforestry technologies and this study was undertaken to address the following questions:

1. What are the the current status of adoption of Agroforestry by the farmers in Teesta and Jamuna river basins?
2. What type of agroforestry systems and technologies preferred and used by the people in the study area?
3. To what extent does agroforestry improve farmers' livelihoods?

1.2 Scope of the Study

In Bangladesh, potential of agroforestry is vast. The main venues of agroforestry are homestead, roadside, railway side, embankment side, Char land, coastal area, deforested area, institutional premises, riverside and so on. Among them Char land is the most important venue for practicing agroforestry systems. The major Char inhabited districts of Bangladesh are Rangpur, Nilphamari, Kurigram, Ghaibanhha, Jamalpur, Mymensingh, Sirajgonj, Bogura, Rajshahi, Chapai Nawabgonj, Pabna, Taingail, Shariatpur, Faridpur, Barishal, Patuakhali, Blola, Manikgonj, Munshigonj and Noakhali. A large number of populations are living in these Char areas and maintaining their livelihood through Char based farming systems. Therefore, for increasing production, maintaining ecological balance and improving socio-economic condition of the Char land people, integrated approach with crop and trees is necessary.

1.3 Objectives of the Study

Thus the main objective of the study is to assess the impact of agroforestry system and technologies on livelihood of Char dwellers in Teesta and Januna river basins and the specific objectives are as follows:

1. To explore the dominant agroforestry systems and species preferred by farmers in Jamuna and Teesta river basins
2. To assess the socio-economic impact of agroforestry technologies on the livelihood of Char dwellers

2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Conventional rural livelihood analyses often neglect the role of environmental products in general and forest and AGROFORESTRY products in particular [39]. However, traditional AGROFORESTRY has been practiced for millennia by agrarian-based societies throughout the world [40]. The World Bank estimates that 1.2 billion people practice some form of AGROFORESTRY on their farms and in their communities [41]. Although AGROFORESTRY has been practiced by these farming communities for a long time, there is inadequate awareness about its potential to the millions that live in poverty [40]. In recent days, agroforestry has progressed as a science-based pathway for achieving important objectives in natural resource management and poverty alleviation [40]. There is increasing evidence that potential of agroforestry to reduce poverty is real and can be put to efficient use in Poverty Reduction Strategies of many countries in Agroforestryrica. In forest-scarce countries, agroforestry has expanded greatly on small farms. In Kenya and Ethiopia, for example, farms account for most timber and pole production [42]. In AGROFORESTRY systems, the cost of tree production may be lower due to joint production with crops and livestock. Trees may even have a positive effect on the incomes of associated crops, as in the case of windbreaks.

According to Alavalapati et al. [43] and [44] agroforestry technologies range from traditional to recent practices and the nature, complexity, and objectives are also vary greatly between the agroforestry practices in tropics and temperate zones. According to Alavalapati et al. [43] and [44], there are eight major agroforestry technologies in tropical system. First, '*taungya* system' that refers to agricultural crops grown during the early stages of forest plantation establishment. Second, home gardens that refers to intimate, multi-storey combinations of a variety of trees and crops in homestead gardens (livestock may or may not be present). Third, improved fallow that refers to fast growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation. Fourth, multipurpose trees that refer to fruit and other trees randomly or systematically planted in cropland or pasture for the purpose of providing fruit, fuel wood, fodder, and timber, among other services, on farms and rangelands. Fifthly, the other type is plantation-crop combinations that

integrate multi storey mixtures of trees and crops (such as coconut, cacao, coffee, and rubber), and shade trees and crops. Sixthly we have '*silvopasture'* which is a practice of combining trees with forage and livestock production, such as grazing in existing forests; using trees to create live fences around pasture; or to provide shade and erosion control. Seventh, shelterbelts and windbreaks that refer to rows of trees around farms and fields planted and managed as part of crop or livestock operations to protect crops, animals, and soil from natural hazards including wind, excessive rain, seawater, or floods. Lastly, alley cropping that combines fast-growing, preferably leguminous woody species in single or grouped rows are applied asmulch into the agricultural production alleys to increase organic matter and nutrients and/or are removed from the field for other purposes such as animal fodder.

2.1 Conceptual Framework for Livelihood Analysis

A study by Babulo et al. [39] used sustainable livelihood approach as a framework of analysis in an attempt to identify the factors that influence a household's choice of livelihood strategy, with a particular focus on the extraction of, and dependence on, forest products in Tigray, Ethiopia (Fig. 1). This study extends the previous study by including forestry services particularly income derived from agroforestry products and services in household livelihood strategies. Similarly, Brown et al. [45] using asset based approach identified distinct livelihood strategies in household survey in Kenya's central and western highlands.

This study adapts the five capitals used in the DFID livelihood framework [46]: human, natural, physical, financial and social capitals as defined below:

2.2 Human Capital

Human capital is considered as one the basic building block or means of achieving livelihood outcomes. At the farm household level, human capital is a factor of the amount and quality of labour available; this varies according to household size, education level, skill levels, and health status.

2.3 Natural Capital

Natural capital comprises land, water, rivers, forests and other biological resources that people utilise to generate a livelihood. One of the principal physical natural resource for a farmer's livelihood is land and any decision related to land use would be affected by his access to land and security of tenure.

2.4 Financial Capital

Financial capital has been used to refer to stocks of money that the household has access to. These include savings held in the bank, credit, stocks and fungible assets such as, jewellery, gold or food stocks. At the farm household level financial capital refers to savings held in the bank, access to credit in the form of loans, and stocks. Financial capital only becomes a useful asset in the household when it is converted into other forms of capital or is used directly for the purchase of food. This ease of switching between uses makes financial capital one of the fundamental assets.

2.5 Physical Capital

This refers to basic infrastructure such as transport, shelter, water, energy, communications and production equipment, which enable people to pursue their livelihoods. At the household level, farm equipment, housing, livestock (used for animal traction) and other personal household properties that can be converted into cash are considered as physical capital.

2.6 Social Capital

Various definitions of social capital have been offered. Social capital refers to features of social organisation, such as networks, norms and trust that facilitate co-ordination and co-operation for mutual benefit. Social capital as "the rules, norms, obligations, reciprocity and trust embedded in social relations, social structures, and society's institutional arrangements, which enable its members to achieve their individual and community objectives". Social analysis as a generic term which encompasses institutional, political, and social analyses.

As depicted in Fig. 1, the livelihood framework focuses on households' access to five types of 'capital' or 'assets'-natural, human, physical, social and financial [39]. The livelihood approach is based on the premise that the resource and asset status of people is fundamental to understanding the options open to them, the strategies they adopt to attain livelihoods, the outcomes they aspire to and the vulnerability context under which they operate.

3. MATERIALS AND METHODS

3.1 Study Area

The study was conducted at four Upazillas covering four districts: two from Jamuna river basin (Kazipur Upazilla under Sirajgong district and Shariakandi Upazilla under Bogura district) and other two from Teesta basin (Kaunia Upazilla under Rangpur district) and Dimla Upazilla under Nilphamari district. Preliminary information on agroforestry in the study area was collected from the district Department of Agricultural Extension office. Randomly selected two unions from each of the four Upazilla and 15 farmers from each union. Thus 30 farmers were surveyed from each of the four Upazillas. A total of 120 respondents were included in the survey of which 30.83 percent are females and 69.17 percent are males. Data on annual income from crops and horticultural produces, farm production costs, monetary value of agroforestry products and services, livestock size, and household size are collected from sampled households in the study areas. The distribution of the respondents by river basin and gender is presented in Table 1.

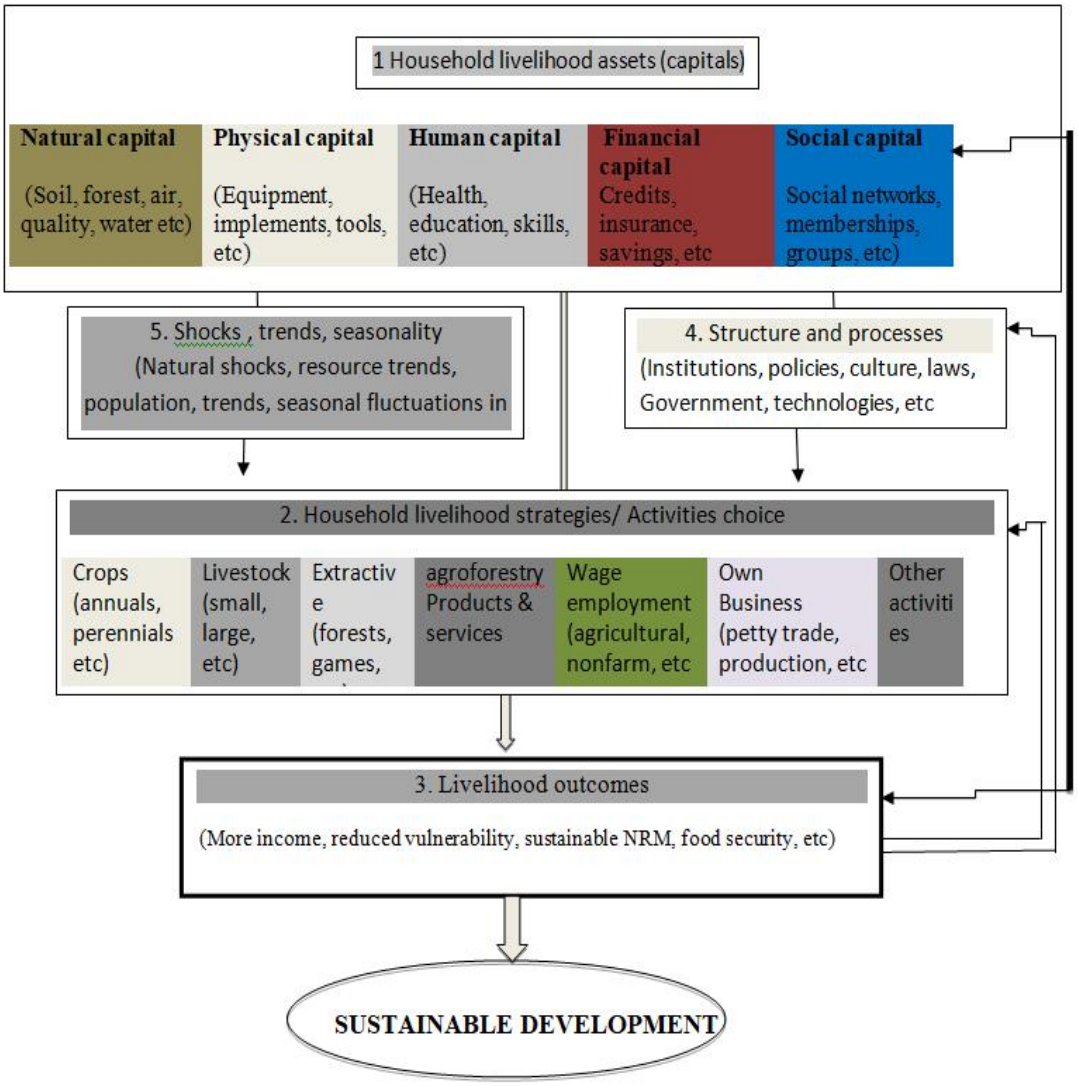

Fig. 1. Conceptual framework of sustainable livelihoods
Source: Adapted and modified from Babulo et al.[39]

Table 1. Distribution of respondents according to river basin and gender

River basin	Female		Male		Total	
	N	%	N	%	N	%
Teesta river basin	19	15.83	41	34.17	60	50.00
Jamuna river basin	18	15.00	42	35.00	60	50.00
Total	37	30.83	83	69.17	120	100.00

3.2 Data Collection

A mixed approach of data collection methods was used for the study. The questionnaire was pre-tested before the final interviews. The interviews were conducted with the head of households. Species composition, including trees, shrubs and agricultural crops, of each selected cropland were recorded through direct agroforestry plot visits with the assistance of the farmers. Farmers replied to open questions about the source of planting materials, tending operations, nutrient supply and plant protection measures carried out in their croplands, which was also be recorded during the field visit. Secondary information was also being collected from internet, DAE reports, statistical year-books and other sources. These were help to cross-check the data collection during the direct interviews. Interviews with the farmers were conducted at a convenient time for the farmers, and they responded freely to each topic.

3.3 Variables of the Study and its Measurement

Age, educational qualification, family size, farming experiences of agf, land holding, knowledge of agroforestry, average annual income from agf product/ services (crop, livestock and tree), adoption of traditional homestead agroforestry practices, agroforestry systems adopted by the respondents in teesta and jamuna river basins, species along with their density, relative density and usage in char areas of teesta and jamuna river basins, benefits from agro forestry farming system practices, problems faced by the farmers for practicing agroforestry, constraints of adopting agroforestry in teesta and jamuna river basins

3.4 Measurement of the Livelihood

Livelihood improvement status of the farmers in char areas was measured by computing a composite livelihood improvement score based on each of the five components of 'livelihood asset pentagon' [46]: (i) human capital (ii) social capital (iii) financial capital (iv) physical capital and (v) natural capital. The capitals were measured against fifteen statements. Each of the statements was put against 4 point rating scale: highly increased, increased, slightly increased, and no change and score given as 4, 3, 2 and 1, respectively for positive statements and the scoring technique was reverse for the negative statements. The total scores for each of the livelihood capital could range from 15 to 60, where 15 indicated no improvement and 60 indicated high improvement regarding the concerned livelihood capital. The overall score for livelihood improvement was computed by adding the scores obtained by all of the capitals of livelihood asset pentagon. Thus, total scores for overall livelihood improvement status could vary from 60 to 240, where 60 indicated no improvement and 240 indicated very high improvement of overall livelihood status of the farmers through practicing agroforestry.

3.5 Data Analysis

Data were arranged in MS Excel. Age, family size and farming experience of the farmers was categorized based on an overall distribution of the respective data while educational qualification of the farmers were categorized based on years of schooling. A four point scale was used for computing the extent of adoption to homestead agroforestry practices. Weights of responses against the applicable ones of the 25 practices were assigned in the following way. A score of 3, 2, 1 and 0 was assigned for high use, medium use, low use and no use respectively. The weights of responses of all homestead agroforestry practices were added together to obtain the extent of use homestead agroforestry practice and the score of the respondents could range from 0 to 75 where 0 indicating no use and 75 indicating high use of agroforestry practices. Responses on types of agroforestry systems practiced and purpose of AGF were expressed as a percentage. In addition, the extents of livelihood improvement of the farmers practicing agroforestry were measured following sustainable livelihoods (SL) framework [47]. A number of possible problems were selected to measure the extent of problems faced by farmers

in practicing agroforestry. The extents of problems faced by the farmers were recorded on a four-point Likert scale. In a similar way, the responses of farmers were taken to evaluate the extent of livelihood improvement through DFID's livelihood (Human, Social, Physical, Natural and Financial) capitals. The Problem Facing Index (PFI) and Livelihood Improvement Index (LII) were then calculated based on the individual and overall responses of the farmers on each statement of problems and livelihood capitals. Conversely, for the LII, higher values were indicating livelihood improvement and smaller values lower livelihood improvement. Statistical analysis (multiple response and descriptive statistics) were performed using SPSS statistical software. Density and relative density of the species planted were measured by using the following equation [8]:

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of household surved}}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

4. RESULTS AND DISCUSSION

4.1 Demographic and Socioeconomic Characteristics

The age of the farmers ranged from 19 to 73 years, with a mean of 44 (Table 2). The farmers were classified into three age groups: 'young' (up to 35 years), 'middle aged' (36–50) and 'old' (> 50). The majority of farmers belong to the middle aged category. Based on the educational level, farmers were divided into five groups. The largest proportion (44.17%) of the farmers had primary educational qualification (1–5 years of schooling), 9.17% farmers had secondary education (6–10 years of schooling), 8.8% had above secondary level (above 10 years of schooling), 28.33% can sign only, and 14.17% of the farmers were illiterate. Regarding family size, 44.17% of the farmers had a medium sized family (5–7 family members), followed by 35% with a large family (>7 family members) and 20.83% had a small family (≤ 4 members). The average farm size of the respondents was 0.79 ha which was higher than that of national average of 0.51 ha [48]. Majority of the respondents had medium farming experiences (50%). Most of the respondents (54.17%) of the farm households had medium annual average income from agroforestry product and services. It was found that all the respondents had low to medium knowledge on agroforestry.

Farmers were practicing agroforestry for different periods. About 56.67% of the farmers had been practicing agroforestry for 5–15 years, 26.67% had more than 15 years of experience and 16.6% had 5 years or less experience. In addition, farmers had an average 20 years farming experience of and an average of 11.65 years agroforestry farming experience.

4.2 Adoption of Traditional Homestead Agroforestry Practices

A four point scale was used for computing the extent of adoption to traditional agroforestry practices. Weights of responses against the applicable ones of the 25 practices were assigned in the following way. A score of 3, 2, 1 and 0 was assigned for high use, medium use, low use and no use respectively. The weights of responses of all traditional agroforestry practices were added together to obtain the extent of use homestead agroforestry practice and the score of the respondents could range from 0 to 75 where 0 indicating no use and 75 indicating high use of agroforestry practices.

In this study the adoption of traditional agroforestry practice score of the respondents ranged from 21 to 63 with the mean value to 30.23 and standard deviation 7.77. Based on the adoption scores, the respondents were classified into 3 categories (Table 3). The overwhelming majority of the respondents (56.67%) were high score category who was found to have higher adoption of traditional agroforestry practices including homestead agroforestry.

4.3 Agroforestry Systems Adopted by the Respondents in Teesta and Jamuna River Basins

The people of the study area have a tradition of practicing agroforestry; recently their practices have been reinforced by the need for socio-economic and environmental sustainability. Three common agroforestry models were found in the study site:

1. Homestead Agroforestry
2. Cropland Agroforestry
3. Boundary Plantation (hedgerows)
4. Alley Cropping
5. Scattered tree planting
6. Composite plantation

Table 2. Socioeconomic Characteristics of the respondents

Characteristics	Measuring unit	Observed range	Categories	Respondents		Mean	SD
				No.	Percent		
Age	Number of Years	19-73	Young (Up to 35)	28	23.33	45.68	12.72
			Middle (36-50)	59	49.17		
			Old (Above 50)	33	27.5		
Educational qualification	Years of schooling	0.0–16	Illiterate (0.0)	17	14.17	5.93	3.45
			Can sign only (0.5)	34	28.33		
			Primary level (1–5)	53	44.17		
			Secondary level (6–10)	11	9.17		
			Above secondary level (> 10)	5	4.17		
Family size	No. of members	4–11	Small (up to 4)	25	20.83	5.89	2.567
			Medium (5-7)	53	44.17		
			Large (Above 7)	42	35		
Farming Experiences of AGF	Years	2-35	Low (below 5 years)	20	16.67	11.65	5.678
			Medium (5-15 years)	68	56.67		
			High (Above 15)	32	26.67		
Land Holding	Hectare	0.03-2.87	Marginal (≤1 ha)	87	72.50	0.785	4..567
			Small (1-2 ha)	26	21.67		
			Medium/Large (≥2 ha)	7	5.83		
Knowledge of Agroforestry	Scale score	12-44	Low	52	43.33	26.16	7.007
			Medium	48	40.00		
			High (above)	20	16.67		
Average annual Income from AGF product/ services (Crop, livestock and tree)	Taka	18398-348567	Low (Below 59803	42	35.00	5980	16849
			Medium (59803-150000)	65	54.17	3.60	.50
			High (Above 150000)	13	10.83		

(Source: Field data collection on March-June 2019)

Table 3. Adoption of traditional agroforestry practiced by the farmers in study areas

Characteristics	Categories	Respondent %	Measuring system	Average	Standard deviation
Adoption of traditional Agroforestry practices	Low score (up to 30) Medium score (30 to 50) High score (above 50)	14.17 29.17 56.67	Score	30.23	**7.77**

Table 4. Agroforestry systems adopted by the respondents in Teesta and Jamuna river basins

Types of tree planting	f	Percent of farmers (%)*	Comments
Homestead agroforestry	113	94.17	*Totals sum to greater than 100% due to the fact that some farmers practice multiple types of agroforestry systems on their homestead cropland simultaneously
Boundary planting	53	44.17	
Composite planting	27	22.50	
Scattered tree planting	39	32.50	
Strip/Alley cropping	18	15.00	

Most of the farmers (94.17%) in Teesta and Jamuna river basins are practicing traditional homestead agroforestry system. On their cropland farmers planted trees in three different ways: boundary planting, scattered tree planting and alley cropping and also practicing composite tree planting (means mixture of different systems and species) system in their land with some shade loving crops like turmeric, zinger, yam etc. The most frequent strategy was the boundary tree planting (44.17%) followed by the the scattered tree plantation technique composite planting system, and the alley of cropland, respectively (Table 4). The density and relative density of growing species in the Teesta and Jamuna river basins with the rank order are presented in Table 5.

Table 5. Species along with their density, relative density and usage in Char areas of Teesta and Jamuna river basins

Sl. no	Species	Scientific name	Density	Relative density (%)	Rank	Uses
1	Jackfruit	*Artocarpusheterophyllus*	1.88	2.28	20	F, T, FW
2	Blackberry	*Syzygiumcumini*	1.69	2.05	22	F, T, FW
3	Coconut	*Cocos nucifera*	1.93	2.35	18	F
4	Litchi	*Litchi chinensis*	2.98	3.61	6	F
5	Jujube	*Zizyphusjujuba*	1.58	1.92	25	F, FW
6	Lemon	*Citrus spp*	2.60	3.16	8	F
8	Guava	*Pisidiumguajava*	3.31	4.02	4	F
9	Starfruit	*Averrhoa carambola*	0.83	1.00	38	F
10	Mango	*Mangiferaindica*	3.05	3.70	5	F, T, FW
11	Betelnut	*Areca catechu*	2.48	3.02	9	F
12	Ataphal	*Annona reticulata*	1.24	1.51	35	F
13	Sajna	*Moringaoleifera*	1.33	1.61	32	F
14	Olive	*Elaocarpusfloribundus*	1.60	1.94	24	F
15	Pomelo	*Citrus grandis*	1.45	1.76	29	F
16	Tal	*Borassusflabellifer*	1.04	1.27	37	F
17	Tetul	*Tamarindusindica*	1.48	1.79	27	F, T, FW
18	Hog plum	*Spondiasmombin*	1.46	1.77	28	F
19	Bel	*Aegle marmelos*	1.27	1.54	34	F
20	Deshi Neem	*Azadirachtaindica*	1.38	1.67	31	T, FW, M
21	Ghora Neem	*Melia azadarach*	1.05	1.28	36	T , FW
22	Horitoki	*Terminalia chebula*	0.80	0.97	39	M, T
23	Amloki	*Phyllanthusemblica*	0.50	0.61	40	F
24	Bohera	*Terminalia bellerica*	1.64	1.99	23	M, T
25	Arjun	*Terminalia arjuna*	1.45	1.76	29	M, T
26	Akashmoni	*Acacia auriculiformis*	4.08	4.95	2	
27	Eucalyptus	*Eucalyptus cameldulensis*	7.54	9.16	1	T, FW
28	Siris	*Albiziasaman*	1.75	2.13	21	T, FW
29	Mahogoni	*Sweteniamahogoni*	4.00	4.86	3	T, FW
30	Lombu	*Khayaanthotheca*	2.34	2.84	10	T, FW
31	Raintree	*Albiziasaman*	1.95	2.37	17	T, FW
32	KaloKoroi	*Albizialebbeck*	2.33	2.82	11	T, FW
33	Sadakoroi	*Albiziaprocera*	1.57	1.90	26	T, FW
34	Gamari	*Gmelinaarborea*	2.88	3.49	7	T, FW
35	Sissoo	*Dalbergiasissoo*	2.12	2.57	14	T, FW
36	Kadam	*Anthocephaluschinensiss*	1.30	1.58	33	FW
37	Ipil ipil	*Leucaenaleucocephala*	2.03	2.46	16	T, FW
38	Shaora	*Streblus asper*	2.23	2.71	13	FW
39	Khoksa	*Ficushispida*	2.28	2.77	12	FW
40	Sonalu	*Cassia fistula*	1.89	2.30	19	FW
41	Mander	*Erythrinaorientalis*	2.07	2.51	15	FW

F = fruit, T = timber, FW= fuel wood, M = medicinal

Eucalyptus *(Eucalyptus camaldulensis)* is widely adaptable in Bangladesh including Char areas due to its fast growing nature, cylindrical stem, and short crown, high adaptability in flood and drought climatic condition and high yield (69 m^3/ha/year). The species can be managed easily. It is not labour intensive and requires limited inputs [49]. Beside this, Mahagoni (*Swietenia mahagoni*) is another abundant species planted in croplands boundaries of Char areas along with Akashmoni (*Acacia auriculiformis*). These species were also adaptable to a wide range of soil and climatic gradients for their small crowns, clear boles and high market values of the timber. The fact from our study that Eucalyptus (*Eucalyptus camaldulensis),* Mahagoni *(Swietenia mahagoni) and* Akashmoni *(Acacia auriculiformis)* were predominant species in the study area is in agreement with the findings of Yasmin et al. [21]. Eucalyptus (*Eucalyptus camaldulensis)* was also the most prevalent woody species in the farmlands of Ethiopia [50] having an IVI value of 63.9 [51].

4.4 Benefits from Agro Forestry Farming System Practices

There is a general identification of the multiple benefits of agro forestry including revenue from sale of wood products and environmental outcomes particularly. The farmers generally believe that the trees planted along with agricultural crops damage the crop production and agroforestry the economic returns. The benefit obtained from the farming practices of upland farmers were relatively high.

The most profitable benefits are 95.83% of the respondents considered is beneficial for better supply of fuel wood followed by timber (82.50%), fodder (77.50%), source of money in emergency (72.50%), fruit (63.33%), increase living standard (49.17%), environmental conservation (34.17%), getting construction materials (31.67%), climate control (28.33%), compost (23.33%), employment (23.1%), traditional medicine (22.50%), soil conservation (18.33%), very few number of respondents were also aware of benefits like protection form flood 12.50% , soil conservation (10.1%) and employment generation and 4.17% (Table 6).

4.5 Problems Faced by the Farmers for Practicing Agroforestry

The farmers mentioned different problems they were facing in practicing agroforestry. Among those, shade cast by trees were the major problems, followed by competition for nutrients between trees and agricultural crops, root competition and pests and diseases infestations. Farmers found that the potency of the chemicals secreted by the trees has little allelopathic effect on annual crops (Table 7).

4.6 Livelihood Improvement of the Respondents in Teesta and Jamuna River Basins

DFID's Sustainable Livelihood framework is widely used as a tool to assess the livelihood of people through the five capitals for sustainable livelihood. Increase in knowledge and skill represents the improvement of human capitals. Managing agroforestry system is a difficult task in which farmers have to select the appropriate tree species and crops for cultivation. Since most farmers have been practicing agroforestry for a long time, this has helped to improve their knowledge and skill of farming. Training from the Government and non-government organizations can underpin the development of human capital. Social capital is reflected through the culture and relationships within individuals and groups. In our study, social capital of the farmers have not improved compared to the other capitals of sustainable livelihood. In Bangladesh most of the farmers belong to the marginal group and do not have enough land for cultivation. Farmers plant trees in the boundary of cropland which cast shade on neighbouring farms, causing conflicts. These conflicts prevent the farmers from creating a situation of trust and hampers their ability to work together. Thus they do not have access to wider institutions from where they can gather knowledge of self-development activities.

The human capital of the farmers improved dramatically by practicing agroforestry. The farmers stated that their knowledge relating to agroforestry improved substantially. The farmers management capacity of trees planted in the cropland also increased resulting in the overall development of their farming skills.

Social capital of the farmers did not improve as much as the other capitals of livelihood. About 64.7% of farmers reported on-going conflict with neighboring farmers due to practicing agroforestry. Moreover, 53.9% responded that there is no change regarding participation in social organizations like NGOs (Table 7). However, 97.1% of farmers agreed with the statement that the relationship with other

communities has improved. Considering physical capital, all of the farmers agreed that forest productivity has increased. 94.1% of farmers mentioned that household infrastructure has also improved (Table 8). Farmers obtained fuel wood for household consumption from trees planted in the cropland. Litter and pruning were added to the soil which improved the soil physical properties resulting in the improvement of natural capital. 96.1% of farmers responded that agricultural productivity has increased due to practicing agroforestry. Farmers mentioned the increase of their income, verifying their improved socioeconomic condition (Table 8).

Farmers practicing agroforestry systems should create a local group and share the benefits they are getting from the practices. In this connection, NGOs working to encourage agroforestry systems can play a vital role to motivate the people and share the gains which can be achieved from practicing agroforestry systems. However, increased household income can lead to increased involvement in different social groups and external activities.

Agroforestry ensures productivity both from trees or crops. The goods received in the form of agriculture or forest products help to ensure the development of physical capital. Timber harvested from the trees also helps to improve the household infrastructure. Improvement of household infrastructure allows greater access to basic needs like education, health, sanitation; otherwise the opportunity costs associated with poor household infrastructure impede them from having access to these basic needs. Some farmers purchased vehicles (bicycles or three wheeler cycles for carrying goods, locally known as “Vans”) or had the ability to meet the transportation cost for marketing their products. Marketing facilities allow them to get maximum selling benefit of their products and guarantee higher income (financial capital). Agroforestry

Table 6. Benefits from agroforestry farming system practices

Sl. No.	Ways how agroforestry contributing toward household livelihood	Frequency	Percentage	comments
1.	Fuel wood	115	95.83	*Total frequencies are higher than total sample size indicating that some farmers suggested more than one measure.
2.	Timber	99	82.50	
3.	Fruit	76	63.33	
4.	Fodder	93	77.50	
5.	Traditional medicine	27	22.50	
6.	Construction materials	38	31.67	
7.	Climate control	34	28.33	
8.	Soil conservation	22	18.33	
9.	Environment conservation	41	34.17	
10.	Water conservation	10	8.33	
11.	Protection from flood	15	12.50	
12.	Compost	28	23.33	
13.	Living standard	59	49.17	
14.	Employment	5	4.17	
15.	Source of money in emergency	87	72.50	

Table 7. Distribution of the farmers according to the problems they faced in practicing agroforestry

Problems	Extent of problems				*PFI	Rank order
	None	Low	Medium	High		
Shade created by the trees	4	44.1	38.2	13.7	168.3	1
Increase of insects, pests and disease infestation	16.5	22.5	54	7	157.5	2
Root competition	16.6	24.5	55.9	3	149.3	3
Competition for nutrients	7.8	35	54.2	3	145	4
Grazing of animals	15.5	56.9	21.6	6	113.8	5
Low production	19.6	52.9	24.5	3	109.6	6
Allelopathic effect	47.1	27.5	18.5	6.9	89.4	7

** PFI problem facing Index*

Table 8. Distribution of the Farmers according to livelihood improvement

Capitals	Extent of agreement				*LII	Rank order
	Highly increased	Increased	Slightly increased	No change		
Human						
Increased overall farming knowledge	0.0	59.8	37.3	2.9	156.9	11
Increased knowledge related to agroforestry	5.0	74.5	20.5	0.0	184.5	2
Increased management capacity related to agroforestry	2.0	77.5	20.5	0.0	181.5	4
Social						
Increased so relationship with other communities	2.9	33.4	60.8	2.9	136.3	12
Increased participation social organizations (e.g. NGO)	2.9	24.6	18.6	53.9	76.5	14
Conflict with the neighbor	0.0	13.7	21.6	64.7	49	15
Physical						
Improved household physical infrastructure	0.0	72.5	21.6	5.9	166.6	8
Natural						
Increased of firewood products	10.8	49.0	35.3	4.9	165.7	9
Increased Forest productivity	0.0	71.6	28.4	0.0	171.6	6
Improve soil physical properties	2.9	63.7	25.5	7.8	161.6	10
Increased tree coverage	15.7	77.5	6.8	0.0	208.9	1
Increased agricultural productivity	5.9	15.7	74.5	3.9	123.6	13
Financial						
Increased household income	0.0	84.3	13.7	2.0	182.3	3
Increased socioeconomic condition	0.0	84.3	7.8	7.8	176.4	5
Increased household expenditure	2.9	69.6	20.6	6.9	168.5	7

**LII =Livelihood Improvement Index*

encourages the farmers to plant trees on their cropland which increases the abundance of tree species. Agroforestry not only ensures productivity and higher income but also ensures tree cover in agricultural landscape from which poor farmers can earn their livelihood [13]. The farmers demanded for fuel wood and timber from agroforestry was reported as similar to the farmers in Rajshahi region of Bangladesh [28]; [52]. In agroforestry systems, leguminous and deciduous species are often preferred for planting. Leguminous species fix atmospheric nitrogen through biological nitrogen fixation which is added to the soil. Moreover, the decomposed agroforestry litter also adds nutrients, resulting in improvement of soil properties and increased agricultural productivity ([23]; [53). Moreover, trees planted in croplands can protect annual crops from severe wind andstorms. Agroforestry systems are considered one of the corner stone's of resource based farming, which is indispensable in the context of climate change and environmental degradation.

Table 9. Constrains of adoption of AGF in char area

Constrain of adopting AGF at char areas	Frequency	Percentage	Rank order	Comments
Lack of education	112	93.33	2	*Total frequencies are higher than total sample size indicating that some farmers suggested more than one measure.
Lack of technical skills	71	59.17	6	
Lack of technical assistance	87	72.50	4	
Lack of marketing facilities	63	52.50	7	
Lack of capital	96	80.00	3	
Lack of awareness	117	97.50	1	
Lack of interest	38	31.67	8	
Lack of transportation facilities	87	72.50	4	

Agroforestry ensures maximum production, increasing farmer's incomes and improving their socioeconomic condition. Farmers can meet other livelihood strategies as they have more availability of cash or liquid assets. Long-term economic gain can be achieved through planting trees in the cropland (Rahman et al., 2016) which triggers socioeconomic development [12]. Agroforestry practices ensure farmers livelihood security along with environmental sustainability [35]. However, the researcher argues for the planned expansion of agroforestry for overall socioeconomic development of the farmers.

Finally, skill and knowledge (human capital) developed through farming assist the farmers in having more access to physical and natural capitals. Development of these capitals enables the farmers to uphold their financial capital. To attain sustainable livelihood outcomes, farmers need to depend upon external environmental factors i.e. trends (population trends, resource trends, national/international economic trend), shocks (human health shock, natural shock, economic shock, conflict) and seasonality (of price, of production, of employment opportunity) over which they have limited or no control.

4.7 Constraints of Adopting Agroforestry in Teesta and Jamuna River Basins

The respondents, local leaders and experts were asked to report about constrains of adopting agroforestry in Char areas (Table 9).

Result indicated that lack of awareness, lack of education, technical skills, capital, technical assistance, interest, marketing and transportation facilities of Char as the main hindrances in the adoption of agroforestry in the Char area of Bangladesh. These all constraints can be easily overcome by launching awareness campaigns, training workshops, providing technical assistance and establishing marketing points.

Several studies have also examined such constraints i.e., marketing and transportation facilities confronting the farmers in practicing agro forestry [54,55]. The majority of these studies have concentrated on classical factors such as land tenure systems, farm size, education, income generation activities and extension etc. These studies also concluded that the basic issue of marketing the agroforestry products was lack of transportation facilities in Chars. It was also concluded that the farmers were not adopting agroforestry mainly due to their lack of awareness about the tree benefits. They considered that the trees compete with agricultural crops for water and nutrients uptake and degrade their farmlands.

5. CONCLUSION AND RECOMMENDATIONS

From the present study it was concluded that the farmers of Teesta and Jamuna river basins were slowly adopting agro forestry mainly due to lack of awareness about the tree benefits and their concern with the comparison of trees and agricultural crops. A majority of the farmers were not educated; therefore they considered that the trees compete with agricultural crops and degrade the land by taking up all water and nutrients. No formal awareness programmes were running here to increase the knowledge of farmers to change their farming attitude towards agro forestry. The government should initiate such projects especially in the Char areas for the capacity building of the farmers and equip them

with the new farming techniques through training and orientation workshops. They should provide scientific guidance to the farmers about suitable tree species grown on agricultural land with agricultural crops, their silvicultural operations and tree management practices along with free supply of seeds and seedlings and loan schemes for the promotion of agro forestry. The outcome of this survey indicated that there is ample scope of introduction of agro-forestry in Teesta and Jamuna river basins. Such surveys are required to be conducted in any area to find out need of the farmers, their interests and scope of implementation of any agro forestry system

Based on the findings obtained and the proceeding discussion the following conclusions have been drawn:

I. Currently the adoption status of agroforestry by the communities in Kasulu District is 91%. They have been using Agroforestry practices for a long time and by 2007 already 89% of the households had adopted the technologies implying that the farmers were aware about the benefits of Agroforestry.
II. Only three types of Agroforestry systems namely Agrosilviculture 42%, Agrosilvipasture 32% and Silvopasture 26% with the Homegardens 26%, Mixed intercropping 25% and Integrated tree/pasture management 17% were the main technologies used in the district.
III. *Brachstegias piciforms* and *Pericopisis angolensis* which are indigenous species and *Senna siamea* and *Eucalyptus maidenii* (exotic) are the most commonly used timber tree species. *Mangifera indica, Citrus sinensis*, *Persea americana* and *Elais guinensis* are fruit trees widely preferred for use in Agroforestry in Kasulu District.
IV. The main uses and services provided by woody perennials for the local communities are fruits 18% for home consumption and sell, fuel wood 17%, timber 17%, soil fertility improvement 11%, shade/shelter 8%, fodder and traditional medicines.
V. Income generation 17%, farmer's awareness of AF benefits 15%, access to extension services 12% and source of manure (9%) were the most enhancing factors of Agroforestry adoption in Kasulu District.
VI. Lack of Agroforestry knowledge, land shortage, lack of monetary capital and unavailability of improved tree germplasm were the most significant factors that limit the adoption of AF systems and technologies.
VII. Improvement of extension services 20%, development of policies which advocate Agroforestry 20% and introduction of improved tree species 19% were the appropriate required measures to improve the adoption and usage of Agroforestry systems and technologies.

5.1 Recommendations

i. The extent of adoption reached by the communities in practicing Agroforestry is significantly high (91%), however more sensitization is required to maintain the existing adoption status reached to ensure its sustainability.
ii. Agroforestry systems and their respective technologies that are mostly preferred by the communities should be emphasized and farmers be advised to diversify Agroforestry components to provide a range of products and services so as to increase their ability of sustaining food supply and income generation to the entire community.
iii. Promotion of more exotic timber tree species is important rather than relying on only two species.
iv. Training of both agricultural extension officers and farmers is needed so as to solve the problem of agroforestry knowledge. Land shortage can be solved by Agroforestry intensification.
v. Lack of monetary capital and improved tree germplasm can be solved by the Government to provide credits through farmer groups, but also educate farmers to have their own tree nurseries such that the seedlings can be accessed easily by farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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