A Comparative Econometric Analysis of Rice and Banana Production and Household Risk Responses under Riverbank Erosion in Pabna District, Bangladesh

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ABSTRACT

Riverbank erosion along the Padma and Jamuna rivers remains a major constraint on agricultural production and rural livelihood resilience in Bangladesh. This study compares the production performance, resource-use efficiency, profitability, and erosion-related monetary gaps of rice and banana cultivation and examines household risk responses in Pabna District. The analysis is based on primary cross-sectional data collected in August 2025 from 300 farm households, equally divided between erosion-prone and non-erosion areas. Separate Cobb–Douglas production functions were estimated for rice and banana in the two environmental settings. Resource-use efficiency, profitability indicators, monetized return gaps, and household risk-perception measures were also analysed. The results reveal substantial crop- and location-specific differences. In erosion-prone areas, only seed cost is marginally significant in the rice and banana models, while the remaining inputs show weak gross-return responsiveness. The sums of the estimated elasticities are 0.168 for rice and 0.204 for banana, indicating decreasing returns to scale. In non-erosion areas, seed, pesticide, fertilizer, labour, and land rent are positively and significantly associated with gross return for both crops. The corresponding returns-to-scale estimates are 2.51 for rice and 2.88 for banana, indicating increasing returns to scale. Rice cultivation generates a benefit–cost ratio of 1.21 in erosion-prone areas and 1.98 in non-erosion areas, while the corresponding ratios for banana are 1.07 and 2.22. The comparative gross-return gaps are Tk. 30,000 per bigha for rice and Tk. 66,300 for banana, while the net-return gaps are Tk. 25,000 and Tk. 62,300, respectively. Household-level evidence further indicates high perceived vulnerability and risk-averse responses, including preference for short-duration crops, cautious investment, income diversification, and reliance on community-based coping mechanisms. The findings demonstrate that riverbank erosion is associated with weak input responsiveness, inefficient resource allocation, low profitability, and constrained agricultural investment. Integrated interventions combining riverbank protection, crop-specific extension, risk-sensitive credit, crop insurance, social protection, and livelihood diversification are required to strengthen resilience in erosion-prone communities.

Keywords: Riverbank erosion, Profitability, Cobb-Douglas, Allocative efficiency, and Risk preferences.

INTRODUCTION

Riverbank erosion is a persistent hazard in Bangladesh, with the Padma and Jamuna rivers continuously reshaping floodplains, displacing households, and undermining livelihoods. Unlike sudden disasters, erosion is gradual, destroying homesteads, cropland, and infrastructure, causing immediate shocks and long-term insecurity (Abraham, 2018; Alam et al., 2023). It is severe in districts like Pabna, where fertile alluvial land supports agriculture but exposes households to land loss (Bhuiyan et al., 2017; Haman, 2025). Land is vital for food security, income, and social security. Erosion removes cultivable land, pushing households into debt, insecure tenancy, wage labor, or migration (Bjornlund et al., 2020; Md. F. Islam & Hossain, 2020). This instability affects both rice and banana cultivation. Rice is central to household food security and the rural economy, whereas banana represents an important commercial crop requiring substantial expenditure on labour, fertilizer, irrigation, and land. Comparing the two crops therefore provides a broader understanding of how erosion-related land instability influences both staple and commercially oriented agricultural production (Botzen et al., 2019; Eshita et al., 2023).

Riverbank erosion impacts extend beyond land loss, shaping household risk perceptions and responses. Facing uncertainty, farm households adopt conservative strategies like reduced investments, short-term crops, diversification, and reliance on off-farm income instead of riskier, higher-return activities (Clech et al., 2024; Djanibekov et al., 2024). These behaviors are influenced not just by resource constraints but also by risk attitudes, loss aversion, social norms, and expectations of shocks (Gazi et al., 2020; Freyer & Bingen, 2021). Understanding these factors is key to explaining different livelihood choices among farmers in similar ecological settings. Although erosion is a major challenge in Bangladesh, literature mainly focuses on physical processes and displacement, with limited analysis of farm performance and risk preferences in an integrated framework (Farhan et al., 2022; Islam et al., 2024). Losses are not only due to damaged land but also how households manage resources and uncertainty. A holistic approach is therefore required to understand how erosion is associated with the production performance, resource-use efficiency, profitability, and risk-related decision environment of both rice and banana cultivation.

This study aims to compare the economic performance of rice and banana cultivation in erosion-prone and non-erosion areas of Pabna District, Bangladesh. Specifically, it examines how production inputs are associated with gross return, evaluates the allocative efficiency of input use, compares crop profitability, estimates erosion-associated monetary gaps, and assesses household risk perceptions and behavioral responses (Fan & Rue, 2020). Separate Cobb–Douglas production functions are estimated for rice and banana to identify whether the two crops respond differently to production inputs under unstable and relatively stable land conditions (Kuddus et al., 2020; Farhan et al., 2022; Khoury et al., 2022). By examining both rice and banana, the study demonstrates how riverbank erosion is associated with the performance of crops that differ substantially in cost structure, profitability, and investment requirements, with wider implications for food security, farm income, and sustainable rural development.

LITERATURE REVIEW

Riverbank erosion is a significant and slow-forming environmental and livelihood challenge in Bangladesh, especially in the floodplain areas of the Padma and Jamuna rivers. Unlike sudden disasters, it gradually destroys homesteads, cropland, infrastructure, and social assets, leading to long-term economic insecurity for rural households. In agricultural communities, where land is vital for income, food security, and social standing, repeated erosion can cause landlessness, displacement, debt, and job instability. The impact extends beyond physical land loss, affecting household decisions, agricultural investments, and risk behaviors. This impact can be understood through three lenses: household livelihood theory, production economics, and risk and resilience theory. The livelihood approach shows how households rely on land, labor, capital, and social networks under environmental stress. Erosion can cause loss of titled land and irrigation access, prompting migration, tenancy, wage work, or diversification. Production economics explains how such instability alters resource use and output, while behavioral and resilience theories show that households respond based on uncertainty, attachment to land, cultural values, and future shock expectations, not just profit (Mallick & Mallick, 2021; Li et al., 2024; Levinthal & Wu, 2025).

Global studies show riverbank erosion causes three main issues. It worsens socio-economic inequality, with wealthier households able to relocate or reinvest, while poorer households often become landless or work in informal jobs (Mensah, 2019; Mu et al., 2024). Erosion also reduces agricultural productivity by discouraging investment due to land insecurity, lowering yields and profits (Nkem et al., 2024; Nafee et al., 2025). Additionally, erosion impacts migration and labor, with some families relying on remittances, but often losing family labor and social ties (Panda, 2025; Qadri et al., 2025). In Bangladesh, these effects are intensified owing to the river system's instability, especially along the Padma and Jamuna rivers. Continuous erosion leads to displacement, landlessness, debt, and weak recovery, disproportionately affecting women, children, and land-poor families, especially in districts like Pabna where agriculture is vital. Erosion affects agricultural productivity and efficiency by disrupting resource allocation due to insecure land tenure, fragmented plots, poor soil quality, limited market access, and credit (Hossain, 1993; Hutton & Haque, 2003). These factors cause underuse of inputs and promote low-input, short-duration cropping. This leads to deviations in resource use efficiency, as shown by the Cobb-Douglas function. Erosion's impact is not just technical but reflects rational responses to environmental risk. Monetization measures like gross return, net return, and benefit-cost ratio better capture erosion's economic impact, showing how it reduces farm profitability through less land, lower yields, and increased risk (Robinson et al., 2018; Talbot et al., 2018; M. Rahman et al., 2022). These estimates aid policy by translating environmental damage into economic terms for support programs.

The behavioral aspect is crucial; households facing erosion often develop risk-averse behaviors, prioritizing short-term survival over long-term investment by choosing low-risk crops, minimizing inputs, avoiding loans, or diversifying income. Some stay on vulnerable land due to attachment, lack of options, or hope of temporary gain (Bhuiyan et al., 2017; Borderon, 2017). This aligns with loss aversion, present bias, and limited adaptation literature. Though individually rational, these actions sustain low productivity and income traps, making erosion both a physical hazard and a behavioral barrier to agricultural transformation. Policy responses in Bangladesh are largely reactive, focusing on embankments, relief, or resettlement, which fail to address land insecurity, credit access, extension services, or long-term resilience (Rashid, 2013; Rahman & Hickey, 2019). More integrated strategies—land tenure, crop insurance, credit, and community adaptation—are recommended but underdeveloped in erosion-prone areas.

Existing studies in Bangladesh have examined the production economics and profitability of banana cultivation, generally reporting that banana can generate substantial commercial returns under favourable production and market conditions (Mukul & Rahman, 2013; Mohiuddin et al., 2020; Rahman et al., 2020; Hossen & Islam, 2025). However, these studies have largely been conducted outside riverbank-erosion settings and do not show how unstable land, repeated displacement, and erosion-related uncertainty alter banana input use and profitability. This is important because banana cultivation involves relatively high production expenditure and longer land commitment than many seasonal crops. Consequently, insecure tenure and the possibility of land loss may discourage investment or lead farmers to use inputs in economically inefficient combinations. Comparing banana with rice therefore helps identify whether erosion-related constraints are similar across crops or particularly severe for more investment-intensive cultivation.

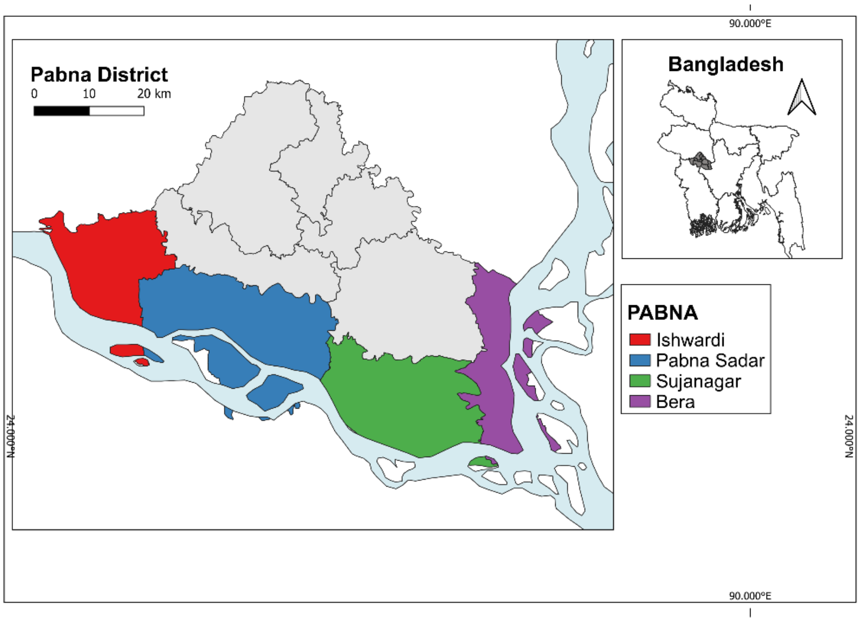
Despite increasing research on riverbank erosion, three important gaps remain. First, many studies document displacement, land loss, and poverty, but comparatively few estimate crop-level production relationships and resource-use efficiency under erosion exposure. Second, monetized evidence on how erosion-related differences in gross return, gross margin, net return, and benefit–cost ratios vary across crops remains limited. Third, household risk preferences are often inferred from livelihood outcomes rather than examined alongside farm-level production and profitability. These gaps are particularly relevant in the Padma–Jamuna corridor of Pabna District, where households cultivate both rice and banana under varying degrees of land stability. This study addresses these gaps by integrating crop-specific Cobb–Douglas estimation, allocative-efficiency analysis, profitability assessment, comparative monetary-gap estimation, and household risk-response analysis within a unified framework.

METHODOLOGY

Study Area and Sample Selection

The study was conducted in Pabna District, Bangladesh, a riverine district located along the Padma and Jamuna rivers, where repeated riverbank erosion has become a major threat to agricultural livelihoods. Pabna was selected purposively because of its chronic exposure to erosion and its strong dependence on agriculture, making it an appropriate setting for examining differences in farm performance and household behavior between erosion-affected and non-erosion areas. Within the district, four upazilas under Pabna district were selected to capture the variation in riverbank conditions and farming environments: Pabna Sadar, Ishwardi, Sujanagar, and Bera.

Figure 1: Study Area Map



Source: Developed by Author using ArcGIS

A multi-stage sampling procedure was followed. In the first stage, Pabna District was purposively chosen. In the second stage, the four study locations were selected on the basis of erosion intensity and relevance to the research objectives. In the final stage, farm households were selected as the ultimate sampling units. A total of 300 households were surveyed, of which 150 were from erosion-affected communities, and 150 were from non-erosion communities. Within each location, households were selected using simple random sampling from a list of eligible farm households. The household head was treated as the principal respondent because they were assumed to be the most informed regarding production decisions, input use, farm income, and responses to erosion-related risk. The distribution of surveyed households was 92 in Ishwardi, 128 in Sujanagar, 53 in Bera, and 27 in Pabna Sadar (see Figure 2).

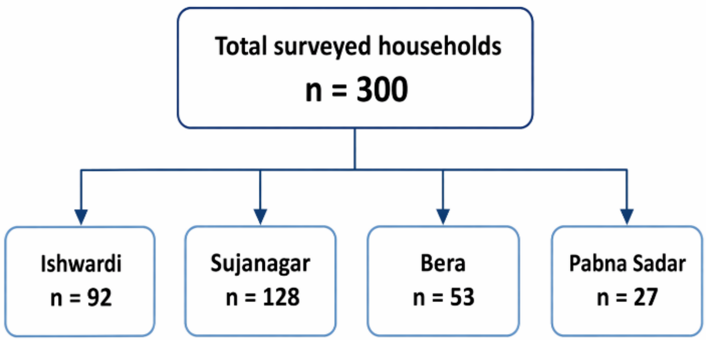
Sample Size

The sample size was determined using the Yamane (1967) formula with a 5.8% sampling error, as follows (Adam, 2020):

$$n = N/1+N(e)^2 \quad (1)$$

where n is the required sample size, N is the population size, and e is the acceptable sampling error.

Figure 2: Sample distribution



According to the Bangladesh Bureau of Statistics, the number of farm holdings in the study area was 184,830. Based on this population, the calculated minimum sample size was approximately 297 households. However, to improve representativeness and allow more robust comparison between erosion and non-erosion groups, the final survey covered 300 households.

Sources of Data

The study relied primarily on primary cross-sectional data, collected in August 2025 through a structured and pre-tested questionnaire. The questionnaire gathered information on household socio-economic characteristics, landholding status, rice and banana cultivation, crop-specific input use, gross return, production costs, profitability, and selected indicators of risk-related behavior and coping responses. Before final data collection, the questionnaire was piloted and revised to improve clarity and consistency. In addition to the structured household survey, semi-structured interviews were conducted with key informants, including relevant agricultural and local officials, to cross-check local conditions and support the interpretation of survey findings.

To supplement the household survey, secondary data were collected from published and institutional sources, including the Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), the Agricultural Statistical Yearbook, the Food and Agriculture Organization (FAO), the Ministry of Agriculture (MOA), and local administrative and agricultural offices. These secondary sources were used mainly for contextual information, validation of farm-level reports, and support in site selection.

Empirical Model

To compare production performance across crops and environmental settings, separate Cobb–Douglas production functions were estimated for rice and banana in erosion-prone and non-erosion areas. Thus, four models were estimated: erosion-prone rice, non-erosion rice, erosion-prone banana, and non-erosion banana. The model was specified in log-linear form because it permits direct interpretation of the estimated coefficients as elasticities of gross return with respect to input expenditure. The model is specified as:

$$\ln Y = \ln A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \mu i \quad (2)$$

where Y denotes gross return from rice or banana production per bigha, A is the constant term, and X_1 to X_7 represent seed cost, cultivation cost, pesticide cost, fertilizer cost, labor cost, irrigation cost, and land rent, respectively. The term μ_i is the random error term, and the β coefficients indicate the response of output to changes in each input. The estimated model was used to derive input coefficients, test statistics, explanatory power, and diagnostic indicators.

Resource - Use Efficiency

Resource-use efficiency was assessed through the ratio of the Marginal Value Product (MVP) of each input to its Marginal Factor Cost (MFC). The efficiency ratio is defined as:

$$r = MVP/MFC \quad (3)$$

The decision rule is that:

- r = 1 ; resource is efficiently utilized
- r > 1; resource is underutilized
- r < 1; resource is overutilized

For the Cobb-Douglas function, the MVP of the i-th input was estimated as:

$$MVP_i = \beta_i \times \bar{y}/\bar{x}_i \quad (4)$$

where β_i is the estimated coefficient of the i-th input, $\bar{y}$ is mean gross return, and $\bar{x}_i$ is the mean level of the relevant input. Since the variables were measured in monetary terms, the MFC of each additional taka of input was taken as one. This approach was applied separately to rice and banana in both erosion-prone and non-erosion areas. It therefore identified whether each input was overutilized, underutilized, or used near its economically efficient level for each crop-area combination.

Elasticities of Production

In the Cobb-Douglas model, each estimated coefficient β_i directly measures the production elasticity of the corresponding input. In each crop-specific Cobb–Douglas model, the estimated coefficient measures the percentage change in gross return associated with a one-percent change in the corresponding input cost, holding other inputs constant. Mathematically,

$$E_p=\delta Y/\delta X_i \times X_i/Y=\beta_i \qquad (5)$$

The decision rule is that:

- Ep = 1; Production elasticity is unity
- Ep > 1; Production is elastic
- Ep < 1; Production is inelastic

Return to scale

The return to scale (RTS) was estimated by summing up the coefficients of all explanatory variables in the Cobb-Douglas function:

$$RTS=\sum\beta_i \qquad (6)$$

Interpretation follows the standard rule:

- RTS=1: constant returns to scale
- RTS>1: increasing returns to scale
- RTS<1: decreasing returns to scale

Separate returns-to-scale values were calculated for rice and banana in each environmental setting, allowing comparison of whether simultaneous proportional increases in all measured input expenditures were associated with less-than-proportional or more-than-proportional increases in crop gross return.

Profitability Analysis

To compare the economic performance of rice and banana cultivation under different erosion conditions, gross return, total variable cost, total fixed cost, total cost, gross margin, net return, and the benefit–cost ratio were calculated separately for each crop and area on a per-bigha basis.

Gross Margin, Net Return

The gross margin (GM) was estimated as:

$$GM=TR-TVC \qquad (7)$$

where TR is total revenue, and TVC is total variable cost.

The net return (π) was estimated as:

$$\Pi = TR - TC \quad (8)$$

or equivalently,

$$\Pi = GM - TFC \quad (9)$$

where TC is total cost and TFC is total fixed cost. Gross margin captures the return over variable costs, while net return indicates the overall profitability of rice and banana cultivation after accounting for both variable and fixed costs.

Cost Analysis

Total variable cost included labor, seed, fertilizer, pesticide, cultivation, and irrigation costs. Land rental value was treated as the fixed or opportunity cost of land. Thus, total cost was calculated as:

$$TC = TVC + TFC \quad (10)$$

This breakdown made it possible to compare the cost structures of rice and banana production in erosion and non-erosion areas and to identify the components that contributed most to reduced profitability.

Revenue Analysis, BCR

The total revenue (TR) from rice and banana cultivation was estimated as:

$$TR = P \times Q \quad (11)$$

where P is the price per unit of rice and Q is total output per bigha.

The benefit-cost ratio (BCR) was then calculated as:

$$BCR = \frac{TR}{TC} \quad (12)$$

A BCR greater than 1 indicates that rice and banana cultivation is profitable, while a BCR below 1 indicates economic loss. Comparing BCRs between erosion and non-erosion groups helped assess how far riverbank erosion reduces the viability of rice farming.

Monetize Adverse Effect on Agricultural Production

The adverse effect of riverbank erosion on agricultural production was monetized by comparing the profitability of rice and banana cultivation between the erosion-affected and non-erosion groups. First, revenue, cost, gross margin, net return, and BCR were calculated separately for each group on a per-bigha basis. Second, the difference in net return between the two groups was interpreted as the monetized loss attributable to riverbank erosion. In other words, the earnings forgone by households in erosion-prone areas relative to households in stable areas represented the economic burden of erosion on rice and banana production. This comparative approach provides a direct and policy-relevant estimate of how erosion reduces farm profitability and weakens household economic security.

RESULTS AND DISCUSSION

Estimation of the Rice Production Function

To assess the effect of riverbank erosion on rice production, separate Cobb-Douglas production functions were estimated for erosion-prone and non-erosion areas using per-bigha input costs. The model included seed cost, cultivation cost, pesticide cost, fertilizer cost, labor cost, irrigation cost, and land rent as explanatory variables. The comparative regression results are presented in Table 4.1.

Table 4.1: Estimated Cobb-Douglas rice production function in erosion-prone and non-erosion areas

Variables	**Erosion-prone area**			**Non-erosion area**		
	Coefficients	Std. error	p-value	Coefficients	Std. error	p-value
Constant (lnA)	3.698	0.853	0.000	12.233	0.553	0.000
Seed Cost (X_1)	0.042*	0.032	0.053	0.30***	0.023	0.002
Cultivation Cost (X_2)	0.003^{ns}	0.040	0.885	0.28^{ns}	0.035	0.231
Pesticide Cost (X_3)	0.022^{ns}	0.040	0.122	0.40***	0.028	0.003
Fertilizer Cost (X_4)	0.012^{ns}	0.024	0.184	0.38***	0.018	0.001
Labor Cost (X_5)	0.022^{ns}	0.039	0.279	0.34**	0.025	0.029
Irrigation Cost (X_6)	0.014^{ns}	0.034	0.491	0.26^{ns}	0.031	0.220
Land Rent (X_7)	0.053^{ns}	0.067	0.123	0.55**	0.050	0.018
	F: 1.74, Prob (F-value): 0.09; R^2: 72.02%; and D-W: 1.98			F: 4.87, Prob (F-value): 0.07; R^2: 84.07%; and D-W: 2.03		
Field Survey 2025	*Note: * p < 0.10, ** p < 0.05, *** p < 0.01, ns = not significant.*					

Source: Authors' Computation

Accordingly, the estimated rice production function for the erosion-prone area can be written as:

$$\ln Y = 3.698 + 0.042\ln X_1 + 0.003\ln X_2 + 0.022\ln X_3 + 0.012\ln X_4 + 0.022\ln X_5 + 0.014\ln X_6 + 0.053\ln X_7$$

Similarly, the estimated rice production function for the non-erosion area is:

$$\ln Y = 12.233 + 0.30\ln X_1 + 0.28\ln X_2 + 0.40\ln X_3 + 0.38\ln X_4 + 0.34\ln X_5 + 0.26\ln X_6 + 0.55\ln X_7$$

The results reveal a marked difference in production response between the two areas. In the erosion-prone area, only seed cost is statistically significant at the 10% level, while the remaining coefficients are positive but statistically insignificant. This indicates that rice production in erosion-affected locations responds only weakly to additional input use. In coefficient terms, the seed-cost elasticity of 0.042 means that a 1% increase in seed cost increases rice output by only 0.042%; for example, a 10% increase in seed expenditure would raise output by just 0.42%, holding other factors constant. The effects of other inputs are even smaller in magnitude. For instance, a 10% increase in cultivation cost would increase output by only 0.03% (0.003×10), while a 10% increase in fertilizer cost would increase output by only 0.12% (0.012×10). Although pesticide cost, labor cost, irrigation cost, and land rent all have positive coefficients, their statistical insignificance suggests that these estimated effects should be interpreted with caution in the erosion-prone area.

In contrast, the non-erosion area shows a much stronger and more meaningful production response. Here, seed cost, pesticide cost, fertilizer cost, labor cost, and land rent are statistically significant and positively associated with rice output. Numerically, the coefficient of 0.30 for seed cost implies that a 1% increase in seed cost raises output by 0.30%, so a 10% increase in seed expenditure would increase output by 3.0%. Likewise, a 10% increase in pesticide cost would increase output by 4.0%, a 10% increase in fertilizer cost would raise output by 3.8%, and a 10% increase in labor cost would increase output by 3.4%. The largest coefficient is observed for land rent (0.55), implying that a 10% increase in land rent is associated with a 5.5% increase in rice output, which may reflect the higher productivity of better-quality or more secure land in non-erosion areas. The higher coefficient of determination in the non-erosion model further suggests that the production structure is more stable and predictable there. Overall, these estimates imply that riverbank erosion weakens the productivity-enhancing effects of farm inputs and constrains the efficiency of rice production.

Estimation of the Banana Production Function

Table 4.2: Estimated Cobb-Douglas banana production function in erosion-prone and non-erosion areas

Variables	**Erosion-prone area**			**Non-erosion area**		
	Coefficients	Std. error	p-value	Coefficients	Std. error	p-value
Constant (lnA)	6.233	0.879	0.000	14.253	0.593	0.000
Seed Cost (X_1)	0.035*	0.030	0.053	0.42***	0.043	0.001
Cultivation Cost (X_2)	0.018ns	0.045	0.885	0.31ns	0.025	0.211
Pesticide Cost (X_3)	0.025ns	0.045	0.122	0.39***	0.018	0.002
Fertilizer Cost (X_4)	0.031ns	0.027	0.184	0.35***	0.015	0.009
Labor Cost (X_5)	0.029ns	0.042	0.279	0.37**	0.015	0.024
Irrigation Cost (X_6)	0.005ns	0.039	0.491	0.34ns	0.021	0.120
Land Rent (X_7)	0.061ns	0.055	0.123	0.70**	0.040	0.019
	F: 1.69, Prob (F-value): 0.10; R^2: 71.05%; and D-W: 1.93			F: 6.87, Prob (F-value): 0.06; R^2: 87.77%; and D-W: 2.01		
Field Survey 2025	*Note: * p < 0.10, ** p < 0.05, *** p < 0.01, ns = not significant.*					

Source: Authors' Computation

The banana results show a substantial difference between the two environmental settings. In the erosion-prone area, seed cost is the only variable that is marginally significant at the 10% level. Its coefficient of 0.035 indicates that a one-percent increase in seed expenditure is associated with only a 0.035% increase in gross return from banana cultivation, holding the other inputs constant. Cultivation, pesticide, fertilizer, labour, irrigation, and land-rent coefficients are positive but statistically insignificant. The overall model is also only marginally significant at the 10% level, and the relatively small coefficients indicate weak gross-return responsiveness under erosion exposure.

In the non-erosion area, seed, pesticide, fertilizer, labour, and land rent are statistically significant and positively associated with banana gross return. The largest coefficient is observed for land rent, at 0.70, followed by seed cost at 0.42, pesticide cost at 0.39, labour cost at 0.37, fertilizer cost at 0.35, and irrigation cost at 0.34. These estimates suggest that banana cultivation on relatively stable land exhibits stronger economic responsiveness to input expenditure. However, cultivation and irrigation costs are not statistically significant and should therefore be interpreted cautiously.

Rice Efficiency Analysis

Rice Resource-use efficiency

Resource-use efficiency was measured through the ratio of Marginal Value Product to Marginal Factor Cost. A ratio greater than one indicates underutilization of an input, while a ratio less than one indicates overutilization. The comparative results for rice production are presented in Table 4.3.

Table 4.3: Comparative allocative efficiency of inputs used in rice production

Inputs	**Erosion-prone area (r)**	**Inference**	**Non-erosion area (r)**	**Inference**
Seed cost	0.98	Over-utilized	0.74	Over-utilized
Cultivation cost	0.32	Over-utilized	0.22	Over-utilized
Pesticide cost	1.19	Under-utilized	1.58	Under-utilized
Fertilizer cost	0.63	Over-utilized	0.26	Over-utilized
Labor cost	0.11	Over-utilized	0.17	Over-utilized
Irrigation cost	1.24	Under-utilized	2.19	Under-utilized
Land rent	1.07	Under-utilized	2.68	Under-utilized
Field Survey 2025				

Source: Authors' Computation

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The results show that in both areas pesticide cost, irrigation cost, and land rent were underutilized, whereas seed cost, cultivation cost, fertilizer cost, and labor cost were overutilized. This indicates that rice farmers in both environments face allocative inefficiencies. However, the pattern is more problematic in the erosion-prone area because input misallocation occurs alongside very weak output responsiveness. In other words, farmers in erosion-prone zones are not only using some inputs beyond their economically optimal level, but they are also receiving limited return from that use. By contrast, although non-erosion farmers also exhibit inefficiency, the stronger productivity response of their production environment suggests greater scope for profitable reallocation, especially toward irrigation, pesticide use, and land-related investment. Thus, erosion appears to intensify the economic consequences of input misallocation by reducing the marginal productivity of farm resources.

Elasticities of rice production and return to scale

Because the Cobb-Douglas coefficients directly represent output elasticities, the same estimated coefficients were used to assess production elasticity and returns to scale. The results are presented in Table 4.4. All estimated elasticities are less than unity, indicating inelastic production response to individual inputs in both areas. However, the aggregate production structure differs sharply. In the erosion-prone area, the sum of the elasticity is only 0.168, which indicates decreasing returns to scale. This means that a proportional increase in all inputs would produce a less than proportional increase in rice output. Such a pattern reflects a constrained production environment, where instability, land insecurity, and erosion-related risk reduce the effectiveness of input use. In contrast, the non-erosion area records an RTS of 2.51, indicating increasing returns to scale. Here, a proportional increase in all inputs would generate a more than proportional increase in output, suggesting that rice cultivation in stable areas benefits from stronger complementarities among production factors.

Table 4.4: Elasticities of rice production and returns to scale in erosion-prone and non-erosion areas

Input	**Erosion-prone area Elasticity**	**Remark**	**Non-erosion area Elasticity**	**Remark**
Seed cost	0.042	Inelastic	0.30	Inelastic
Cultivation cost	0.003	Inelastic	0.28	Inelastic
Pesticide cost	0.022	Inelastic	0.40	Inelastic
Fertilizer cost	0.012	Inelastic	0.38	Inelastic
Labor cost	0.022	Inelastic	0.34	Inelastic
Irrigation cost	0.014	Inelastic	0.26	Inelastic
Land rent	0.053	Inelastic	0.55	Inelastic
Sum of elasticities (RTS)	**0.168**	**Decreasing returns to scale**	**2.51**	**Increasing returns to scale**
Field Survey 2025				

Source: Authors' Computation

This contrast provides strong empirical support for the argument that riverbank erosion depresses not only farm profitability but also the underlying technical performance of agricultural production.

Banana Efficiency Analysis

Banana Resource-use efficiency

Table 4.5: Comparative allocative efficiency of inputs used in banana production

Inputs	Erosion-prone area (r)	Inference	Non-erosion area (r)	Inference
Seed cost	0.54	Overutilized	0.95	Overutilized
Cultivation cost	0.49	Overutilized	0.15	Overutilized
Pesticide cost	0.61	Overutilized	2.26	Underutilized
Fertilizer cost	0.29	Overutilized	0.40	Overutilized
Labor cost	7.86	Underutilized	0.25	Overutilized
Irrigation cost	7.30	Underutilized	2.92	Underutilized
Land rent	9.66	Underutilized	3.22	Underutilized
Field Survey 2025				

Source: Authors' Computation

Banana production displays a distinct pattern of allocative inefficiency. In the erosion-prone area, seed, cultivation, pesticide, and fertilizer costs are overutilized, whereas labour, irrigation, and land rent are underutilized. The particularly high ratios for labour, irrigation, and land rent indicate large differences between their marginal value products and marginal factor costs. These values should nevertheless be interpreted with caution because the corresponding regression coefficients are statistically insignificant.

In the non-erosion area, seed, cultivation, fertilizer, and labour are overutilized, while pesticide, irrigation, and land rent are underutilized. One important crop-specific difference is observed for pesticide expenditure: it is overutilized in erosion-prone banana cultivation but underutilized in the non-erosion area. This indicates that recommendations for input adjustment should be crop- and location-specific rather than applied uniformly across all farms.

Elasticities of banana production and return to scale

Table 4.6: Elasticities of banana production and returns to scale in erosion-prone and non-erosion areas

Input	Erosion-prone area Elasticity	Remark	Non-erosion area Elasticity	Remark
Seed cost	0.035	Inelastic	0.42	Inelastic
Cultivation cost	0.018	Inelastic	0.31	Inelastic
Pesticide cost	0.025	Inelastic	0.39	Inelastic
Fertilizer cost	0.031	Inelastic	0.35	Inelastic
Labor cost	0.029	Inelastic	0.37	Inelastic
Irrigation cost	0.005	Inelastic	0.34	Inelastic
Land rent	0.061	Inelastic	0.70	Inelastic
Sum of elasticities (RTS)	**0.204**	**Decreasing RTS**	**2.88**	**Increasing RTS**
Field Survey 2025				

Source: Authors' Computation

Each individual banana elasticity is less than one in both areas, indicating an inelastic gross-return response to individual input expenditure. However, the aggregate production structures differ substantially. The sum of the coefficients in the erosion-prone area is 0.204, indicating decreasing returns to scale. Thus, a proportional increase in all measured input costs is associated with a less-than-proportional increase in banana gross return.

In the non-erosion area, the sum of the coefficients is 2.88, indicating increasing returns to scale. A proportional increase in all inputs is therefore associated with a more-than-proportional increase in gross return. The contrast suggests that stable land conditions are associated with stronger complementarities among banana-production inputs, while erosion exposure constrains the economic return obtained from additional expenditure.

Profitability Analysis

The comparative profitability of rice and banana production in erosion-prone and non-erosion areas was assessed using gross return, total variable cost, total fixed cost, total cost, gross margin, net return, and benefit-cost ratio. The results are shown in Table 4.7.

Table 4.7: Profitability of Rice and Banana production

Items	**Rice**		**Banana**	
	Erosion-prone area (Tk.)	**Non-erosion area (Tk.)**	**Erosion-prone area (Tk.)**	**Non-erosion area (Tk.)**
Gross return	31,500	61,500	53,700	120,000
Total variable cost	16,000	11,000	40,000	32,000
Total fixed cost	10,000	20,000	10,000	22,000
Total cost	26,000	31,000	50,000	54,000
Gross margin	15,500	50,500	13,700	88,000
Net return	5,500	30,500	3,700	66,000
BCR	**1.21**	**1.98**	**1.07**	**2.22**
Field Survey 2025				

Source: Authors' Computation

Both crops generate positive net returns in the two areas, but profitability is substantially lower under erosion exposure. Rice cultivation in the erosion-prone area produces a gross return of Tk. 31,500, a net return of Tk. 5,500, and a BCR of 1.21. In the non-erosion area, the corresponding figures are Tk. 61,500, Tk. 30,500, and 1.98.

The contrast is even larger for banana. In the erosion-prone area, banana generates a gross return of Tk. 53,700 and a net return of only Tk. 3,700, producing a BCR of 1.07. The BCR is only slightly above one, indicating that banana cultivation is marginally profitable under erosion exposure. In the non-erosion area, banana generates a gross return of Tk. 120,000, a net return of Tk. 66,000, and a BCR of 2.22.

Total production cost is slightly higher in the non-erosion area for both crops, largely because the opportunity cost of stable land is higher. However, the higher cost is more than compensated for by substantially greater gross and net returns. The results therefore indicate that low profitability in erosion-prone areas is associated primarily with weak revenue generation rather than simply with higher total production cost.

Monetize the Adverse Effect of Erosion

The adverse effect of riverbank erosion on rice production was monetized by directly comparing the economic performance of rice cultivation between erosion-prone and non-erosion areas. Table 4.8 presents the differences in gross return, gross margin, net return, total cost, and BCR.

Table 4.8: Monetized adverse effect of riverbank erosion on rice and banana production per bigha

Indicators	**Rice**			**Banana**		
	Non-erosion area (Tk.)	**Erosion-prone area (Tk.)**	**Difference**	**Non-erosion area (Tk.)**	**Erosion-prone area (Tk.)**	**Difference**
Gross return	61,500	31,500	30,000	120,000	53,700	66,300
Gross margin	50,500	15,500	35,000	88,000	13,700	74,300
Net return	30,500	5,500	25,000	66,000	3,700	62,300
Total cost	31,000	26,000	5,000	54,000	50,000	4,000
BCR	**1.98**	**1.21**	**0.77**	2.22	1.07	1.15
Field Survey 2025						

Gap = non-erosion value minus erosion-prone value.
Monetary figures are in Bangladeshi taka per bigha.

Source: Author's Computation

The comparative results reveal substantial economic gaps between erosion-prone and non-erosion areas for both crops. Rice gross return is lower by Tk. 30,000 per bigha in the erosion-prone area, while gross margin and net return are lower by Tk. 35,000 and Tk. 25,000, respectively. The rice BCR gap is 0.77.

Banana exhibits a larger absolute monetary gap. Gross return is lower by Tk. 66,300 per bigha, gross margin by Tk. 74,300, and net return by Tk. 62,300 in the erosion-prone area. The banana BCR falls from 2.22 to 1.07, producing a gap of 1.15. Although the total cost difference is relatively small, the return difference is substantial. This indicates that the observed profitability disadvantage is associated mainly with lower revenue and gross-margin performance rather than a large difference in total production cost.

The absolute gap is greater for banana than for rice. However, this should not automatically be interpreted as proof that banana is causally more vulnerable because the two crops have different production scales, crop durations, and return structures. The results nevertheless show that erosion-prone banana farmers face an especially narrow profitability margin and limited capacity to absorb further production or market shocks.

Risk Perceptions and Behavioral Responses

The preference for short-duration crops indicates a general effort to limit exposure to land instability. At the same time, some households continue banana cultivation because of its potential commercial return. The very low banana BCR in erosion-prone areas suggests that households undertaking such cultivation face a narrow economic margin when land conditions are unstable.

Table 4.9: Risk perceptions toward riverbank erosion among surveyed households

Item	**Strongly agree (%)**	**Agree (%)**	**Neutral (%)**	**Disagree (%)**	**Strongly disagree (%)**
Frequently worry about losing land or assets due to riverbank erosion	36.7	35.0	13.3	10.0	5.0
Riverbank erosion significantly impacts my decisions related to agriculture or livelihood	31.7	40.0	15.0	10.0	3.3
Have experienced significant losses due to riverbank erosion	43.3	30.0	11.7	8.3	6.7
Expect riverbank erosion to worsen in the coming years	38.3	36.7	13.3	6.7	5.0
The threat of riverbank erosion discourages me from investing in agriculture	30.0	33.3	18.3	11.7	6.7

The results indicate a high level of perceived vulnerability among households exposed to riverbank erosion. A large majority of respondents reported frequent concern about land or asset loss, while more than seven in ten agreed that erosion significantly affects their agricultural or livelihood decisions. Similarly, most respondents reported having already experienced substantial erosion-related losses and expected the situation to worsen in the future. Importantly, nearly two-thirds stated that the threat of erosion discourages them from investing in agriculture. These findings suggest that risk preferences in erosion-prone communities are shaped by repeated exposure to uncertainty, loss, and insecure land conditions. Rather than behaving as profit-maximizing investors, farmers appear to adopt a more defensive decision-making logic in which avoiding loss becomes more important than pursuing higher but uncertain returns. This helps explain why erosion-prone farmers respond weakly to additional input use and remain trapped in low-return farming systems.

To understand how these perceptions translate into action, Table 4.10 presents the main behavioral responses adopted by households to manage erosion-related risk. These include income diversification, preference for short-duration crops, investment in preventive measures, dependence on community advice, and reliance on institutional support.

Table 4.10: Behavioral responses to erosion-related risk among surveyed households

Item	Always (%)	Often (%)	Sometimes (%)	Rarely (%)	Never (%)
Diversify my income sources to reduce risks associated with erosion	23.3	28.3	30.0	13.3	5.0
Prefer growing short-duration crops to mitigate risks of riverbank erosion	26.7	31.7	25.0	11.7	5.0
Invest in preventive measures against erosion	18.3	25.0	31.7	16.7	8.3
I frequently consult neighbors/community members on risk management practices	21.7	33.3	28.3	11.7	5.0
I rely on government or NGOs' support to handle erosion-related risks	16.7	23.3	31.7	18.3	10.0

The behavioral evidence shows that farmers rely on a mixed risk-management strategy rather than a single adaptation pathway. More than half of respondents reported that they always or often diversify income sources, and an even larger share preferred short-duration crops, indicating a clear tendency toward low-risk and short-horizon production choices. Community consultation also emerged as an important coping mechanism, reflecting the role of informal knowledge networks where formal extension and risk information are limited. By contrast, investment in preventive measures and reliance on government or NGO support were less frequent, suggesting that financial constraints and limited institutional coverage reduce the feasibility of more robust adaptation. Taken together, these findings show that erosion-prone households exhibit strongly risk-averse preferences, expressed through cautious production choices, limited farm investment, and partial movement toward diversification. This behavioral pattern is consistent with the earlier results on allocative inefficiency and low profitability, and it reinforces the conclusion that riverbank erosion affects not only physical production conditions but also the decision environment within which farmers allocate resources and plan their livelihoods.

CONCLUSION AND POLICY RECOMMENDATION

This study examined how riverbank erosion is associated with the production performance, resource-use efficiency, profitability, and risk-related behavior of farm households cultivating rice and banana in Pabna District, Bangladesh. Separate Cobb–Douglas production functions were estimated for the two crops in erosion-prone and non-erosion areas. The results reveal a clear difference between unstable and relatively stable agricultural environments.

In erosion-prone areas, gross return responds only weakly to additional input expenditure. Seed cost is marginally significant in both the rice and banana models, while the remaining input coefficients are statistically insignificant. The sums of the estimated coefficients are 0.168 for rice and 0.204 for banana, indicating decreasing returns to scale. In non-erosion areas, seed, pesticide, fertilizer, labour, and land rent are positively and significantly associated with gross return for both crops. The corresponding returns-to-scale estimates are 2.51 for rice and 2.88 for banana, indicating increasing returns to scale. These findings suggest that stable land conditions are associated with stronger economic responsiveness and greater complementarity among production inputs. The resource-use efficiency results show that no crop-area combination achieves complete allocative efficiency. In rice production, seed, cultivation, fertilizer, and labour are overutilized, while pesticide, irrigation, and land rent are generally underutilized. Banana displays a more varied pattern. In the erosion-prone area, seed, cultivation, pesticide, and fertilizer are overutilized, while labour, irrigation, and land rent are underutilized. In the non-erosion area, pesticide, irrigation, and land rent are underutilized, while seed, cultivation, fertilizer, and labour are overutilized. These findings indicate that input-management recommendations must be crop- and location-specific. Profitability differs substantially between the two areas. Rice generates BCRs of 1.21 in the erosion-prone area and 1.98 in the non-erosion area. Banana generates corresponding BCRs of 1.07 and 2.22. The comparative gross-return gaps are Tk. 30,000 per bigha for rice and Tk. 66,300 for banana, while the net-return gaps are Tk. 25,000 and Tk. 62,300. Banana cultivation in erosion-prone areas is particularly marginal, with a net return of only Tk. 3,700 per bigha. These results show that erosion exposure is associated with a substantial reduction in households' capacity to generate and reinvest agricultural income. The household-level findings also reveal high perceived vulnerability. Most respondents worry about land and asset loss, believe that erosion affects agricultural and livelihood decisions, expect erosion to worsen, and report that erosion discourages agricultural investment. Households respond through income diversification, preference for short-duration crops, cautious investment, community consultation, and partial reliance on government and NGO support. These strategies reflect rational efforts to limit losses but may also reinforce low-investment and low-return agricultural systems.

The findings have several policy implications. First, riverbank stabilization should combine scientifically planned embankments, revetments, geo-bag protection, and continuous monitoring of erosion hotspots. Second, agricultural extension programmes should provide crop-specific recommendations rather than uniform packages. Rice support should focus on balanced input use, irrigation, and efficient labour allocation, while banana support should address the high expenditure and investment risk associated with fertilizer, irrigation, labour, and secure land access. Third, risk-sensitive credit, crop insurance, emergency cash assistance, and compensation for verified land loss should be introduced or expanded. Fourth, secure access to cultivable land and improved rural infrastructure, market access, transport, and storage facilities are necessary to protect the returns from commercially oriented crops. Finally, livelihood diversification and vocational training should reduce excessive household dependence on unstable agricultural land.

The study is limited by its cross-sectional design, focus on one district, and reliance on gross return rather than physical crop yield as the dependent variable in the production functions. The household risk measures are also not crop-specific. Consequently, the findings identify strong comparative associations but do not establish definitive causal effects. Future research should use panel data, clearly defined crop-specific samples, physical yield measures, geospatial erosion indicators, hydrological data, and crop-specific risk modules to provide stronger evidence on the long-term consequences of riverbank erosion.

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