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Proceeding Paper

AGROFORESTRY AS A CLIMATE-SMART STRATEGY: EXAMINING THE FACTOR AFFECTING FARMERS' ADOPTION

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Abstract: Agroforestry production systems have shown growing adoption in Bangladesh, offering ecological and economic benefits in the face of climate change. This study investigates the scale of agroforestry adoption, investment returns, factors influencing uptake, and challenges faced by farmers. Using a multistage random sample of 340 respondents, we find that while 75% of farmers are aware of agroforestry, adoption remains limited. Our analysis focuses on specific tree-crop combinations favored by farmers as agroforestry practices. The results demonstrate that in cropland agroforestry, Eucalyptus tree with rice (69.05% adoption rate) is predominant, while homestead/orchard systems agroforestry favor mango tree intercropped with potato (73.33%). Financial and investment analyses using Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Internal Rate of Return (IRR) prove that agroforestry is a more favorable alternative for farmers considering adoption, as it provides superior BCR, NPV, and IRR. For example, litchi-based agroforestry systems with vegetables like brinjal (eggplant), potato and chilies offer higher NPVs (19.00, 19.73 and 18.46, respectively) and IRRs (54.45, 68.00 and 47.19, respectively) compared to monocropping where NPV was 14.38. A binary logistic model reveals that larger farm sizes, younger respondents, higher education levels, training experiences, more frequent extension visits, and improved market access positively influence agroforestry adoption. The study also identifies key challenges for farmers using the Problem Facing Index (PFI). The most significant obstacles include lack of training facilities (PFI-894), shortage of skilled labor (PFI-687), and insufficient technical expertise (PFI-647). Therefore, to promote wider adoption, targeted training programs that address the identified challenges are crucial. It will empower farmers to realize the tangible benefits of agroforestry as a sustainable and climate-smart agricultural practice.

Keywords: Agroforestry; CSA; Adoption; Farmer's income; Investment analysis

1. Introduction

Climate change poses a formidable challenge to global agricultural systems, threatening food security, livelihoods, and the overall sustainability of farming practices [1]. As the world confronts the challenges posed by a changing climate, the need for innovative and sustainable solutions is imperative [2], [3]. Among the array of climate-smart strategies, agroforestry stands out as a promising approach that integrates trees and shrubs into agricultural landscapes to simultaneously mitigate and adapt to climate change [4]. Agroforestry is recognized as an integrated land-use management approach that has gained attention for its multifaceted benefits [5]. As an integrated land-use management approach, agroforestry has gained attention for its potential to mitigate and adapt to climate change while promoting sustainable agricultural practices [6], [7]. The synergistic relationship between trees, crops, and livestock in agroforestry systems contributes to enhanced resilience, carbon sequestration, soil fertility, and water conservation [8]. These multifunctional landscapes have been recognized for their ability to provide a more robust and diversified livelihood for farmers, reducing vulnerability to climate-induced shocks [9]. While the benefits of agroforestry are evident, the adoption of such practices by farmers is influenced by a complex interplay of factors. These factors range from socio-economic and cultural considerations to institutional support, knowledge dissemination, and policy frameworks [10], [11] Understanding these factors is essential for designing targeted interventions that encourage widespread adoption of agroforestry, thereby harnessing its full potential as a climate-smart strategy. Research in this field has indicated that the adoption of agroforestry practices varies significantly across different regions and farming communities. Factors such as land tenure systems, access to resources, market dynamics, and farmers' perceptions play a crucial role in shaping adoption patterns. Additionally, the effectiveness of extension services, agroforestry training programs, and policy incentives can either facilitate or hinder the uptake of these practices. For instance, studies emphasize the potential of agroforestry as a low-hanging fruit in climate change mitigation [12]. The synergies between agroforestry and climate resilience have been explored and highlighting the robust approach of evergreen agriculture in promoting food security in Africa [13]. These studies provide foundational insights into the benefits and potential of agroforestry, setting the stage for more nuanced examinations of the factors influencing adoption. In this context, this study seeks to delve into the nuanced factors affecting farmers' adoption of agroforestry as a climate-smart strategy. Through a comprehensive approach that includes synthesizing existing literature, conducting field surveys, and analyzing case studies, the research aims to contribute valuable insights into the intricacies of agroforestry adoption. This knowledge is pivotal for developing context-specific strategies, policies, and extension programs that promote the widespread adoption of agroforestry, fostering sustainable and climate-resilient agricultural systems.

2. Methodologies

2.1. Study Area

The selection of the study area was predicated on the prevalence of agroforestry practices, focusing on the implementation in the Baliadangi Upazila of the Thakurgaon District within the Rangpur Division of Bangladesh. Encompassing an area of 284.12 square kilometers, Baliadangi Upazila is situated between 25°59′ to 26°12′ north latitudes and 88°10′ to 88°22′ east longitudes.

2.2. Materials and Methods

In this study, a meticulously designed survey questionnaire was employed to explore farmers' perceptions, attitudes, and adoption behaviors concerning agroforestry practices. This survey will encompass various dimensions, including socio-economic characteristics, land tenure dynamics, resource accessibility, awareness of agroforestry benefits, and factors influencing adoption decisions. A multistage random sampling procedure was employed to collect data. A sample size of 340 households was established using Cochran's formula [14], taking into account a 95% confidence interval and a 5% margin of error. The data collection phase will target a diverse sample of farmers through in-person interviews utilizing both closed-ended questions for quantitative rigor and open-ended questions for qualitative depth. Data quality was enhanced through focus group discussions (FGD) and key informant interviews and supplementary data were collected from authoritative sources. Data analysis was performed utilizing the statistical software STATA-14.00. Descriptive statistics and logistic regression analysis (logit model) were employed to discern the factors influencing agroforestry adoption, encompassing socioeconomic variables, resource accessibility, and awareness of agroforestry practices. In the context of investment analysis, key financial metrics such as Discounted Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR) was employed. The Problem Confrontation

Index (PCI) was calculated by multiplying the weighted sum of the problems' responses. Each farmer was asked to rate the complexity of each challenge by selecting one of the four options: "Very High," "High," "Medium," "Low," or "Not at all." These replies were given weights of 4, 3, 2, 1 and 0 accordingly [15].

3. Results

3.1. Demographic profile of the respondents' in the study area

The study reveals significant insights into the demographic and economic landscape of the respondents. The data indicates that the majorities of participants are relatively young, with an average age of 42 years, and predominantly lack formal education, as reflected by an average educational status score near 7. Marital status leans towards married, suggesting family-centric households. The average household size is substantial at 5. Land ownership is notably small, with most respondents relying on external sources for land. The financial situation is challenging, with a low average annual income of 118735.87 taka, predominantly derived from low-wage agricultural work. Monthly expenditures, averaging around 10,000 taka, further underscore the economic constraints faced by the households. Overall, the findings paint a picture of a community grappling with limited resources, emphasizing the need for targeted interventions to address their economic challenges.

Table 1. Demographic profile of the respondents' in the study area.

Variables	Mean	St.Err.	Min	Max
Adoption of agroforestry as climate smart strategy	0.582	0.64	0	1
Age of the respondent (Years)	42	2.74	19	67
Farm size (Hectares)	0.97	3.27	0.19	5.71
Family size (Number)	5	2.17	2	7
Education level (Years of Schooling)	6.81	7.87	0	12
Marital status (Binary variable)	0.87	0.31	0	1
Training experience (Binary variable)	0.38	0.92	0	1
No. of extension visit (No. of visit/month)	0.48	1.94	0	6
Improved market access (Binary variable)	0.62	4.11	0	1
Income level (Yearly in BDT)	118735.87	85901.27	50000	375000
Farming Experience (Number of years)	12.91	5.48	3	60

Note: (Binary variable, if yes 1, otherwise 0).

3.2. Major agroforestry practices and tree-crop combination

The investigation into agroforestry practices in the study area reveals a nuanced landscape characterized by varying tree-crop combinations within cropland and homestead/orchard-based agroforestry systems. Notably, in cropland agroforestry, the preeminent practice involves the strategic pairing of Eucalyptus with rice, attaining a substantial adoption rate of 69.05%. This is succeeded by Eucalyptus synergies with maize and wheat. Conversely, in homestead/orchard-based agroforestry, mango intercropped with potato emerges as the predominant choice, boasting an impressive adoption rate of 73.33%, underscoring its popularity among local farmers. Additional favored combinations include mango with red amaranth, litchi with red amaranth, and litchi with rice. These rankings not only underscore the diversity in tree-crop amalgamations but also shed light on farmers' discerning preferences, influenced by the intricate interplay of regional agroecological nuances and agricultural practices. This comprehensive insight derived from the table facilitates a deeper comprehension and advocacy for sustainable and diversified farming systems.

Table 2. Major agroforestry practices adopted by the farmers in the study area.

Crop land agroforestry			Homestead /orchard based agroforestry		
Tree–Crop combination	**Practiced by farmers (%)**	**Rank order**	**Tree-Crop combination**	**Practiced by farmers (%)**	**Rank order**
Eucalyptus + Maize	57.14	2	Mango + Potato	73.33	1
Eucalyptus + Rice	69.05	1	Mango + Bean	69.05	3
Eucalyptus + Wheat	52.38	3	Mango + Brinjal	64.29	5
Eucalyptus + Mustard	2.38	6	Mango + Onion +Garlic	52.38	7
Mahogany + Rice	42.86	4	Mango + Red amaranth	73.81	2
Mahogany + Wheat	42.86	4	Mango + Radish	23.81	15
Mahogany + Maize	42.86	4	Mango + Pointed gourd	28.57	13
Mahogany + Napier	2.38	6	Mango + Tomato	42.86	8
Akashmoni + Rice	2.38	6	Mango + Cauliflower	14.29	16
Mango + Rice	42.86	4	Litchi + Potato	66.67	4
Mango + Wheat	42.86	4	Litchi + Malabar spinach	40.48	9
Litchi + Rice	52.38	3	Litchi + Onion	35.72	11
Litchi + Mustard	42.86	4	Litchi + Red amaranth	57.14	6
Mango + Turmeric	9.52	5	Litchi + Sweet gourd	38.10	10
Akashmoni + Maize	2.38	6	Malta + Potato	2.38	20
			Guava + Cucumber	7.14	19
			Lemon + Corolla	9.52	18

3.3. Investment analysis of different agroforestry combinations

The following table presents a detailed analysis of three different tree species cultivation frameworks: monocrop, agroforestry (agroforestry combined with vegetables), and important economic metrics including net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR). As related crops, potatoes, bringal (eggplant), and chillies are included in the agroforestry model. In more detail, Litchi performs better than Monocrop options in the agroforestry paradigm, with an IRR of 28 and a greater NPV of 14.38. Notably, Bringal, Potato, and Chilli had BCR values of 1.77; this was 2.00, and 1.46, respectively. In a similar vein, Mango shows higher economic returns under Agroforestry than Monocrop, with an NPV of 18.36 and an IRR of 45. The BCR values obtained from the integration of Potato, Bringal, and Chilli are 1.63, 2.22, and 1.91, respectively. Eucalyptus, Akashmony, and Mahogany are similar in that they have higher NPV and IRR values in the agroforestry space, and they are paired with vegetable crops that have better BCRs.

Table 3. Investment analysis of the different popular combinations of agroforestry system.

Tree	Monocrop		Agroforestry (combine with vegetables)								
			Chilli			Bringal			Potato		
	NPV[1]	IRR	BCR	NPV[1]	IRR	BCR	NPV[1]	IRR	BCR	NPV[1]	IRR
Litchi	14.38	28	1.77	18.46	47.19	2.00	19.00	54.45	1.46	19.73	68
Mango	18.36	45	1.91	21.18	72.6	2.22	22.40	83.49	1.63	23.00	88
Mahogany	10.95	25	1.46	15.50	50.82	1.41	13.46	33.88	1.21	16.38	57
Eucalyptus	14.38	28	1.69	17.78	43.56	1.96	18.54	48.4	1.46	19.73	68
Akashmony	7.45	22	1.17	12.22	47.19	1.35	12.79	52.03	1.37	13.08	55

Note: NPV[1] (Net Present Value at Year 1 in thousand USD).

3.4. Factors affecting farmer's adoption of agroforestry as climate smart strategy

Table 3 shows the result of logit model effect of explanatory variables on the dependent variables. This result of this study reflects that farm size(p<0.01), age of the respondent(p<0.01), education (p<0.05), training (p<0.05), number of extension visit (p<0.01) and improved market access (p<0.10) has positive significant influence on the adoption of climate change strategy by the farmers, implying that an increase in these explanatory variables results in the positive increase in the adoption of climate change strategy.

Table 4. Factors affecting farmer's adoption of agroforestry as climate smart strategy.

Variables	Coefficient	St.Err.	t-value	Sig
Farm size	0.022	0.005	4.13	***
Age of the respondent	3.121	0.389	8.03	***
Education level	1.583	0.71	2.23	**
Training experience	0.004	0.002	2.15	**
No. of extension visit	0.771	0.167	4.63	***
Improved market access	0.401	0.208	1.93	*
Household size	-0.236	0.506	-0.47	
Income level	0.103	0.068	1.51	
Distance from the nearest market	-0.018	0.014	-1.22	
Constant	-2.489	0.902	-2.76	***
Mean dependent var	0.517	SD dependent var		0.501
Pseudo r-squared	0.395	Number of obs		294
Chi-square	160.944	Prob > chi2		0.000
Akaike crit. (AIC)	266.286	Bayesian crit. (BIC)		303.122
*** *p<.01*, ** *p<.05*, * *p<.1*				

3.5. Major problem faced by the farmer for adopting agroforestry

The study comprehensively examines challenges faced by farmers in the study area, providing insights into agroforestry complexities. A detailed figure categorizes issues impacting labor dynamics, productivity, environment, and infrastructure, contributing to a Problem Composite Index (PCI). The top concerns are the lack of training facilities (1st, PCI-894) and a shortage of skilled labor (2nd, PCI-687). Insufficient expertise (3rd, PCI-647) and pest-related issues (4th, PCI-625) are also significant. Land availability, marketing infrastructure, and quality inputs follow in PCI rankings. Farmers express concerns about allelopathy, land damage from spreading roots, and complex production worries. Issues like trees falling on crops, limited access to high-quality seedlings, and theft rank lower.

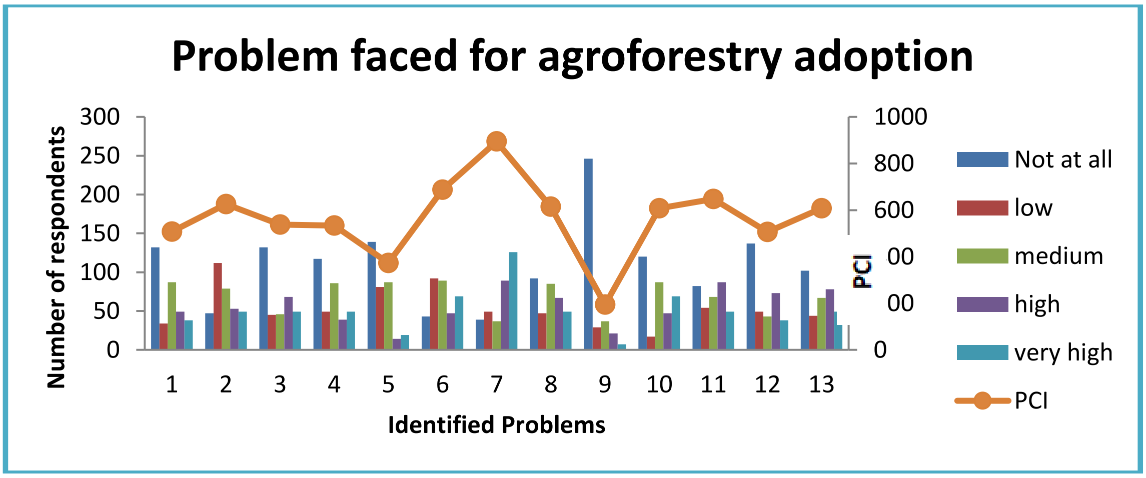

Figure 1. Graph showing different problem faced by the farmer for agroforestry adoption. Notes:1= Less productive than a monoculture, 2=Insect and pest harbor, 3=Allelopathic impact, 4=Land damaged by quickly spreading roots, 5=Trees falling on crops, 6=Absence of skilled labor, 7=Inadequate facilities training, 8=Lack of land availability, 9=Issues with thieves, 10=Absence of marketing infrastructure, 11=Insufficient expertise and technical assistance, 12=Lack of access to high-quality seedlings, 13=Absence of quality fungicide, insecticide, and fertilizer.

4. Discussion

The agroforestry practices identified in the study underscore the diverse combinations of tree-crop pairings within cropland and homestead-based systems [16]. Notably, Eucalyptus paired with rice and mango intercropped with potato emerge as popular choices, emphasizing the farmers' preferences influenced by local agroecological nuances [17],[18]. The investment analysis of different agroforestry combinations adds depth to the understanding of economic viability. Litchi and Mango, when integrated with vegetables, demonstrate higher net present values (NPV) and internal rates of return (IRR) compared to monocrop options [19], This highlights the potential for increased sustainability and profitability through the strategic integration of tree species with diverse crops. The factors influencing farmers' adoption of agroforestry as a climate-smart strategy further enrich the study. Farm size, age of the respondent, education, training, number of extension visits, and improved market access positively influence adoption [20]. This aligns with existing literature emphasizing the role of knowledge, education, and external support in promoting sustainable agricultural practices. The challenges faced by farmers for adopting agroforestry practices are comprehensively explored. Lack of training facilities and a shortage of skilled labor emerge as the primary concerns. Pest-related issues, insufficient expertise, and land availability also pose significant challenges [15].

5. Conclusion

In conclusion, the research provides a holistic understanding of the socio-economic and agroecological context, shedding light on the challenges and opportunities for promoting agroforestry as a climate smart strategy. The findings have implications for policymakers, extension services providers, and researchers working towards sustainable agricultural development.

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