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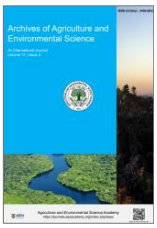

Original Research Article

Role of credit in mechanization of paddy production in a selected area of Bangladesh

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ABSTRACT

Agricultural credit plays an important role in facilitating the adoption of mechanized technologies and improving the productivity of paddy farming in Bangladesh. This study examined the socioeconomic characteristics of Boro rice farmers, assessed credit sources and farm profitability, estimated the impact of agricultural credit on the level of mechanization, and identified the major constraints to mechanization in Mymensingh district, Bangladesh. Primary data were collected through a field survey using a semi-structured interview schedule from 80 Boro rice farmers, comprising 40 credit recipients and 40 non-credit farmers. Descriptive statistics, profitability analysis, and Propensity Score Matching (PSM) were employed to analyze the data. The results showed that NGOs were the principal source of agricultural credit (60%), with most farmers receiving loans ranging from Tk. 30,000 (US$245.28) to Tk. 50,000 (US$408.80). Boro rice cultivation was profitable for both groups; however, credit recipients achieved higher net returns and benefit–cost ratios than non-credit farmers. The PSM analysis demonstrated that agricultural credit had a positive and statistically significant effect on farm mechanization. Credit recipients achieved a mean mechanization score of 4.00 compared with 3.32 for matched non-credit farmers, resulting in an Average Treatment Effect on the Treated (ATT) of 0.68. Despite these benefits, farmers faced several problems and constraints in adopting mechanization including complex bureaucratic procedures for credit, lack of collateral and high machinery prices. The findings highlight the simplification of the loan application procedures, machinery subsidies and the expansion of extension services to accelerate mechanization and promote sustainable Boro rice production in Bangladesh.

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INTRODUCTION

Agriculture remains a key sector of the Bangladeshi economy, playing a central role in ensuring food security, creating rural employment, and supporting the livelihoods of millions of rural households despite the country's ongoing structural transformation. Although the share of agriculture in Bangladesh's GDP has gradually declined with the expansion of the industrial and service sectors, the sector still contributes approximately 11–11.5% of GDP and employs about 44% of the national workforce, highlighting its continued importance for rural livelihoods and national food security (FICCI, 2024; ACIAR, 2025). Boro rice is the dominant and most important rice-growing season in Bangladesh, accounting for approximately 55% of national rice production and playing a critical role in ensuring national food security and rice self-sufficiency (BBS, 2025; FAO, 2025). Unlike the rain-fed Aman and Aus seasons, Boro rice is cultivated during the dry season (November–June) under irrigated conditions and is predominantly grown using high-yielding varieties, contributing to higher and more stable yields (BINA, 2024). As the largest contributor to Bangladesh's rice production, Boro rice remains central to the country's food

security and agricultural development. Beyond its contribution to national rice production, the high productivity and relative stability of Boro rice make it a cornerstone of Bangladesh's food security strategy. Its high productivity and relatively stable performance under irrigated conditions help ensure a reliable domestic rice supply, reduce dependence on imports, and buffer fluctuations in rice production caused by adverse weather during the *Aman* and *Aus* seasons (BINA, 2024). Achieving further productivity gains, however, increasingly depends on expanding agricultural mechanization and improving farmers' access to the financial resources needed to adopt mechanized technologies.

Agricultural mechanization has become an important strategy for improving labour productivity and production efficiency in modern farming systems. Mechanized tillage and harvesting reduce manual labour requirements, enabling farmers to cultivate larger areas or reallocate labour to other productive activities (Gebiso *et al*., 2024; Ahammad *et al*., 2025). Mechanization also improves the timeliness of field operations, such as planting and harvesting, which is essential for maximizing crop yields. By facilitating timely farm operations despite labour shortages and adverse weather conditions, mechanization enhances production efficiency, increases crop yields, and reduces post-harvest losses. However, the adoption of agricultural machinery often requires substantial upfront investment, making access to agricultural credit and other financial resources a key determinant of mechanization adoption among smallholder farmers. Empirical evidence from developing countries consistently demonstrates that agricultural mechanization improves farm productivity, production efficiency, and economic performance. Studies from China and Ethiopia show that mechanization increases crop yields, farm returns, and production efficiency (Peng *et al*., 2022; Gebiso *et al*., 2024). In addition to these production benefits, mechanization also contributes to improved household welfare and food security. For example, evidence from Pakistan indicates that mechanized farming systems improve both farm performance and household food availability compared with non-mechanized systems (Yasar *et al*., 2024). Collectively, these findings suggest that while mechanization offers substantial productivity and welfare benefits, its adoption depends heavily on farmers' ability to finance machinery investments, highlighting the importance of agricultural credit.

In Bangladesh, agricultural mechanization has expanded in recent years, although its adoption remains uneven among smallholder farmers. Mechanized transplanting and harvesting have improved the efficiency and timeliness of farm operations while reducing dependence on manual labour, particularly during peak production periods (Islam, 2020; Karim *et al*., 2026). However, despite these recognized benefits, limited access to affordable agricultural credit continues to constrain the adoption of mechanization, restricting farmers' ability to purchase agricultural machinery or hire mechanized services (Islam *et al*., 2024; Rahman *et al*., 2021). These challenges are particularly evident among smallholder farmers in regions such as Mymensingh, where institutional, financial, and infrastructural barriers further limit the use of modern agricultural technologies. Consequently, agricultural credit plays a critical role in overcoming these constraints by enabling farmers to invest in agricultural machinery or access mechanized services, thereby accelerating mechanization adoption and promoting sustainable agricultural development (Adesiyan, 2025; Rayhan *et al*., 2023). Despite growing interest in agricultural credit and mechanization, empirical evidence on how access to agricultural credit influences farm-level mechanization decisions in Bangladesh remains limited. Existing studies have primarily focused on aggregate credit trends or broader agricultural modernization, with relatively little attention to the relationship between agricultural credit, mechanization adoption, and farmers' socioeconomic characteristics (Yeasmin *et al*., 2025; Jamal *et al*., 2023). This study addresses this gap by examining the relationship between agricultural credit and the level of mechanization among Boro rice farmers in Mymensingh District using Propensity Score Matching to reduce selection bias and provide robust farm-level evidence.

Therefore, this study examines how agricultural credit influences mechanization among Boro rice farmers in Mymensingh District, Bangladesh. Specifically, the study aims to: i) compare the socioeconomic characteristics of credit recipients and non-recipients; ii) assess the impact of agricultural credit on farm mechanization and profitability; and iii) identify the major constraints to accessing agricultural credit and adopting mechanization. The findings are expected to provide evidence to support policies and financial interventions that enhance mechanization and improve the productivity and sustainability of Boro rice farming in Bangladesh.

MATERIALS AND METHODS

Study area

The study was conducted in Mymensingh District, Bangladesh, one of the country's major Boro rice-producing regions. The district is characterized by fertile alluvial soils, favorable agro-climatic conditions, and extensive irrigation facilities that support intensive Boro rice cultivation. The district has also experienced increasing adoption of agricultural mechanization, while access to institutional agricultural credit remains uneven among smallholder farmers. These characteristics make Mymensingh District an appropriate study area for examining the relationship between agricultural credit and the level of mechanization in Boro rice production.

Sampling procedure and data collection

A total of 80 Boro rice farmers were surveyed, comprising 40 farmers who had received agricultural credit and 40 farmers without agricultural credit. The sample size was determined considering the study objectives, available resources, and consistency with comparable farm-level studies conducted in Bangladesh. To ensure representativeness, farmers were stratified by credit status, and random selection was applied within each stratum. Data were collected through semi-structured interviews conducted in Bangla, lasting 45–60 minutes each. The questionnaire was pre-tested with 10 farmers to refine clarity and reliability. In addition, two focus group discussions (FGDs) with 8–10 participants each and farm observations were conducted to validate the survey findings, gain deeper insights into farmers' credit utilization and mechanization practices, and triangulate the quantitative data. After data collection, the completed questionnaires were checked for completeness and consistency, coded, and entered the statistical software for subsequent analysis.

Analytical framework

To address the study objectives, both descriptive and econometric techniques were employed. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the socioeconomic characteristics of the respondents. Profitability analysis was conducted to estimate the economic performance of Boro rice production,

while Propensity Score Matching (PSM) was employed to examine the relationship between agricultural credit and the level of mechanization by minimizing selection bias arising from non-random credit participation.

Profitability analysis

The profitability of Boro rice production was assessed using net return analysis, where net return was calculated as the difference between gross return and the total production cost, including both variable and fixed costs. The net return was estimated using the following equation:

$$\pi = P_y Y - \sum_{i=1}^{n} (P_{xi} X) - TFC \quad (1)$$

Where, = Net return (Tk./ha/season); P_y= Price of the product (Tk./kg); Y= Amount of the production per hectare/season (Kg); P_{xi}= Price of i^{th} inputs (Tk.); X_i =Amount of the i^{th} inputs per hectare/season (kg); TFC= Total fixed cost (Tk.); i=1,2,3.....,n (number of inputs).

Propensity Score Matching (PSM) Framework

Since participation in agricultural credit programmes is not randomly assigned, direct comparisons between credit recipients and non-recipients may produce biased estimates due to systematic differences in their socioeconomic characteristics. Therefore, Propensity Score Matching (PSM) was employed to minimize selection bias and obtain a more reliable estimate of the effect of agricultural credit on the level of mechanization. PSM creates a comparable control group by matching farmers with similar observable characteristics, thereby reducing selection bias arising from non-random participation in agricultural credit programmes (Rosenbaum & Rubin, 1983; Caliendo & Kopeinig, 2008).

The propensity score represents the conditional probability of receiving agricultural credit given a set of observed covariates and was estimated using a binary logistic regression model as follows:

$$PS = P(T = 1 \mid X) = \frac{\exp(\mathrm{X}\beta)}{1 + \exp(\mathrm{X}\beta)} \quad (2)$$

Where, *PS* is the propensity score, *T* denotes the treatment status (1 = farmer received agricultural credit; 0 = farmer did not receive agricultural credit), *X* represents the vector of observed covariates, and β is the vector of parameters estimated from the logistic regression model.

Following the estimation of propensity scores, a one-to-one nearest-neighbour matching algorithm without replacement was applied to match each credit recipient with the most comparable non-credit farmer based on their propensity scores. The impact of agricultural credit on the level of mechanization was measured using the Average Treatment Effect on the Treated (ATT), which is expressed as:

$$ATT = E[Y(1) - Y(0) \mid T = 1] \approx \frac{1}{N_T} \sum_{i \in T} \left(Y_i - Y_{m(i)}\right) \quad (3)$$

Where, Y_i denotes the observed mechanization level of the treated farmer, $Y_{m(i)}$represents the mechanization level of the matched control farmer, and N_T is the total number of treated farmers.

The variables included in the Propensity Score Matching (PSM) model are presented in Table 1. The treatment variable was farmers' access to agricultural credit, while the outcome variable was the level of mechanization. These variables were selected because they are expected to influence both farmers' access to agricultural credit and their adoption of agricultural mechanization, thereby satisfying the conditional independence assumption underlying PSM.

Table 1. Definition and measurement of variables used in the propensity score matching analysis.

Variable	Type	Measurement
Treatment variable		
Agricultural credit (T)	Binary	1 = Farmer received agricultural credit; 0 = Farmer did not receive agricultural credit
Outcome variable		
Mechanization level (Y)	Ordinal	Adoption score (0–5) based on use of machinery in land prep, transplanting, irrigation, harvesting, and threshing
Covariates		
Age	Continuous	Age of household head (years)
Education	Continuous	0–16 scale (no schooling to tertiary)
Family size	Continuous	Total number of household members
Earning members	Continuous	Number of income-earning household members
Elderly members	Continuous	Number of household members aged >64 years
Children	Continuous	Number of household members below working age
Agricultural income	Continuous	Monthly income from agricultural activities (Tk/month)
Non-agricultural income	Continuous	Monthly income from non-agricultural activities (Tk/month)
Food expenditure	Continuous	Monthly household expenditure on food (Tk/month)
Landholding	Continuous	—

Note: Average family size = 5.54 members. Exchange rate: US$1 = Tk. 122.31 (Field Survey, 2025).

Matching quality assessment

The quality of the propensity score matching procedure was assessed by comparing the balance of observable covariates between credit recipients and non-credit recipients before and after matching. Covariate balance was evaluated using standardized mean differences (SMD), which measure the differences in covariate distributions between the treated and matched control groups. Following Austin (2009), an SMD of less than 10% after matching was considered indicative of satisfactory covariate balance. The balance diagnostics were used to verify that the matching procedure effectively reduced observable differences between the treatment and control

groups before estimating the Average Treatment Effect on the Treated (ATT).

RESULTS AND DISCUSSION

Socioeconomic characteristics of respondents

Table 2 presents the socioeconomic characteristics of the sampled Boro rice farmers. Credit recipients were generally older than non-credit farmers, with a higher proportion aged 46 years and above (57.5% compared with 45.0%), whereas the non-credit group was more concentrated in the 30–45 years age category. This pattern suggests that older farmers, owing to their greater farming experience, accumulated assets, and stronger relationships with financial institutions, may have better access to agricultural credit. Medium-sized households (4–6 members) predominated in both groups, accounting for 75.0% of credit recipients and 65.0% of non-credit farmers, with an average family size of 5.54 members. Such household sizes are likely to provide sufficient family labour for labour-intensive Boro rice production while reducing dependence on hired labour during peak farming operations. Regarding education, most respondents had completed primary or secondary education, while credit recipients exhibited a slightly higher level of educational attainment than non-credit farmers. This finding indicates that education may facilitate farmers' access to institutional credit by improving financial literacy, access to information, and the ability to adopt improved agricultural technologies. These findings are consistent with recent studies in Bangladesh, which identified farmers' age, education, household characteristics, and resource endowments as important factors influencing access to agricultural credit and the adoption of improved agricultural technologies (Sarker *et al.*, 2021; Rayhan *et al.*, 2024; Yeasmin *et al.*, 2025). Table 2further shows noticeable differences in farm size and household income between credit recipients and non-credit farmers. A larger proportion of credit recipients (72.5%) operated small farms (0.51–2.49 acres), whereas most non-credit farmers (80.0%) belonged to the marginal farm category (≤0.50 acre). This pattern suggests that farmers with relatively larger landholdings may have greater access to agricultural credit, as they often possess stronger repayment capacity and collateral, making them more attractive to formal lending institutions. Similarly, a higher proportion of non-credit farmers fell within the middle- and high-income categories, while 40.0% of credit recipients belonged to the low-income group. This finding indicates that agricultural credit may play an important role in easing financial constraints faced by resource-limited farmers, enabling them to finance production activities despite having relatively lower household incomes. Overall, the observed differences suggest that both farm size and economic conditions are important factors associated with farmers' access to agricultural credit, which is consistent with recent evidence from Bangladesh highlighting the influence of landholding and household economic status on credit accessibility and agricultural investment (Rayhan *et al.*, 2024; Yeasmin *et al.*, 2025).

Table 2. Socioeconomic characteristics of credit recipient and non-credit Boro rice farmers.

Characteristics	Category	Credit recipients (n = 40) n (%)	Non-credit farmers (n = 40) n (%)
Age (years)	<29	1 (2.5)	2 (5.0)
	30–45	16 (40.0)	20 (50.0)
	≥46	23 (57.5)	18 (45.0)
Family size (members)	Small (2–3)	2 (5.0)	2 (5.0)
	Medium (4–6)	30 (75.0)	26 (65.0)
	Large (≥7)	8 (20.0)	12 (30.0)
Education level	Illiterate	6 (15.0)	8 (20.0)
	Primary (1–5 years)	14 (35.0)	10 (25.0)
	Secondary (6–10 years)	12 (30.0)	15 (37.5)
	Higher secondary (11–12 years)	5 (12.5)	6 (15.0)
	Graduate and above	3 (7.5)	1 (2.5)
Farm size (acre)	Marginal (<0.50)	11 (27.5)	32 (80.0)
	Small (0.51–2.49)	29 (72.5)	8 (20.0)
Monthly household income (Tk.)	Low income <12,900 (<US$ 105.47)	16 (40.0)	9 (22.5)
	Middle income 12,900–21,500 (US$ 105.47–US$ 175.78)	14 (35.0)	17 (42.5)
	High income >21,500 (>US$ 175.78)	10 (25.0)	14 (35.0)

Note: Average family size = 5.54 members. Exchange rate: US$1 = Tk. 122.31 (Field Survey, 2025).

Agricultural credit characteristics

Table 3 summarizes the credit characteristics of the borrowing farmers. Non-governmental organizations (NGOs) were the predominant source of agricultural credit, providing loans to 60.0% of the borrowers, followed by commercial banks (30.0%) and informal sources (10.0%). The dominance of NGO financing reflects their extensive rural outreach, simplified lending procedures, and relatively lower collateral requirements, making them more accessible to smallholder farmers than formal banking institutions. Despite the expansion of institutional agricultural credit in Bangladesh, many farmers continue to rely on NGOs because of their flexible loan disbursement and repayment arrangements, particularly during the time-sensitive Boro production season (Bangladesh Bank, 2024; Yeasmin *et al.*, 2025). Regarding loan size, most borrowers (42.5%) received loans ranging from Tk. 30,000 to Tk. 50,000, while 35.0% obtained less than Tk. 30,000 and only 22.5% received more than Tk. 50,000. This distribution indicates that al-

though agricultural credit is available, the relatively modest loan amounts may limit farmers' ability to invest in capital-intensive mechanization technologies and other long-term productivity-enhancing inputs. Adequate access to credit has been shown to improve farmers' investment capacity and agricultural productivity, suggesting that expanding both the availability and size of institutional loans could facilitate greater mechanization among smallholder rice farmers (Rayhan *et al.*, 2024; Yeasmin *et al.*, 2025). Table 4 shows that Boro rice cultivation was more profitable for credit recipients than for non-credit farmers. Although the total production cost was slightly lower for credit recipients, they obtained a higher average yield (8,520 kg ha^{-1}) and earned nearly twice the net return (Tk. 57,078 ha^{-1}) compared with non-credit farmers (Tk. 28,943 ha^{-1}). They also achieved a higher benefit–cost ratio (1.29 compared with 1.14), indicating that every taka invested in production generated a better return for farmers who had access to credit. These findings suggest that access to agricultural credit helped farmers make more effective production decisions and use available resources more efficiently, resulting in higher farm profitability.

Table 3. Agricultural credit characteristics of borrowing farmers.

Variable	Category	Frequency	Percentage
Source of credit	NGO	24	60.0
	Bank	12	30.0
	Informal	4	10.0
Amount of credit received	<Tk. 30,000 (<US$245.28)	14	35.0
	Tk. 30,000-50,000 (US$245.28- US$408.80)	17	42.5
	>Tk. 50,000(>US$408.80)	9	22.5

Exchange rate: US$1 = Tk. 122.31 (Field Survey, 2025).

Table 4. Per-hectare costs and returns of boro rice cultivation under credit and non-credit farming.

Item	Credit	Non-credit
Variable Costs (Tk./ha)		
Seedling	13226 (US$ 108.14)	13087 (US$ 107)
Human labour	31800 (US$ 260)	42600 (US$ 348.30)
Land preparation	9927(US$ 81.16)	9751(US$ 79.72)
Urea	7380 (US$ 60.34)	7770 (US$ 63.53)
TSP	5670 (US$ 46.36)	5895 (US$ 48.20)
MoP	3198 (US$ 26.15)	3484(US$ 28.48)
Gypsum	1840 (US$ 15.04)	1872(US$ 15.31)
Zinc	1500 (US$ 12.26)	1750 (US$ 14.31)
Insecticides	3136 (US$ 25.64)	3224 (US$ 26.36)
Herbicides	1371(US$ 11.21)	1488 (US$ 12.17)
Irrigation	15448 (US$ 126.30)	16446 (US$ 134.46)
Transportation	4031(US$ 32.96)	3975 (US$ 32.50)
Threshing	124 (US$ 1.01)	2904 (US$ 23.74)
Combine harvester	12761(US$ 104.33)	5849 (US$ 47.82)
Total Variable Cost	111412 (US$ 910.90)	120095 (US$ 981.89)
Fixed Costs (Tk./ha)		
Land use cost	78743 (US$ 643.80)	78925(US$ 645.29)
Interest on operating capital	3342 (US$ 27.32)	3602(US$ 29.45)
Total Fixed Cost	82085 (US$ 671.12)	82527(US$ 674.74)
Total Cost (Tk./ha)	193497 (US$ 1582.02)	202622 (US$ 1656.63)
Returns		
Yield (kg/ha)	8,520	7,720
Gross return (Tk./ha)	250575 (US$ 2048.69)	231565(US$ 1893.26)
Gross margin (Tk./ha)	139163 (US$ 1137.79)	111470(US$ 911.37)
Net return (Tk./ha)	57078 (US$ 466.67)	28943(US$236.64)
Benefit–Cost Ratio (Undiscounted)	1.29	1.14

Source: Exchange rate: US$1 = Tk. 122.31 (Field Survey, 2025).

Profitability of boro rice production

Table 4 shows that Boro rice cultivation was more profitable for credit recipients than for non-credit farmers. Although the total production cost was slightly lower for credit recipients, they obtained a higher average yield (8,520 kg ha^{-1}) and earned nearly twice the net return (Tk. 57,078 ha^{-1}) compared with non-credit farmers (Tk. 28,943 ha^{-1}). They also achieved a higher benefit–cost ratio (1.29 compared with 1.14), indicating that every taka invested in production generated a better return for farmers who had access to credit. These results suggest that agricultural credit was associated with more efficient resource utilization and higher farm profitability. The observed profitability advantage of credit recipients appears to be largely associated with greater use of mechanized farm operations. Farmers with access to credit spent less on manual labour while

investing more in mechanized harvesting, suggesting greater reliance on mechanized operations. By contrast, expenditures on seeds, fertilizers, and crop protection materials differed only marginally between the two groups, indicating that the higher profitability of credit recipients was primarily associated with improved operational efficiency rather than greater input use. This is particularly important in Boro rice cultivation, where labour shortages during peak transplanting and harvesting periods often delay field operations and increase production costs. By easing financial constraints, agricultural credit enables farmers to adopt labour-saving technologies that improve the timeliness of farm operations and reduce avoidable production losses. These results suggest that agricultural credit was associated with more efficient resource utilization and higher farm profitability. Sujan *et al.* (2025) reported that the adoption of combine harvesters significantly reduced labour use and production costs while increasing net returns among Boro rice farmers in Bangladesh. Similarly, Ahmed *et al.* (2025) found that efficient labour management and the appropriate use of production inputs were key determinants of the profitability of Boro rice cultivation. Likewise, Yeasmin *et al.* (2025) showed that improved access to agricultural credit strengthened farmers' capacity to invest in productive farm activities, leading to higher rice productivity and improved economic returns. Overall, these findings suggest that improving farmers' access to affordable agricultural credit can facilitate mechanization adoption and contribute to more profitable and sustainable Boro rice production.

Impact of agricultural credit on the level of mechanization

Covariate balance after matching

Before estimating the treatment effect, the quality of the matching procedure was assessed by comparing the standardized mean differences (SMD) of the selected covariates before and after matching (Table 5). Prior to matching, several covariates exhibited noticeable imbalance between credit recipients and non-credit farmers, particularly agricultural income, rented land, and family size. After matching, the standardized differences for all covariates were reduced to below the commonly accepted 10% threshold, indicating that the treated and matched control groups became sufficiently comparable. These results suggest that the matching procedure effectively minimized observable differences between the two groups, thereby providing a more reliable basis for estimating the impact of agricultural credit on mechanization (Caliendo & Kopeinig, 2008; Austin, 2009).

Average Treatment Effect on the Treated (ATT)

Table 6 presents the estimated Average Treatment Effect on the Treated (ATT) obtained from the Propensity Score Matching (PSM) analysis. After matching farmers with similar socioeconomic characteristics, credit recipients recorded a mean mechanization score of 4.00, compared with 3.32 for matched non-credit farmers, resulting in an ATT of 0.68. The estimated treatment effect was statistically significant ($t = 3.49$, $p < 0.01$), indicating that access to agricultural credit had a positive and significant effect on the level of mechanization among Boro rice farmers in the study area. The findings suggest that access to agricultural credit helped farmers overcome financial constraints and increased their ability to invest in or hire mechanized farm services. By easing liquidity constraints, credit enables farmers to adopt modern production technologies that reduce reliance on manual labor and facilitate more efficient farm operations. These findings are consistent with Rayhan *et al.* (2023), who reported that access to rural credit significantly increased both the adoption and intensity of agricultural technology use among Boro rice farmers in Bangladesh, with particularly strong impacts observed among farmers receiving NGO credit. Their results similarly demonstrate that improved access to credit encourages farmers to adopt modern agricultural technologies. The present findings are further supported by Yeasmin *et al.* (2025), who found that improved access to agricultural finance enhanced farmers' investment capacity, leading to higher rice productivity and better economic returns. Likewise, Sujan *et al.* (2025) showed that the adoption of combine harvesters significantly reduced labor requirements and production costs while increasing farm profitability, highlighting the economic benefits of agricultural mechanization. Although their study examined machinery adoption rather than credit access, the findings reinforce the important role of financial resources in facilitating the adoption of labor-saving technologies.

Table 5. Covariate balance before and after propensity score matching.

Variable	Before Matching SMD (%)	After Matching SMD (%)
Age	-12.5	-3.8
Family size	18.3	6.1
Earners	-15.2	-7.3
Agricultural income	22.6	3.1
Total land	11.2	2.4
Own land	-18.7	-3.9
Rented land	27.4	6.8

Table 6. Average Treatment Effect on the Treated (ATT) of agricultural credit on mechanization level.

Group	Matched Sample (N)	Mean Mechanization Score	ATT	*t*-value	*p*-value
Credit recipients (Treated)	38	4.00	0.68	3.49	0.0007
Non-credit farmers (Matched control)	38	3.32	–	–	–

Source: Authors' estimation based on Field Survey, 2025.

Similarly, Salam & Sarker (2023) reported that farmers adopting improved rice technologies achieved significantly higher technical efficiency and productivity after controlling for selection bias through Propensity Score Matching, providing further evidence that greater adoption of modern agricultural technologies contributes to improved farm performance. Overall, the PSM analysis provides robust evidence that agricultural credit plays an important role in promoting mechanization among Boro rice farmers. Improving farmers' access to affordable, timely credit can facilitate the adoption of modern agricultural technologies by easing financial constraints, thereby enhancing production efficiency and supporting the continued modernization of Bangladesh's rice sector.

Problems and constraints affecting the adoption of agricultural mechanization

Table 7 presents the major constraints affecting the adoption of agricultural mechanization among Boro rice farmers. The findings indicate that the high price of machinery (Mean = 1.96), limited access to agricultural credit (Mean = 2.38), and fragmented and small landholdings (Mean = 2.76) were perceived as the three most serious barriers to mechanization. These results suggest that financial and structural constraints remain the primary obstacles preventing smallholder farmers from investing in or accessing mechanized farm services. The findings are consistent with recent evidence from Bangladesh. Sujan *et al.* (2025) identified high machinery costs and machinery-related operational constraints as major factors limiting the adoption of combine harvesters among Boro rice farmers. Similarly, Banik *et al.* (2026) reported that high machinery prices, fragmented landholdings, limited access to custom hiring services, and inadequate technical support significantly constrained the adoption of modern agricultural machinery among smallholder farmers. Moazzem *et al.* (2025) also highlighted that inadequate access to appropriate financing remains one of the major challenges limiting investment in agricultural machinery, despite ongoing policy initiatives to promote mechanization. These findings reinforce the importance of reducing financial barriers while improving access to mechanization services. Although farmers also reported the lack of skilled machinery operators, high fuel and maintenance costs, delayed machinery availability, shortages of spare parts, and weak extension services as constraints, these were perceived as less severe than the financial and structural barriers. Nevertheless, addressing these operational challenges would improve the effective utilization of agricultural machinery and encourage wider adoption of mechanized farming practices.

Overall, the results highlight that improving farmers' access to affordable agricultural credit, expanding custom hiring services, reducing the cost of mechanization, and strengthening technical support and extension services could substantially accelerate the adoption of agricultural mechanization among Boro rice farmers in Bangladesh.

Table 7. Ranking of constraints affecting the adoption of agricultural mechanization among boro rice farmers.

Constraint	Total Score	Mean Score	Rank
High price of machinery	157	1.96	1
Lack of credit facilities	190	2.38	2
Fragmented and small landholdings	221	2.76	3
Lack of skilled mechanics or operators	334	4.18	4
High fuel and maintenance costs	349	4.36	5
Machinery not available when needed	487	6.09	6
Shortage of spare parts	554	6.93	7
Weak agricultural extension services	580	7.25	8

Source: Field Survey, 2025.

Conclusion

This study examined the role of agricultural credit in promoting mechanization among Boro rice farmers in Mymensingh district, Bangladesh. By comparing credit recipients with non-credit farmers and applying Propensity Score Matching (PSM), the study assessed differences in farm profitability, estimated the causal effect of agricultural credit on mechanization, and identified the major constraints limiting the adoption of mechanized farming. The findings showed that farmers with access to agricultural credit achieved better economic performance than non-credit farmers. Credit recipients obtained higher yields, greater net returns, and superior benefit–cost ratios, indicating that access to credit enabled farmers to invest more efficiently in productive farm operations and improve the profitability of Boro rice cultivation. After controlling for observable socioeconomic differences through Propensity Score Matching, the study found that agricultural credit had a positive and statistically significant impact on the level of mechanization. Credit recipients recorded significantly higher mechanization scores than comparable non-credit farmers, confirming that access to finance plays an important role in facilitating the adoption of modern agricultural technologies. Despite these benefits, the wider adoption of mechanization continues to be constrained by the high cost of agricultural machinery, limited access to affordable credit, fragmented landholdings, and inadequate technical support. Therefore, policies aimed at expanding affordable agricultural credit should be complemented by machinery-sharing and custom hiring services, improved extension and technical assistance, and innovative financing mechanisms for agricultural machinery. Such integrated interventions would accelerate the adoption of mechanized farming, improve farm profitability, and contribute to the long-term sustainability of Boro rice production in Bangladesh.

DECLARATIONS

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