

Farmers' perception and adoption of agroforestry practices in Manikganj sadar upazila, Bangladesh

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Abstract

This study assessed farmers' socio demographic characteristics, information sources, practices, perceptions, knowledge, and adoption of agroforestry, and identified factors influencing adoption in Manikganj Sadar Upazila, Bangladesh. Data were collected from 100 randomly selected farmers using a pre tested semi structured questionnaire through face-to-face interviews, supported by personal observation and Focus Group Discussions. Data were analyzed using descriptive statistics, a four-point Likert scale, and the Chi-square test at the 5% significance level. Results showed that middle-aged farmers (36–50 years) constituted 62% of respondents and males accounted for 87%. Educational attainment was low (41% primary, 36% no formal education). Most respondents (54%) had 11–20 years of farming experience, and medium landholdings (1.1–2.0 ha) were most common (43%). Farming was the principal livelihood for 59% of households. Farmer to farmer communication was the leading information source (48%). Cropland agroforestry was the most widely practiced (38%) and preferred (29%) system, followed by homestead, fruit-based, and boundary plantation. Farmers held positive perceptions, with 40% viewing agroforestry as a means to increase household income and 36% recognizing improved farm productivity. Strong agreement was recorded for improved soil fertility (70%), reduced erosion (67%), and increased profitability (67%). Most respondents (39%) correctly understood agroforestry as the integration of trees, crops, and livestock. Chi-square analysis identified educational qualification ($\chi^2 = 13.194$, $p = 0.040$) and land size ($\chi^2 = 18.705$, $p = 0.028$) as significant determinants of adoption. Formal education and adequate land access are the primary drivers of agroforestry adoption, and targeted extension and educational interventions could enhance adoption among smallholder farmers in the study area.

Introduction

Agroforestry is the deliberate integration of trees with crops and/or animals on the same land management unit. It is recognized as a sustainable land-use approach that enhances ecosystem services, agricultural productivity, and rural livelihoods through multifunctional contributions to food production, soil improvement, biodiversity conservation, climate adaptation, and income diversification (Pattanayak et al. 2003). In smallholder systems marked by land scarcity, environmental degradation, and climatic variability, it functions as both a production system and a risk-management strategy, supporting climate resilience while enhancing biodiversity, soil health, farm productivity, and diversified income streams (Hoque et al. 2025). Adoption decisions are strongly associated with farmers' perceptions of benefits for household income, food security, fuelwood supply, and farm protection (Gashu et al. 2025). Agroforestry has long been integral to rural practices in Bangladesh, especially in homestead areas and on smallholder farms. Homestead agroforestry is widely practiced and often preferred, with farmers cultivating multifunctional plants, fruit trees, vegetables, and timber species around their homesteads (Hoque et al. 2025). Significant obstacles to wider adoption include high initial costs, limited technical knowledge, land-ownership constraints, and weak market access (Raj et al. 2014). Farmers' perceptions play a central role in agroforestry adoption (Rigueiro-Rodriguez et al. 2008). Whether the practice is regarded as beneficial, risky, labour-intensive, profitable, or compatible with

existing systems depends on perception. Adoption levels correlate strongly with perceived benefits, while farm size, family labour, soil fertility, and access to education and extension services are significant predictors (Meijer et al. 2015). Agroforestry is advocated globally for contributing to the Sustainable Development Goals, including poverty reduction, zero hunger, climate action, life on land, and sustainable production (Garrity 2004). Farm trees reduce pressure on natural forests and increase resilience by supplying timber, fuelwood, fruit, fodder, shade, medicine, and environmental protection. It stabilizes production systems and restores ecological functions in areas affected by soil erosion, land degradation, and climate stress (Catacutan et al. 2017). Bangladesh is highly vulnerable to climate-related risks, including irregular rainfall, extreme temperatures, flooding, riverbank erosion, and cyclones (Muhammed et al. 2008). Manikganj Sadar Upazila forms part of a climate-sensitive environment where farmers face rainfall variability, declining soil fertility, and market uncertainty. Agroforestry helps diversify production, buffer income losses, improve microclimatic conditions, and promote soil and water conservation (Pantera et al. 2021). Localized data on farmers' perceptions and influencing factors in Manikganj Sadar Upazila remain limited. Adoption behaviour is context-specific and varies with farm size, education, extension contact, seedling access, perceived profitability, labour availability, tenure security, and market access (Rahman et al. 2013). Institutional and socio-economic factors significantly influence adoption in Bangladesh. Decisions are shaped by access to resources, information, and supporting services, yet limited market opportunities and insufficient technical knowledge constrain uptake (Mercer 2004). Farmers are more inclined to adopt when they perceive clear benefits and possess necessary resources (Montambault & Alavalapati 2005). Homestead agroforestry is particularly important because it functions well on small plots and supplies products year-round (Nath et al. 2010). The theoretical foundation rests on the premise that uptake of agricultural innovations is influenced by perceived benefit, compatibility, simplicity, observability, and risk-management attributes. Innovations aligned with local conditions are more likely to be adopted (Alamgir et al. 2014). Agroforestry adoption is driven by perceived advantages such as fuelwood, fruit, shade, improved soil, and income diversification, while drawbacks including competition for light and nutrients, delayed returns, and labor requirements may deter it (Ndayambaje et al. 2013). A clear research gap exists regarding farmers' perceptions and the socio-economic determinants of agroforestry adoption in Manikganj Sadar Upazila. Although agroforestry is increasingly recognized as a sustainable land-use strategy in Bangladesh, most previous studies have concentrated on biophysical aspects or general practices in other regions. Very limited attention has been given to how local farmers specifically perceive different agroforestry systems namely homestead, cropland, fruit-based, and boundary plantation and to the socio-economic factors that shape their adoption decisions in this particular upazila. The present study was therefore undertaken to fill this research gap by systematically investigating farmers' perceptions of agroforestry practices and by identifying the key socio-economic factors influencing adoption of agroforestry practices. The current study was conducted in Manikganj Sadar Upazila with the following objectives: 1. To investigate and analyze farmers' perceptions of different agroforestry practices; 2. To determine the socio-economic factors influencing adoption of agroforestry practices in Manikganj Sadar Upazila.

Materials and Methods

Study area

The study was conducted in Manikganj Sadar Upazila, Manikganj District, Dhaka Division, central Bangladesh. The upazila was selected because agriculture is the primary livelihood and farmers practice diversified systems, including homestead agroforestry, boundary plantations, fruit-based agroforestry, and tree-crop combinations. Its favorable agroecological conditions and extensive agricultural activities make it a suitable setting for assessing farmers' perceptions and adoption of agroforestry.

Manikganj Sadar Upazila lies between 23°48' and 24°02' N latitude and 89°58' and 90°10' E longitude, covering approximately 214.35 km² (BBS, 2024). It is bounded by Satoria Upazila to the north, Singair Upazila to the east, Harirampur and Ghior Upazilas to the west, and the Padma River to the south. The region features fertile alluvial floodplain soils deposited by the Padma, Kaliganga, and Dhaleshwari rivers, with predominantly flat, low-lying terrain. The tropical monsoon climate has three distinct seasons (summer, monsoon, and winter), average annual rainfall of 1,800–2,100 mm, and temperatures ranging from 12°C in winter to 35°C in summer, supporting cereals, vegetables, fruits, timber, and multipurpose trees.

According to the Bangladesh Bureau of Statistics (2024), the upazila has a population of approximately 340,000–350,000 and a density exceeding 1,500 persons per km². Most households depend on agriculture, livestock, fisheries, and small-scale rural enterprises. Literacy rates are comparatively high, and agricultural extension services actively promote improved farming technologies, fruit cultivation, social forestry, and agroforestry practices.

Population and sampling

The target population comprised farmers residing in Manikganj Sadar Upazila who were actively engaged in agricultural production and had knowledge of or experience with agroforestry practices. A total of 100 farmers were selected as respondents. Respondents represented different age groups, educational backgrounds, farm sizes, and farming experiences to ensure diverse representation of the farming community. The sample provided primary data for assessing farmers' perceptions, the extent of agroforestry adoption, and the socio-economic and institutional factors affecting adoption.

Data collection and calculation

Both primary and secondary data were used. Primary data were collected through a pre-tested, partially structured questionnaire administered via face-to-face interviews with the 100 selected farmers. The questionnaire covered demographic and socio-economic characteristics, knowledge and perception of agroforestry, existing practices, factors influencing adoption, benefits and constraints, and suggestions for improvement. Interviews were conducted in Bengali after explaining the study objectives and obtaining informed verbal consent. Field observations and informal discussions supplemented the questionnaire responses. Completed questionnaires were checked daily to minimize errors.

Secondary data were obtained from published and unpublished sources, including books, peer-reviewed journals, research reports, government publications, and policy documents related to agroforestry, farmers' perception, and adoption. Statistical and background information on the study area were drawn from the Bangladesh Bureau of Statistics (BBS), Bangladesh Agricultural Research Council (BARC), Bangladesh Forest Department, Department of Agricultural Extension (DAE), and other relevant agencies.

Focus Group Discussions (FGDs) were conducted as a complementary qualitative method. Each FGD consisted of 10 purposively selected farmers with practical knowledge of agroforestry, totaling 100 participants across sessions. A semi-structured discussion guideline was used to explore knowledge, perceptions, adoption behavior, benefits, challenges, and recommendations. Discussions were facilitated in a participatory manner. Qualitative responses were reviewed, categorized into major themes, and, where appropriate, coded for integration with quantitative findings.

Variables measured

Demographic and socio-economic variables included age (below 25, 25–35, 36–50, above 50 years), gender (male, female), educational qualification (no formal education, primary, secondary, higher secondary or above), farming experience (< 5, 5–10, 11–20, > 20 years), land size (< 0.5, 0.5–1, 1.1–2, > 2 ha), annual household income (below BDT 100,000; 100,001–200,000; 200,001–400,000; above BDT 400,000), main source of income (farming, animal production, forest products, business, others), family size (1–3, 4–6, 7–9, > 9 members), and experience in agroforestry practices (< 5, 5–10, 11–15, 16–20, > 20 years).

Agroforestry practices were categorized into four systems: homestead agroforestry, cropland agroforestry, fruit-based agroforestry, and boundary plantation. Farmers' perceptions were assessed across positive and restrictive dimensions (e.g., effects on productivity, income, food security, and ease of practice). Knowledge of agroforestry was recorded as production of crops with trees, production of trees with crops and livestock, only trees, only crops, or no idea. Information sources included mass media, other farmers, friends, neighbors, or combinations thereof.

Statistical analyses

Survey data were entered into Microsoft Excel and checked for completeness, consistency, and coding accuracy. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarize socio-economic characteristics, information sources, agroforestry practices, knowledge, and adoption. Farmers' attitudes toward agroforestry were measured on a four-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree), and mean perception scores were calculated. The association between socio-economic characteristics and adoption of agroforestry practices was examined using the Chi-square (χ^2) test of independence at the 5% significance level ($\alpha =$

0.05). A p-value < 0.05 indicated a statistically significant association. Results were presented in tables and figures.

Results

Socio-economic characteristics of respondents

The socio-economic profile of the 100 respondents is summarized in Table 2. The majority of farmers (62%) were aged 36–50 years, followed by those above 50 years (19%) and 25–35 years (18%); only 1% were below 25 years. Male farmers predominated (87%), while females accounted for 13%. Primary education was the most common level (41%), followed by no formal education (36%) and secondary education (23%). Most respondents had substantial farming experience: 54% reported 11–20 years and 28% more than 20 years. Landholdings of 0.5–1 ha were most frequent (50%), followed by 1.1–2 ha (32%). Annual household income was concentrated in the BDT 100,001–200,000 range (65%). Farming was the main income source for 44% of respondents, followed by animal production (28%). Family sizes of 7–9 members (35%) and more than 9 members (30%) were common. Experience in agroforestry practices was highest in the 5–10 years category (32%), with 76% of respondents having more than 5 years of experience.

Table 1
Formulas were applied in the analysis

Name	Equations	Details	Source
Mean	$\bar{x} = \frac{\sum x}{n}$	$\sum x$ = Sum of observations n = Number of observations	Gravetter & Wallnau (2017)
Standard Deviation	$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$	x = Individual observation $\bar{x}$ = Mean n = Number of observations	Gravetter & Wallnau (2017)
Chi-square Test	$\chi^2 = \sum \frac{(O - E)^2}{E}$	O = Observed frequency E = Expected frequency	Pearson (1900)
Degrees of Freedom	$df = (r - 1)(c - 1)$	r = Number of rows c = Number of columns	Gravetter & Wallnau (2017), Pearson (1900)
Likert Scale Mean Score	$\bar{X} = \frac{\sum (f \times s)}{N}$	f = Frequency s = Likert score N = Total respondents	Likert (1932)
Percentage Distribution	$P = \frac{f}{N} \times 100$	P = Percentage f = Frequency N = Total respondents	Gravetter & Wallnau (2017)
Significance Level	$\alpha = 0.05$	If p < 0.05: Significant If p ≥ 0.05: Not Significant	Fisher (1925), Field (2018)

Table 2
Socio-economic characteristics of the respondents (n = 100)

Socio economic characteristics	Categories	Frequency	percentage	Mean	SD
Age	Below 25 years	1	1.0	43.68	9.485
	25–35 years	18	18.0		
	36–50 years	62	62.0		
	Above 50 years	19	19.0		
Gender	Male	87	87.0	-	-
	Female	13	13.0		
Educational qualification	No formal education	36	36.0	3.07	3.013
	Primary	41	41.0		
	Secondary	23	23.0		
Farming experience	Less than 5 years	2	2.0	16.62	6.166
	5–10 years	16	16.0		
	11–20 years	54	54.0		
	More than 20 years	28	28.0		
Main source of income	Farming	44	44.0	-	-
	Animal production	28	28.0		
	Forest products	17	17.0		
	Businessman	11	11.0		
Family size	1–3 members	9	9.0	7.58	2.861
	4–6 members	26	26.0		
	7–9 members	35	35.0		
	More than 9 members	30	30.0		
Land size (ha)	Less than 0.5 ha	3	3.0	1.33	0.802
	0.5–1 ha	50	50.0		
	1.1–2 ha	32	32.0		
	Above 2 ha	15	15.0		

Socio economic characteristics	Categories	Frequency	percentage	Mean	SD
Annual household income	Below BDT 100,000	13	13.0	170000	76870.6
	100,001–200,000	65	65.0		
	200,001–400,000	22	22.0		
Experience in agroforestry practice	Less than 5 years	15	15.0	12.10	6.750
	5–10 years	32	32.0		
	11–15 years	17	17.0		
	16–20 years	27	27.0		
	More than 20 years	9	9.0		

Information sources, practices, perceptions, and adoption of agroforestry

Farmers primarily obtained information about agroforestry from fellow farmers (48%), followed by neighbors (16%) and a combination of neighbors and mass media (15%) in Table 3. Sole reliance on mass media was reported by 9%, friends by 7%, and a combination of mass media and other farmers by 5%. These results indicate that interpersonal, farmer-to-farmer knowledge exchange remains the dominant channel for disseminating agroforestry information in the study area. Cropland agroforestry was the most common system (38%), followed by homestead agroforestry (33%), boundary plantation (17%), and fruit-based agroforestry (12%). Farmers preferred systems that could be integrated directly with crop cultivation, enabling efficient land use; the relatively lower adoption of fruit-based agroforestry suggests technical, financial, or management constraints. Farmers generally held positive perceptions of agroforestry: the largest share (40%) viewed it as an effective means of increasing household income, while 36% believed it enhances farm productivity. Fourteen percent considered it difficult to practice because of management and resource constraints, and 10% regarded it primarily as a means of ensuring food security. Overall, economic and productivity benefits were more strongly recognized than challenges or food-security roles. In terms of adoption preference, cropland agroforestry ranked highest (29%), followed by homestead agroforestry (27%), fruit-based agroforestry (24%), and boundary plantation (20%). Farmers favored systems that deliver multiple economic and environmental benefits while making efficient use of available land and farm resources.

Table 3
Information sources, practices, perceptions, and
adoption of agroforestry

Information source about Agroforestry practice	
From another farmer	48%
Neighbor	16%
Both neighbor and mass media	15%
Mass media	9%
Friend	7%
Both mass media and other farmer	5%
Agroforestry practices in the study area	
Homestead Agroforestry	38%
Cropland Agroforestry	36%
Fruit-based Agroforestry	15%
Boundary Plantation	11%
Farmers' perception of agroforestry practices	
Increase household income	40%
Increase farm productivity	36%
Difficult to practice	14%
Means to food security	10%
Adoption of different agroforestry practices	
Homestead Agroforestry	27%
Cropland Agroforestry	20%
Fruit-based Agroforestry	29%
Boundary Plantation	24%
Knowledge of agroforestry practices	
Production of trees with crops and livestock	39%
Only trees production	30%
Production of Crops with trees	32%
Only crops production	7%

Information source about Agroforestry practice	
No idea	2%

Tree and crop composition

A diverse range of tree species and agricultural crops was recorded across agroforestry systems in Table 4. Homestead systems were dominated by fruit and multipurpose trees (e.g., *Mangifera indica*, *Artocarpus heterophyllus*, *Cocos nucifera*) intercropped with vegetables and spices. Cropland agroforestry integrated timber and shade trees with cereals, vegetables, and pulses. Fruit-based systems contained the greatest diversity of fruit trees, while boundary plantations were dominated by timber, bamboo, and multipurpose species.

Table 4
Tree and crop species recorded in different agroforestry systems

Practices	Tree species found	Agricultural crops found
Homestead Agroforestry	<i>Mangifera indica</i> , <i>Syzygium cumini</i> , <i>Artocarpus heterophyllus</i> , <i>Psidium guajava</i> , <i>Cocos nucifera</i> , <i>Phoenix dactylifera</i> , <i>Ziziphus mauritiana</i> , <i>Limonia acidissima</i> , <i>Anona squamosa</i> , <i>Punica granatum</i> , <i>Manilkara zapota</i> , <i>Artocarpus lacucha</i> , <i>Averrhoa carambola</i> , <i>Diospyros malabarica</i>	<i>Lagenaria siceraria</i> , <i>Cucurbita moschata</i> , <i>Benincasa hispida</i> , <i>Capsicum annuum</i> , <i>Allium cepa</i> , <i>Allium sativum</i> , <i>Zingiber officinale</i> , <i>Curcuma longa</i>
Cropland Agroforestry	<i>Vachellia nilotica</i> , <i>Swietenia mahagoni</i> , <i>Samanea saman</i> , <i>Ficus benghalensis</i> , <i>Polyalthia longifolia</i> , <i>Mangifera indica</i> , <i>Syzygium cumini</i> , <i>Artocarpus heterophyllus</i> , <i>Psidium guajava</i> , <i>Cocos nucifera</i> , <i>Phoenix dactylifera</i> , <i>Ziziphus mauritiana</i> , <i>Limonia acidissima</i> ,	<i>Oryza sativa</i> , <i>Triticum aestivum</i> , <i>Zea mays</i> , <i>Setaria italica</i> , <i>Solanum tuberosum</i> , <i>Solanum melongena</i> , <i>Raphanus sativus</i> , <i>Lablab purpureus</i> , <i>Trichosanthes dioica</i> , <i>Cucumis sativus</i> , <i>Momordica charantia</i>
Fruit-based Agroforestry	<i>Mangifera indica</i> , <i>Syzygium cumini</i> , <i>Artocarpus heterophyllus</i> , <i>Litchi chinensis</i> , <i>Psidium guajava</i> , <i>Cocos nucifera</i> , <i>Ziziphus mauritiana</i> , <i>Aegle marmelos</i> , <i>Limonia acidissima</i> , <i>Syzygies samarangense</i> , <i>Carissa carandas</i> , <i>Anona squamosa</i> , <i>Annona reticulata</i> , <i>Punica granatum</i> , <i>Manilkara zapota</i> , <i>Artocarpus lacucha</i> , <i>Averrhoa carambola</i> , <i>Tamarindus indica</i> , <i>Citrus limon</i> , <i>Citrus maxima</i> , <i>Phyllanthus emblica</i>	<i>Allium cepa</i> , <i>Allium sativum</i> , <i>Zingiber officinale</i> , <i>Curcuma longa</i> , <i>Agave amica</i> , <i>Tagetes erecta</i> , <i>Luffa aegyptiaca</i> , <i>Capsicum annuum</i>
Boundary plantation	<i>Bambusa vulgaris</i> , <i>Calamus rotang</i> , <i>Albizia procera</i> , <i>Samanea saman</i> , <i>Swietenia mahagoni</i> , <i>Acacia auriculiformis</i> , <i>Dalbergia sissoo</i> , <i>Ficus benghalensis</i> , <i>Polyalthia longifolia</i> , <i>Lagerstroemia speciosa</i> , <i>Vachellia nilotica</i>	<i>Musa paradisiaca</i> , <i>Carica papaya</i> , <i>Allium cepa</i> , <i>Allium sativum</i> , <i>Zingiber officinale</i> , <i>Curcuma longa</i>

Association between socio-economic factors and adoption

Chi-square tests of independence were performed to examine associations between selected socio-economic characteristics and adoption of agroforestry practices in Table 5. Educational qualification ($\chi^2 = 13.194$, $df = 6$, $p = 0.040$) and land size ($\chi^2 = 18.705$, $df = 9$, $p = 0.028$) showed statistically significant associations with adoption at the 5% level. Age, farming experience, and annual household income were not significantly associated with adoption ($p > 0.05$).

Table 5
Chi-square test of association between socio-economic variables and agroforestry adoption

Independent Variable	χ^2 (Chi-square)	df	p-value	Significance
Age	8.77	9	0.459	Not Significant
Educational qualification	13.194	6	0.04	Significant
Farming experience	10.362	9	0.322	Not Significant
Land size	18.705	9	0.028	Significant
Annual household income	4.113	6	0.661	Not Significant
<i>Note: ns = not significant at $\alpha = 0.05$.</i>				

Farmers' attitudes toward agroforestry

Respondents generally expressed positive attitudes toward the benefits of agroforestry in Table 6. High levels of agreement were recorded for improvements in soil fertility (70% agree + 22% strongly agree), reduction of soil erosion (67% + 24%), profitability (67% + 20%), farm income (65% + 22%), biodiversity (63% + 25%), and household food security (61% + 17%). A majority also agreed that agroforestry helps reduce climate-change impacts (52% + 22%). Perceptions were more divided regarding suitability for small farmers (44% agree) and the need for high investment (53% agree). Overall, farmers viewed agroforestry as environmentally and economically beneficial, while concerns remained about affordability and suitability for small-scale producers.

Table 6
Farmers' attitudes toward agroforestry practices (Likert scale, %)

Row Labels	Disagree	Strongly agree	Agree	Strongly disagree	Total
Agroforestry helps reduce climate change impacts	24%	22%	52%	2%	100
Agroforestry improves biodiversity	10%	25%	63%	2%	100
Agroforestry improves household food security	19%	17%	61%	3%	100
Agroforestry improves soil fertility	6%	22%	70%	2%	100
Agroforestry increases farm income	11%	22%	65%	2%	100
Agroforestry is profitable	11%	20%	67%	2%	100
Agroforestry is suitable for small farmers	27%	6%	44%	23%	100
Agroforestry reduces soil erosion	6%	24%	67%	3%	100
Agroforestry requires high investment	22%	6%	53%	19%	100

Discussion

The discussion interprets the results in light of relevant socio-economic theory and compares them with findings from previous empirical studies conducted both in Bangladesh and other developing countries, in order to situate the present research within the broader body of agroforestry literature. The chapter is organized into four main sections. The first section examines the socio-demographic profile of the respondents, including age, gender, education, farming experience, land size, and income, and how these characteristics shape farmers' engagement with agroforestry. The second section explores the sources through which farmers obtain information about agroforestry and the specific practices they have adopted. The third section discusses farmers' perceptions, attitudes, and the diversity of tree and crop species observed in the study area. The final section identifies the key socio-economic determinants of adoption and assesses farmers' overall level of knowledge regarding agroforestry. Together, these sections aim to provide a comprehensive understanding of the factors influencing agroforestry adoption and to highlight areas where policy and extension support could strengthen future uptake.

Socio-demographic profile of the respondents

The study found that middle-aged farmers (36–50 years), who made up 62% of respondents, dominate agroforestry adoption in Manikganj Sadar Upazila, since they combine practical experience with the economic responsibility needed for long-term land-use decisions. Very young farmers, at only 1%, played a marginal role, likely due to limited experience and a preference for non-farm work. Mercer (2004) found

that mature and experienced farmers adopt agroforestry more readily than younger farmers, which is consistent with the pattern observed in the present study. Men accounted for 87% of respondents, reflecting the socio-cultural reality of rural Bangladesh, where land ownership, extension access, and farm decision-making remain male-dominated. Meijer et al. (2015) reported that women's limited participation in agroforestry is associated with household responsibilities and restricted land ownership, which is consistent with the present study where only 13% of respondents were women. Educational attainment was generally low: 41% of farmers had only primary schooling, 36% had none, and just 23% had secondary education, giving a mean score of 1.87. Rahman et al. (2017) emphasized that education is an important determinant of agroforestry adoption; similarly, the present study found that while farmers could grasp basic agricultural concepts, limited schooling likely restricted their exposure to advanced agroforestry knowledge. Meijer et al. (2015) suggested that experienced farmers are generally more confident in adopting agroforestry practices. Consistent with these findings, the present study revealed that farming experience was substantial, with 54% of respondents having 11–20 years of experience and 28% having more than 20 years in farming. Ndayambaje et al. (2013) reported that farmers with moderate to larger landholdings are more likely to integrate trees with crops because they can allocate land without significantly reducing agricultural productivity. In agreement with these studies, the present study found that 43% of respondents owned 1.1–2.0 hectares of land, indicating that most farmers possessed sufficient land to adopt agroforestry practices effectively. Rahman et al. (2017) reported that farmers with moderate household income are generally more capable of investing in agroforestry practices. Similarly, the present study found that household income was concentrated in the middle bracket (BDT 100,001–200,000) for 65% of respondents, indicating a moderate financial capacity to invest in agroforestry. Ndayambaje et al. (2013) reported that farming and livestock are closely integrated livelihood components that support agroforestry adoption. Similarly, the present study found that farming remained the main livelihood for 59% of households, with livestock serving as a significant secondary source (29%), reflecting the complementary role of mixed farming in supporting agroforestry.

Information sources and agroforestry practices adopted

Nearly half of respondents (48%) learned about agroforestry from fellow farmers rather than mass media (9%) or friends (7%), underscoring the importance of informal, peer-based knowledge networks over formal extension channels. Miah et al. (2006) emphasized that farmer to farmer communication builds confidence in adopting new practices. Similarly, the present study found that interpersonal communication was a key source of information for agroforestry adoption, suggesting that community-based and lead-farmer extension models could further boost awareness. Cropland agroforestry was the most common system in the study area (38%), followed by homestead agroforestry (33%), boundary plantation (17%), and fruit-based agroforestry (12%). Rahman et al. (2017) reported that farmers generally prefer agroforestry systems that integrate easily with existing crops, provide quicker economic returns, and require lower initial investment. The findings of the present study are consistent with these observations, indicating that farmers favor such systems, whereas fruit-based agroforestry is less preferred due to its longer gestation period and higher establishment costs. When it came to actual adoption rather than mere presence, cropland agroforestry again led at 29%, followed by homestead

(27%), fruit-based (24%), and boundary plantation (20%). Garrity (2004) reported that homestead agroforestry systems are highly valued for providing fruit, timber, fuelwood, and household food security, whereas boundary plantation, despite being less preferred, continues to play important roles in land demarcation and wind protection. The findings of the present study are consistent with these earlier observations.

Species diversity, farmers' perceptions, and attitudes

Homestead and fruit-based systems in the study area are rich in fruit species such as mango, jackfruit, jamun, and guava, while timber species dominate cropland and boundary plantations. Kabir and Webb (2008) reported that diversified integration of cereals, vegetables, spices, and fruit with trees supports food security, income generation, and efficient land use. The findings of the present study are consistent with these observations, as farmers practiced diversified agroforestry systems that combined multiple crop species with trees. Farmers generally view agroforestry favorably, 40% see it as a way to raise household income and 36% credit it with improving farm productivity. Mercer (2004) reported findings consistent with the present study, where fewer respondents associated agroforestry with food security (10%) or considered it difficult to manage (14%), suggesting that economic motives outweigh nutritional or ease-of-management considerations. Attitudes toward agroforestry's broader benefits were also strongly positive, majorities agreed it improves soil fertility (70%), reduces erosion (67%), raises profitability (67%), boosts farm income (65%), enhances biodiversity (63%), and strengthens food security (61%), with just over half (52%) linking it to climate change mitigation. Jose (2009) reported that financial and institutional constraints, particularly high initial investment costs, often limit the adoption of agroforestry despite farmers' generally positive perceptions. Consistent with these findings, farmers in the present study were less convinced of agroforestry's suitability for smallholders and frequently cited high initial investment as a major barrier.

Determinants of adoption and farmers' knowledge

Statistical analysis identified educational qualification ($\chi^2 = 13.194$, $p = 0.040$) and land size ($\chi^2 = 18.705$, $p = 0.028$) as the socio-economic factors significantly associated with agroforestry adoption, while age, farming experience, and household income showed no significant relationship. Pattanayak et al. (2003) reported that formal education helps farmers appreciate the long-term benefits of agroforestry, while larger landholdings provide farmers with greater flexibility to allocate land to tree-based systems without compromising food-crop production. The findings of the present study are consistent with these observations. In terms of conceptual understanding, most farmers (39%) correctly described agroforestry as the integration of trees, crops, and livestock, but a notable share (30%) still equated it narrowly with tree production alone, and 22% understood it only as tree-crop integration. Very few reported no knowledge at all (2%). Mercer (2004) suggested that effective extension services and farmer training are essential for improving farmers' understanding of agroforestry. This indicates reasonably broad awareness in Manikganj Sadar Upazila; however, persistent misconceptions about the holistic nature of agroforestry remain, highlighting the continued need for extension services and farmer training. Taken together, these findings suggest that while farmers in the study area are experienced,

moderately resourced, and generally positive about agroforestry's economic and environmental value, targeted interventions in education, land-access support, and knowledge dissemination particularly through peer networks could further strengthen adoption across the community.

Conclusions

This study assessed the socio-demographic characteristics, information sources, practices, perceptions, and determinants of agroforestry adoption among 100 farmers in Manikganj Sadar Upazila, Bangladesh. Agroforestry is a well-established and economically valued system, practiced mainly by middle-aged, experienced male farmers with moderate landholdings and income. Cropland and homestead agroforestry were the most widely practiced and preferred systems, reflecting a preference for practices that integrate easily with existing crops and yield quicker returns. Fruit-based and boundary systems were less adopted due to higher costs and longer gestation periods. Farmers held largely positive perceptions, recognizing agroforestry's contributions to soil fertility, erosion control, biodiversity, farm income, and food security. Educational qualification and land size were the only socio-economic factors significantly associated with adoption; age, farming experience, and household income showed no significant influence. Access to education and land, rather than experience or wealth alone, therefore appears to drive uptake. Heavy reliance on informal farmer-to-farmer communication, rather than formal extension services, highlights a gap in institutional outreach. Persistent misconceptions about the holistic nature of agroforestry further indicate the need for targeted training. Overall, agroforestry holds strong potential for strengthening rural livelihoods and environmental resilience, provided educational, financial, and institutional barriers are addressed.

Declarations

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Author Contributions

Abhihek Sarker contributed to investigation, data curation, formal analysis, visualization, and writing of the original draft. Shupriya Das contributed to conceptualization, methodology, investigation, data curation, formal analysis, visualization, and writing of the original draft. Md Abdul Wadud contributed to conceptualization, methodology, supervision, investigation, validation, and review and editing of the manuscript. Md Tariqul Islam contributed to conceptualization, methodology, formal analysis, validation, supervision, project administration, and review and editing of the manuscript. Md Tariqul Islam also served as the corresponding author. All authors reviewed and approved the final manuscript.

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Data Availability The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Figures

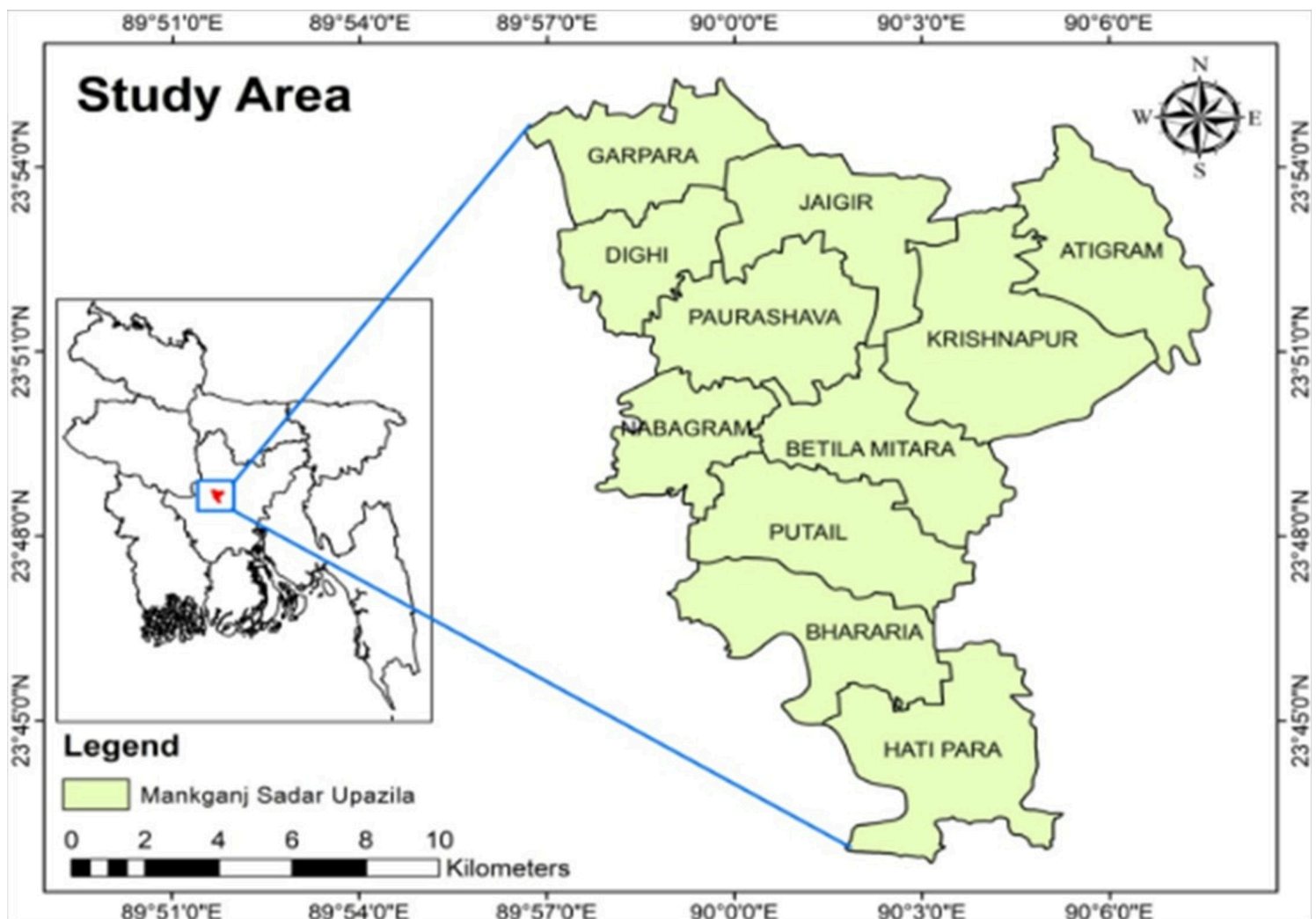


Figure 1

Study area map of Manikganj Sadar Upazila

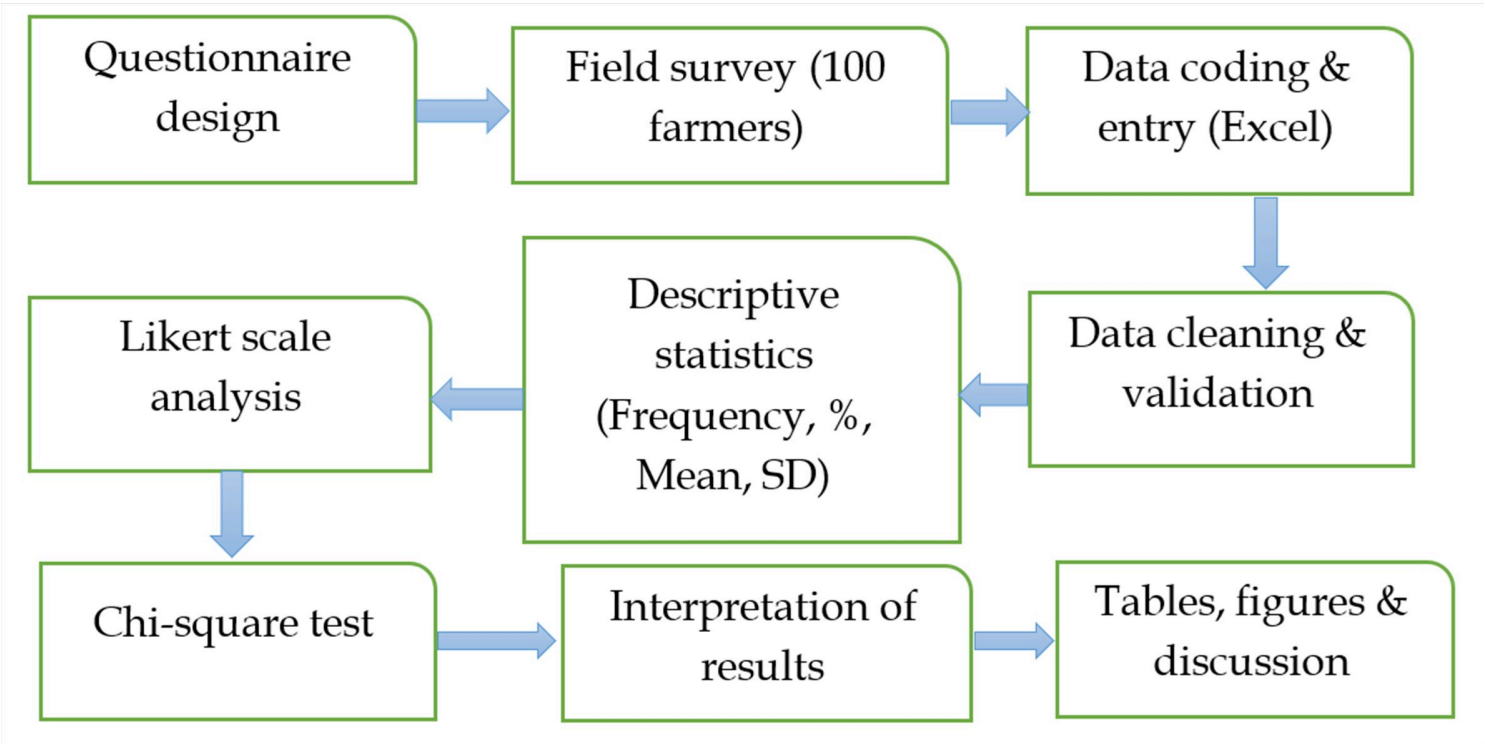


Figure 2

Flow chart of work plan of the study