

The Impact of Climate Change on Jute Production in Gaibandha District, Bangladesh

Ibrahim Hossain^{1*}, Rima Akter Rakhi², Shahorare Ahomed¹, Mst. Shifat Rumana³, Abdullah-Al-Mamun⁴, Md. Mostafizur Rahman³

Abstract

Jute plays a crucial role in Bangladesh's agricultural economy, especially in Gaibandha District, where it is a key crop for rural livelihoods. However, climate change, characterized by rising temperatures and unpredictable rainfall, poses significant threats to jute production. While numerous studies have explored the broader impact of climate change on agriculture, there is a gap in understanding how localized climate conditions specifically affect jute farming in Gaibandha, with many existing studies generalizing across the country and overlooking the district's unique challenges. This study examines the impact of climate change on jute production in Gaibandha, using a mixed-methods approach that combines quantitative climate data (2014–2023) and agricultural statistics with qualitative insights from 50 farmer interviews. The results show a steady increase in average temperatures, often exceeding 36°C, disrupting photosynthesis and causing water stress, which affects plant growth and yields. Declining rainfall during the key growing months of May to August further hinders germination and retting, resulting in poor fiber quality. A multiple linear regression analysis indicated that temperature alone explained 70% of yield variability ($R^2 = 0.7$), but additional variables like rainfall and soil conditions are needed for a more accurate model. The study also identified significant socio-economic barriers, such as limited access to climate-smart resources and inadequate institutional support, which exacerbate the challenges farmers face. This research provides unique insights into Gaibandha's vulnerabilities, emphasizing the need for targeted adaptation strategies like drought-resistant jute varieties, modern retting technologies, and better institutional support. Future research should expand to other regions, include more variables, and assess the effectiveness of climate adaptation policies.

Keywords: Climate Change, Jute Production, Adaptation Strategies, Agriculture, Gaibandha District

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INTRODUCTION

Climate change significantly impacts global agriculture, threatening crop production and food security. In Bangladesh, where agriculture is vital, its effects are particularly severe, endangering millions of farmers. Jute (*Corchorus* spp.), known as the “golden fiber” for its economic importance, is a key cash crop in the country. Gaibandha District, located in Rangpur Division, is a major center for jute production, benefiting from fertile soils and favorable climate conditions (Khan et al., 2021) [1]. However, rising temperatures, erratic rainfall, and extreme weather events like floods and droughts have increasingly threatened jute farming in this region (Chowdhury & Rahman, 2022) [2]. These climatic changes disrupt farming practices and jeopardize the livelihoods of farmers dependent on jute cultivation. While research on the broader

impacts of climate change exists, there is limited focus on Gaibandha (Islam & Ahmed, 2019) [3]. This study fills this gap by analyzing climate data, interviewing farmers, and surveying experts to inform policies aimed at strengthening jute farming resilience and supporting rural economies. Several studies have examined the impact of climate change on jute production in Bangladesh, but gaps remain in understanding localized effects and adaptation strategies. Rising temperatures in northern Bangladesh, including Gaibandha, disrupt photosynthesis, diminishing fiber quality and leading to lower jute yields, highlighting the need for adaptation strategies to mitigate these impacts. Similarly, noted that irregular rainfall not only reduces yields but also increases susceptibility to pests and diseases, with climate change intensifying both droughts and floods. Hossain and Rahman (2019) revealed that although farmers are aware of climate variability, they lack specific knowledge regarding its effects on jute farming, indicating a significant gap in knowledge transfer from researchers to local communities [4]. Ahmed et al. (2020) projected a 10% reduction in jute yield for every 1°C temperature increase, but their national-level analysis limits insights into localized impacts, such as those in Gaibandha [5]. Khan et al. (2018) found that jute farmers in Gaibandha use traditional methods like crop rotation and intercropping to adapt to climate changes but emphasized the need for better education and support [6]. Climate adaptation policies tailored specifically to the needs of jute farmers. The socio-economic impacts on rural, jute-dependent communities, pointing out that rising input costs and poverty exacerbate challenges for smallholder farmers, highlighting the need for targeted support. Hossain et al. (2021) examined gender dynamics in agricultural adaptation, noting that female farmers face unique challenges, though their study did not focus on jute farming in Gaibandha, suggesting a need for gender-specific research [7]. Bhuiyan et al. (2020) stressed the importance of developing climate-resilient jute varieties and increasing research investments [8]. Ahmed et al. (2021) emphasized sustainable soil management to combat soil degradation from extreme weather events [9]. Rahman et al. (2022) criticized existing policies, advocating for localized approaches to address regional challenges in Gaibandha [10]. Despite these contributions, research on the socio-economic impacts of climate change on jute farmers in Gaibandha remains limited. While existing research offers valuable insights into the impact of climate change on jute production, there are notable gaps. One major gap is the lack of localized studies focusing on Gaibandha District, which has unique climatic conditions that influence jute farming. Most studies generalize findings across Bangladesh, overlooking regional variations that could significantly affect jute cultivation (Sultana et al., 2023) [11]. Moreover, there is limited exploration of qualitative factors such as farmers' perceptions, traditional knowledge, and local adaptation strategies.

While quantitative data on yield reductions and economic impacts are crucial, understanding how farmers respond to climate variability is essential for creating effective adaptation strategies. Additionally, interdisciplinary approaches combining agricultural and social sciences are underexplored, with much of the research focusing solely on yield impacts or economic assessments while neglecting social factors like community support and gender dynamics. There is also a lack of research into the socio-economic factors affecting the resilience of jute farmers to climate change. In Gaibandha, jute farmers face challenges such as erratic rainfall, rising temperatures, and extreme weather events like floods and droughts, which disrupt soil moisture and hinder plant growth, leading to lower yields and poor fiber quality. Warmer temperatures also increase pest infestations, further threatening crop productivity (Sultana et al., 2018) [12]. These changes endanger the economic stability of farming households, underscoring the need for focused research on Gaibandha's jute production and targeted adaptation strategies (Miah, 2020) [13]. To provide a comprehensive understanding of how climate variability affects jute production in Gaibandha District, Bangladesh, and identify effective strategies for farmers to adapt to these changes. In this study there are some specific objectives such as Identify climate variables affecting jute farming, the impact of climate change on jute production and evaluate existing adaptation strategies used by farmers.

STUDY AND DATASET

Study Area

Gaibandha district, located in the northwestern part of Bangladesh within Rangpur division, is positioned at approximately 25.3° N latitude and 89.55° E longitude as shown in Figure 1. It is bordered

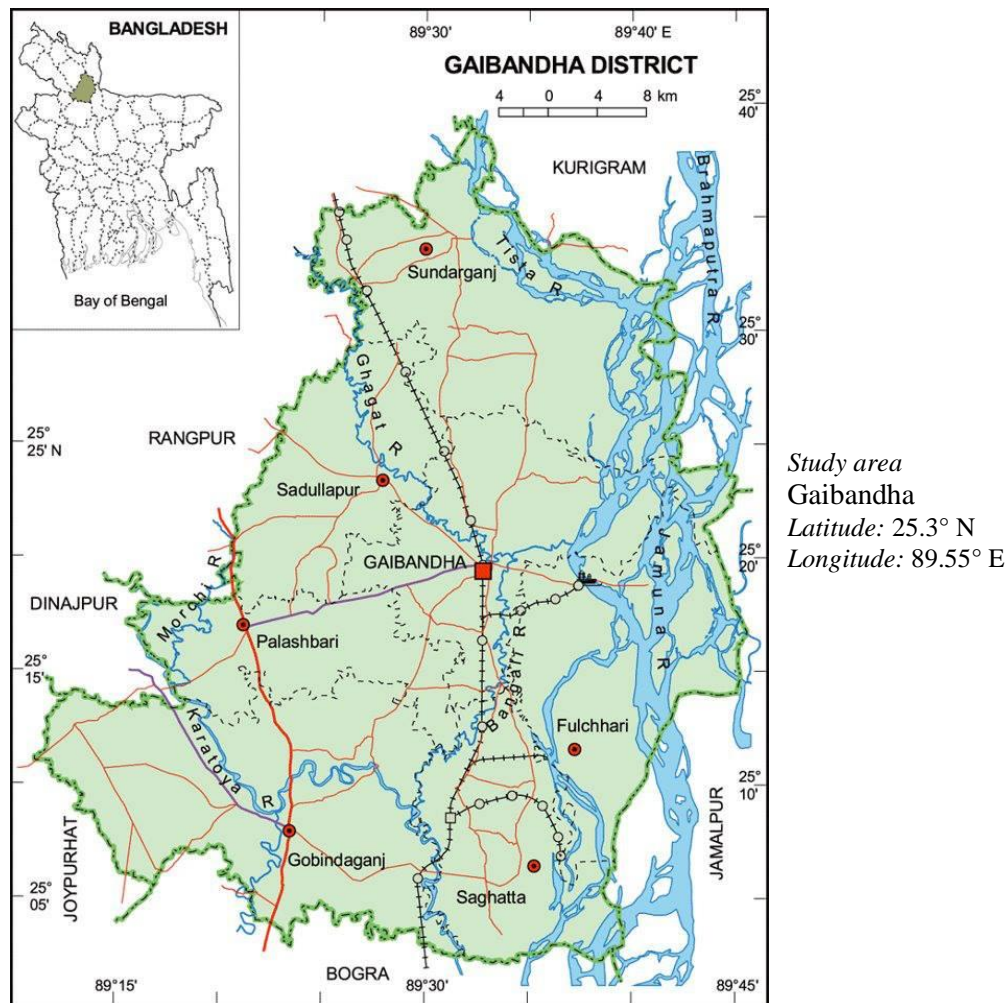


Figure 1. Study area

(Source: National Information Bureau (March 2015) <https://gaibandha.gov.bd/>)

by Bogra to the south, Jamalpur to the east, Kurigram to the north, and Dinajpur to the west. Covering about 2,800 square kilometers, the district features flat terrain and fertile alluvial soil, making it ideal for agriculture, especially jute farming. Despite its favorable conditions, Gaibandha is experiencing significant climate change impacts, prompting its selection for this study.

Data Collection

The data collection for this research encompasses both quantitative and qualitative components, employing specific methodologies and sources to gather relevant information regarding the impact of climate change on jute production in Gaibandha District. So, the main data collection methods of this research will be as follows shown in Figure 2.

The quantitative data utilized in this study will be secondary data, which includes various climate variables and agricultural statistics pertinent to jute cultivation. Primary data points include temperature, heat waves, precipitation, humidity, drought conditions, flood occurrences, and agricultural statistics. The research's qualitative component will feature semi-structured interviews with 50 farmers from Radhakrishnapur village in Gaibandha District. These interviews will delve into farmers' firsthand experiences with the effects of climate change on jute farming. Key areas of discussion will include their perceptions of climate variability, adaptation methods, difficulties encountered in jute cultivation, and the broader implications of climate change on their livelihoods. The following table 1 summarizes the quantitative data sources.

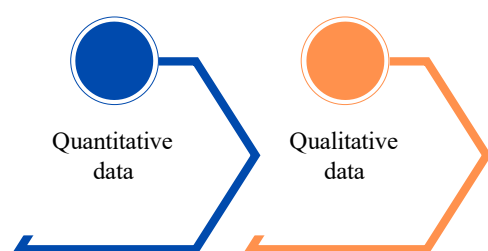


Figure 2. Data collection methods.

Table 1. Data sources, areas, and timelines for climate and agricultural analysis.

Data type	Source	Area	Timeline
Temperature	Rangpur Meteorological Office	Gaibandha	2014–2024
Heat waves	Business Standard Report (newspaper)	Rangpur Division	2022 and 2023
Precipitation	Bangladesh Meteorological Department (BMD) - Rangpur Meteorological Office	Gaibandha	Average for May, June, July, August from 2014 to 2023
Humidity	Bangladesh Meteorological Department (BMD)	Gaibandha	Five-year average from 2000 to 2020 (May to June)
Drought conditions	Department of Agriculture Extension (DAE)	Riverine area of Jamuna, Teesta, and Brahmaputra	2014, 2018, 2021, 2023
Floods	Bangladesh Water Development Board (BWDB) and Gaibandha District Agricultural Office Reports	Gaibandha	Specific events: July–August 2014, July 2016, June–September 2017, July–August 2020, July 2022
Agricultural statistics	Bangladesh Bureau of Statistics (BBS), Department of Agricultural Extension Gaibandha	Gaibandha	2000–2023

METHODOLOGY

Method of the Study

This study utilized a mixed-methods approach to examine the impact of climate change on jute production in Gaibandha District, focusing on farmers' challenges and adaptation strategies. Quantitative data, including climate records (temperature, rainfall, humidity) from 2014 to 2024, were sourced from the Bangladesh Meteorological Department, while jute production statistics came from the Bangladesh Bureau of Statistics and the Department of Agricultural Extension. Data on floods and droughts was also collected. Additionally, semi-structured interviews with 50 farmers from Radhakrishnapur village explored their experiences with climate variability and adaptation. Quantitative analysis employed statistics and time-series methods, while qualitative data were thematically analyzed, offering comprehensive insights and practical recommendations.

Method Procedure

Quantitative data for this study was sourced from various institutions. Meteorological data on rainfall, temperature, and humidity (2014–2024) were collected from the Bangladesh Meteorological Department (BMD). Agricultural statistics, including jute yield trends and economic indicators, were obtained from the Bangladesh Bureau of Statistics (BBS) and the Department of Agricultural Extension (DAE). Additionally, records of flood and drought occurrences were gathered from the Bangladesh Water Development Board (BWDB). These data were analyzed using statistical software for trend analysis, correlation studies, and regression modeling. Qualitative data were collected through semi-structured interviews with 50 farmers, capturing their observations on climate variability, farming practices, and socioeconomic challenges. The discussions focused on their perceptions of weather changes, coping strategies like adjusted planting schedules and crop diversification, and the impacts on fiber quality and yield. Quantitative data analysis examined trends in jute yield against climate variables, employing time-series analysis to identify significant climatic shifts over two decades. Qualitative data

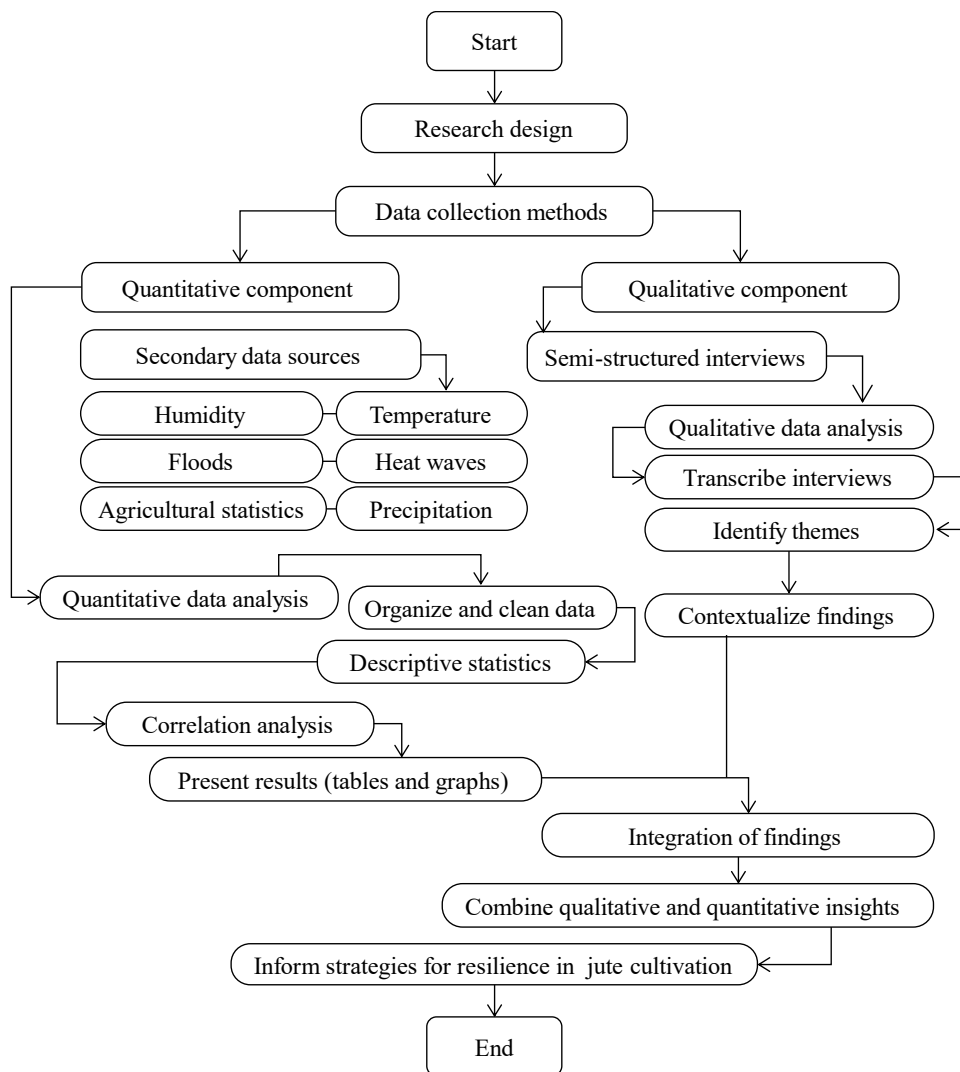


Figure 3. Research structure.

were transcribed and thematically analyzed to identify recurring patterns related to water scarcity, traditional retting methods, and economic impacts. Findings from both methods were integrated to formulate comprehensive recommendations for sustainable jute farming as shown in Figure 3. The reliability of the results was ensured through triangulation of data sources, while peer reviews of interview analyses added credibility to the qualitative findings.

RESULTS AND DISCUSSION

This research examines climate change's effects on jute production in Gaibandha, combining data to highlight challenges and adaptations among farmers. It explores yield changes, climate-production links, and socio-economic impacts. Findings aim to guide policymakers and stakeholders in enhancing resilience and supporting sustainable jute farming through actionable recommendations.

Figures 4–6 highlights jute production trends in Gaibandha from 2000 to 2023, showing variations in cultivated area and yield per acre. Over the 23 years, production increased in some years due to favorable weather and improved practices as shown in Table 2 but declined in others due to adverse conditions, pest outbreaks, and market fluctuations. The overall trend reveals a gradual decline in production, pointing to broader challenges such as economic shifts, changing crop preferences, and environmental impacts. These insights are vital for stakeholders seeking to address challenges and support sustainable jute farming in the region.

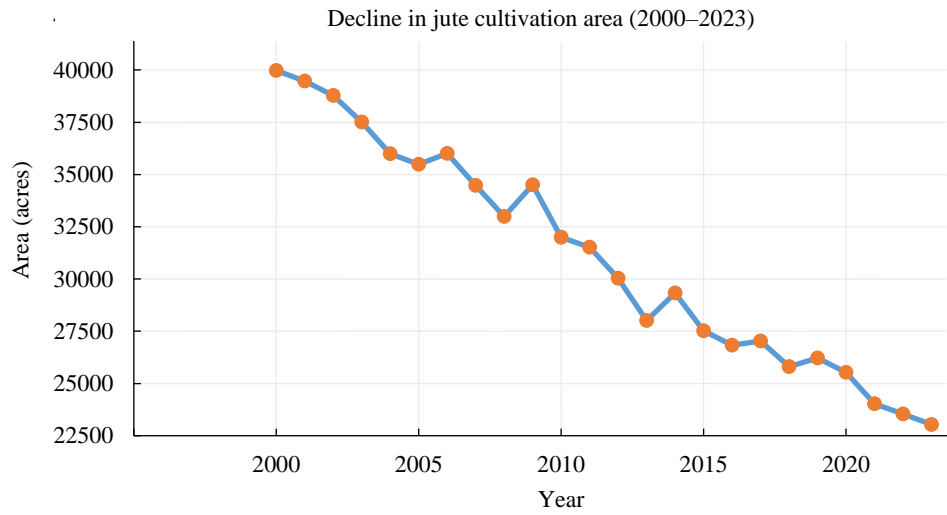


Figure 4. Decline in jute cultivation area.
(Source: Bangladesh Bureau of Statistics (BBS) (2000-2023))

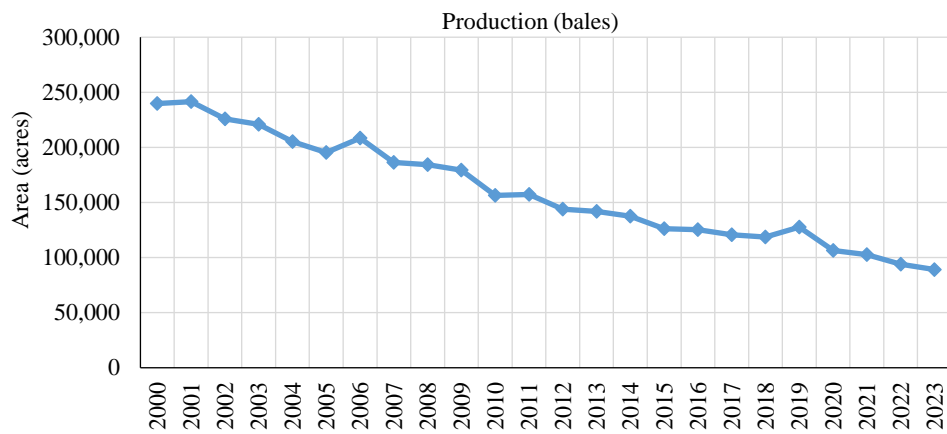


Figure 5. Jute production quantity.
(Source: Agricultural Statistics 2000-2023, Dhaka: Government of the People's Republic of Bangladesh.)

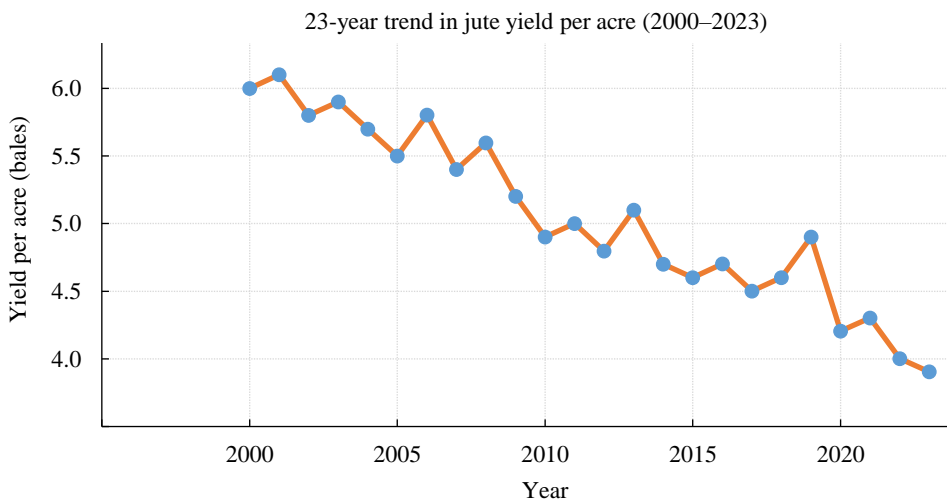


Figure 6. Trend in jute yield per acre.
(Source: Trend in Jute Yield per Acre (2000-2023), The Department of Agricultural Extension (DAE) Office, Gaibandha.)

Table 2. Cultivation and retting timeline.

Activity	Month	Description
Sowing	Mid-April to June	Seeds are sown in prepared fields.
Growing season	June to September	Plants grow throughout the monsoon season, relying on rainfall.
Harvesting	Late July to September	Mature plants are harvested for fiber extraction.
Retting	August to September	Soaking harvested jute in water (3 to 14 days) to separate fibers from the stem.

Source: Bangladesh Jute Research Institute (BJRI) <http://www.bjri.gov.bd/>

The Impact of Climate Change on Jute Production

Climate change poses significant challenges to agricultural systems worldwide, and jute production is no exception. As a crucial cash crop, jute plays a vital role in the economies of several developing countries. This section examines how shifts in temperature, precipitation patterns, and extreme weather events, driven by climate change, affect jute cultivation.

Impact of Temperature Changes on Jute Growth

Recent BMD data analysis shown in Figure 7 indicates a significant upward trend in average temperatures in Bangladesh from April to September over the past decade, with several recent years exceeding the critical threshold of 36°C. This temperature increase presents substantial implications for jute cultivation, influencing growth and overall yield in various ways.

An analysis of the Temperature Index for Gaibandha shown in Figure 8 reveals the significant influence of temperature fluctuations on jute growth. Jute thrives in warm, humid conditions, with an optimal range of 25°C to 35°C. However, prolonged exposure to temperatures exceeding 36°C can disrupt physiological processes such as photosynthesis and respiration, inhibiting growth. Elevated temperatures often lead to increased evaporation rates, causing water stress that stunts growth, reduces fiber quality, and lowers yields. Consistent moisture is critical during key growth stages, and extreme heat exacerbates drought conditions. Additionally, warmer temperatures promote pest and pathogen proliferation, which further threaten jute health and reduce yields (Islam et al., 2021) [14]. Fluctuations in temperature also disrupt flowering and fiber development, resulting in poor seed set and reduced fiber quality. Rising temperatures in Bangladesh underscore the need for adaptive strategies to ensure sustainable jute production amid climate challenges.

Impact of Heat Waves on Jute Growth

In 2022, Bangladesh faced rising temperatures as extreme heat waves began to affect the region, setting the stage for more intense heat events in the coming years. This heat primarily impacted vulnerable agricultural workers, foreshadowing further challenges. By 2023, a severe heat wave in April forced nationwide school closures, affecting over 33 million children. Temperatures reached nearly 43°C, leading to public health concerns and widespread agricultural damage.

In 2024, Bangladesh experienced record-breaking heat, reaching 43.7°C during a 30-day heat wave, causing crop failures, water shortages, and at least 15 heatstroke deaths (Bangladesh Meteorological Department, 2024) as shown in Figure 9. Such extreme temperatures pose significant challenges for jute production, as the crop thrives best between 25°C and 35°C. Temperatures exceeding this range induce physiological stress, reducing growth and yield (Rahman & Kader, 2016; Bhowmik & Das, 2019) [15,16]. Heat waves also accelerate soil evaporation, depleting moisture critical for germination and early growth, and creating drought-like conditions. Furthermore, excessive heat disrupts pollination, resulting in poor seed formation and reduced viability, while also fostering pest infestations and diseases, which further damage jute crops. Agricultural laborers face health risks from extreme heat, leading to labor shortages during critical farming periods. Combined with economic losses from crop failures, these factors underscore the significant threats heat waves pose to sustainable jute farming in Bangladesh (Bashar et al., 2021) [17].

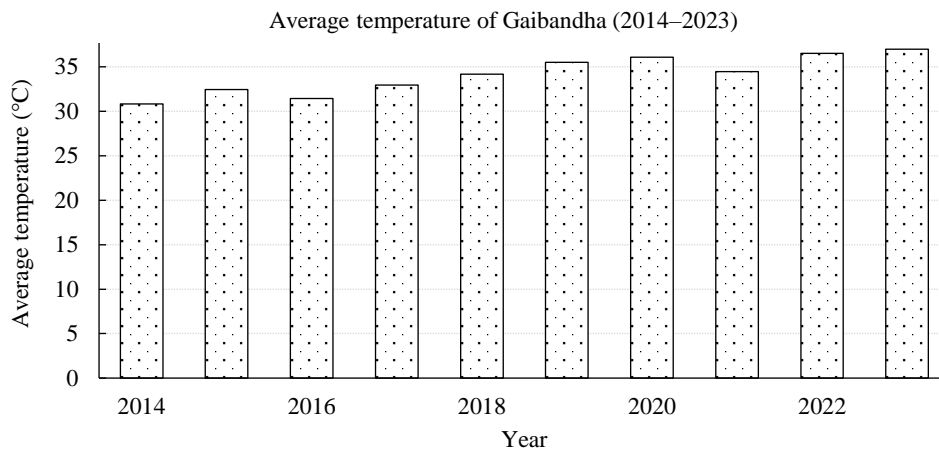


Figure 7. Temperature index of Gaibandha.
 (Source: Bangladesh Meteorological Department (BMD) <https://www.bmd.gov.bd/>)

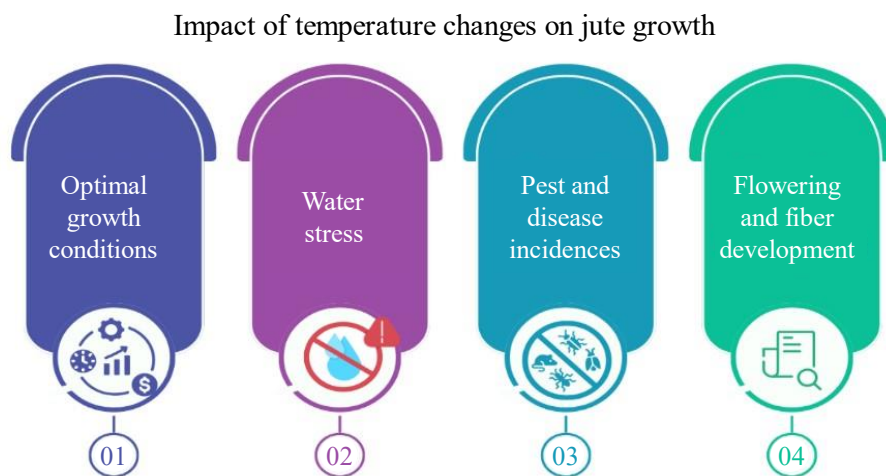


Figure 8. Impact of temperature.

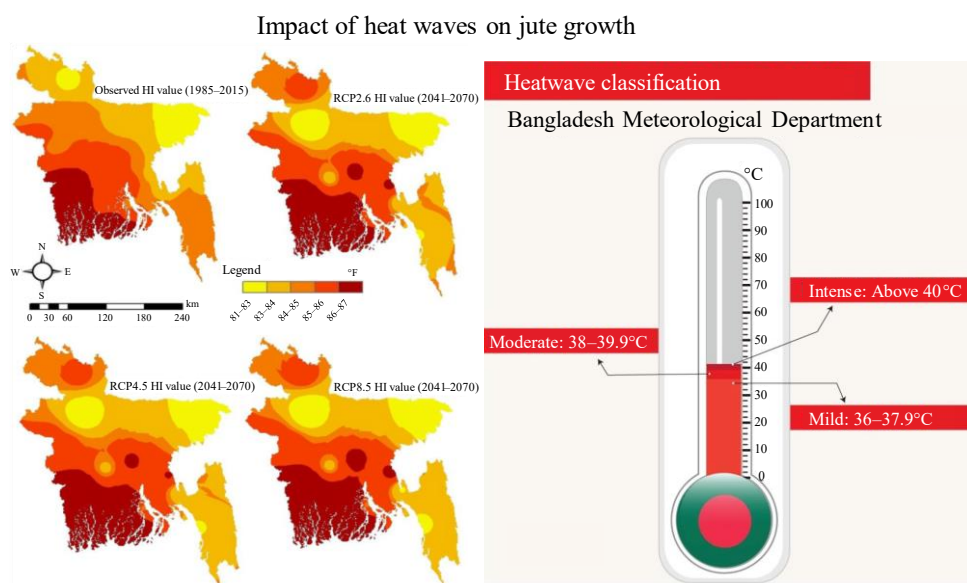


Figure 9. Impact of heat waves.
 Source: Impact of Heat waves on Jute Growth Business Standard, 13 June 2024, <https://www.ibsnews.net/>

Impact of Humidity Changes on Jute Growth

Figure 10 illustrates average humidity levels in Bangladesh, recorded every four years from 2000 to 2020 by the Bangladesh Meteorological Department (BMD). Humidity has remained stable, ranging from 75% to 79%. However, fluctuations in jute production are more influenced by factors such as rising temperatures, water stress, extreme heat, pests, and soil conditions rather than humidity alone. Despite consistent humidity levels of 76%–79%, these other environmental challenges significantly impact yields. Farmers must address broader environmental stresses to improve jute production.

Impact of rainfall Changes on Jute Growth

Rainfall plays a crucial role in the cultivation of jute, one of the most important cash crops in tropical regions shown in Figure 11. Variations in rainfall patterns can significantly affect jute growth, influencing factors such as seed germination, plant development, and fiber quality.

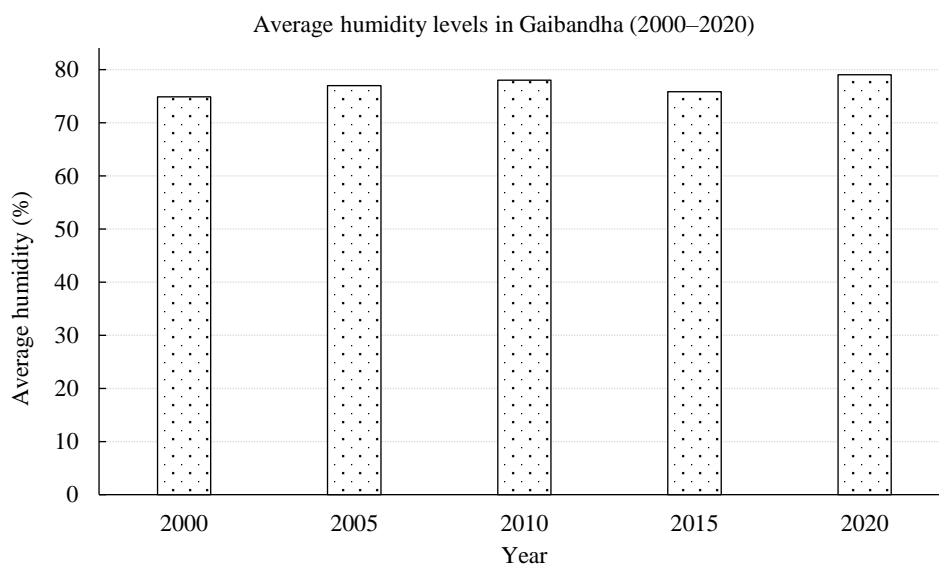


Figure 10. Average humidity levels.

Sources: Bangladesh Meteorological Department (BMD). (2023). *Climatological Data of Bangladesh: Humidity Records*. Dhaka: Government of the People's Republic of Bangladesh.

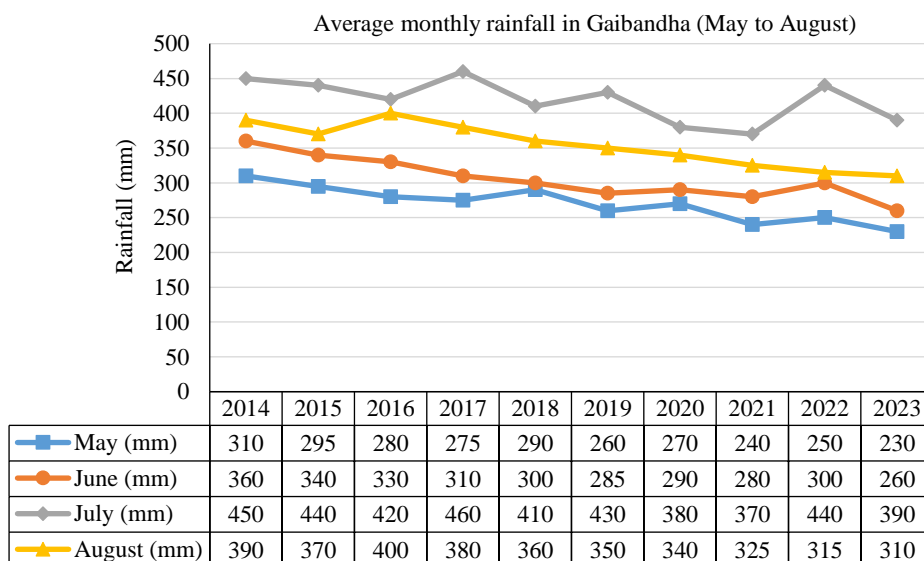


Figure 11. Average monthly rainfall in Bangladesh (May to August) over the last 10 years

Source: Bangladesh Meteorological Department (BMD) <https://www.bmd.gov.bd/>



Figure 12. Effect of rainfall over jute production.

(Source: Prothom Alo, Photographer: Kazi Ashfaq Hamid, July 2020, Gaibandha Sadar.)

Jute, a key cash crop in Bangladesh, thrives with annual rainfall of 1000–1500 mm, primarily during May to August. This monsoon rainfall is vital for jute's growth stages, from germination to harvest. However, recent trends show a decline in rainfall during these crucial months, jeopardizing jute production.

- *May*: Ideal rainfall of 250 mm has fallen to 230 mm.
- *June*: Required 300 mm reduced to 260 mm.
- *July*: Necessary 400 mm now averages 390 mm.
- *August*: Expected 350 mm dropped to 310 mm.

Insufficient rainfall during germination hinders seed sprouting due to inadequate soil moisture. During the vegetative stage, consistent moisture is essential for healthy stem and leaf development. Reduced rainfall leads to stunted growth, weaker plants, and lower biomass, compounding challenges throughout jute's growth cycle.

As shown in Figure 12, adequate rainfall is vital during jute's flowering stage as it significantly influences fiber quality and yield. Water stress during this period can result in poor seed set, reduced fiber production, and disrupted flowering timing, which is critical for optimal fiber growth. Post-harvest, jute fibers require sufficient water for retting, a process that separates fibers from the stem. Insufficient rainfall reduces water availability, delaying retting or causing it to be incomplete, leading to lower-quality fibers prone to damage and degradation.

The stripping process, which depends on properly retted fibers, becomes inefficient and labor-intensive when water is scarce. Poor retting also lowers the market value of jute products. Although jute is resilient, consistent rainfall is essential to sustain high-quality production, making recent declines in rainfall a significant concern for Bangladesh's jute industry.

Drought in Gaibandha (2014–2023)

Droughts have worsened over the years, particularly in 2018, 2021, and 2023, where rainfall deficits reached over 40%. This directly impacted jute production, with yields dropping by up to 35% in drought years as shown in Figures 13 and 14.

India's control over major rivers, such as the Teesta, Brahmaputra, and Jamuna, has had significant consequences for the water flow into Gaibandha. During certain periods, India releases excess water, causing extreme floods, while at other times, it diverts or stores water, leading to severe droughts downstream in Bangladesh.

Erratic water management shown in Table 3 by India has led to significant disruptions in Gaibandha's jute production, with both flooding and drought causing major challenges. In 2020, sudden high-water release from the Jamuna submerged fields, destroying 12,000 hectares of jute crops, while droughts in 2018

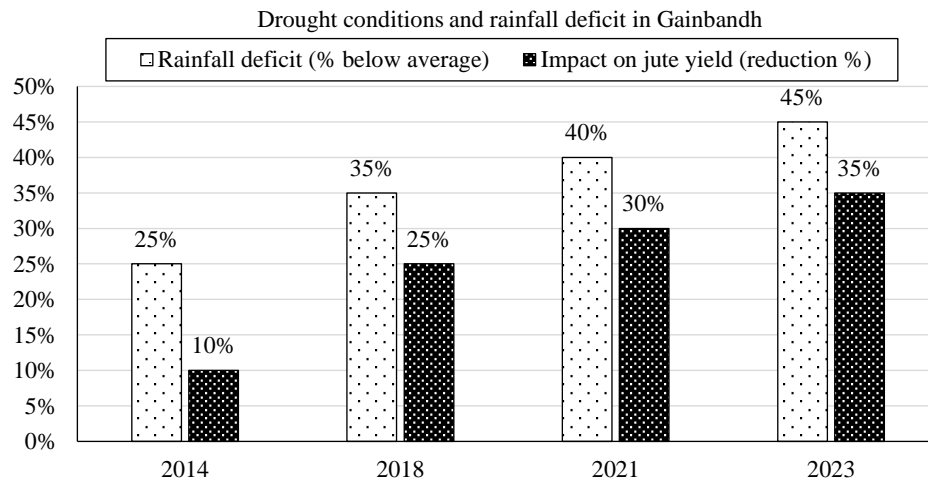


Figure 13. Drought conditions in Gaibandha (2014–2023).
(Source: Bangladesh Meteorological Department (BMD), Department of Agriculture Extension (DAE), and Local Government Engineering Department (LGED)).

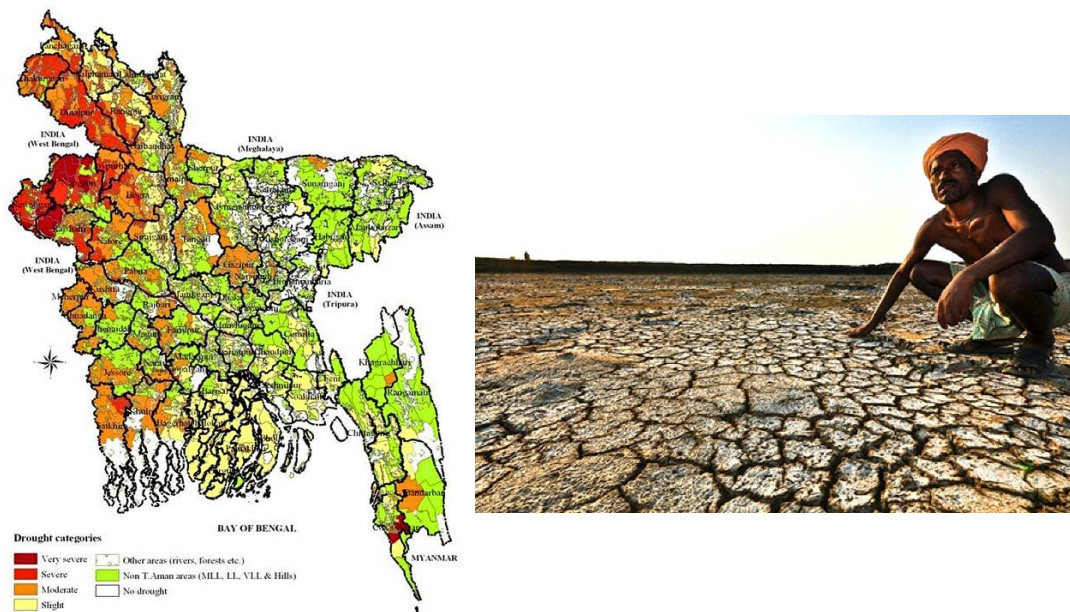


Figure 14. Effect of drought.
Source: Image 1: Chowdhury, Farhan Ali, National Geographic Society, July 2022.
Image 2: Green Lens Media, Photographer: Sarah Khan, 2018, Char Kamarjani, Gaibandha.

Table 3. River conditions of Gaibandha

Year	River	Water release (India)	Bangladesh water level impact	Season
2016	Teesta	High release in monsoon	Extreme floods in July	Monsoon
2018	Brahmaputra	Diversion for irrigation	Water level below normal, drought	Pre-monsoon
2020	Jamuna	Sudden release during rains	3.2 m rise, extreme flood in August	Monsoon
2023	Teesta and Jamuna	Low release in dry season	River dried up, severe drought	Pre-monsoon (April–June)

(Source: Teesta River Joint Committee, International Rivers Reports, and BWDB).

and 2023 caused water stress, reducing yields by 25-35%. Floods rot crops, and drought weakens fibers, both lowering quality and farmer income. Mismanagement of rivers like the Teesta and Jamuna exacerbates

these issues, complicating cultivation and retting processes. This instability demands a reassessment of agricultural practices in flood-prone regions to address water supply inconsistencies effectively.

Challenges of Jute Retting Due to Water Scarcity

In Gaibandha District, traditional jute retting relies on local water bodies like ponds and lakes but increasing water scarcity has disrupted these practices. BWDB data shows an 18% decline in pond and lake areas between 2015 and 2023. Multiple factors contribute to this reduction as shown in Figure 15.

The scarcity of water bodies in Gaibandha hinders efficient jute retting, as unpredictable rainfall and prolonged dry spells reduce water availability as shown in Figure 16. Insufficient water for submerging jute bundles hampers fiber degradation, producing coarse, low-quality fibers that are less marketable.

Report on Jute Farming Questionnaire Responses

This report analyzes data from a questionnaire administered to 50 jute farmers, aiming to explore current farming practices, challenges faced, perceptions of climate change, and the level of community support available. The questionnaire covered various aspects of jute farming, including demographics, cultivation methods, weather patterns, challenges, coping strategies, technology adoption, and support from agricultural services and community collaboration. Both quantitative and qualitative data were collected to provide a holistic understanding of jute farming. Interviews followed a structured format, encouraging participants to share experiences and socio-economic impacts. The findings aim to inform policymakers, agricultural organizations, and community leaders, enabling them to address farmers' challenges and develop strategies to enhance the sustainability and resilience of jute farming in the region.

The survey's demographic data reveal key participant details. Of the 50 respondents, 95% were male and 5% female as shown in Figure 17. With an average farming experience of 20 years, participants demonstrated significant expertise, suggesting their insights are deeply informed by extensive familiarity with agricultural practices and the challenges of the farming sector.

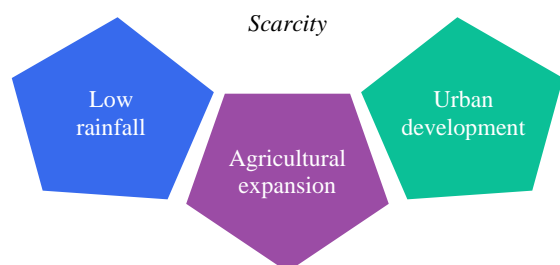


Figure 15. Challenges of jute retting.

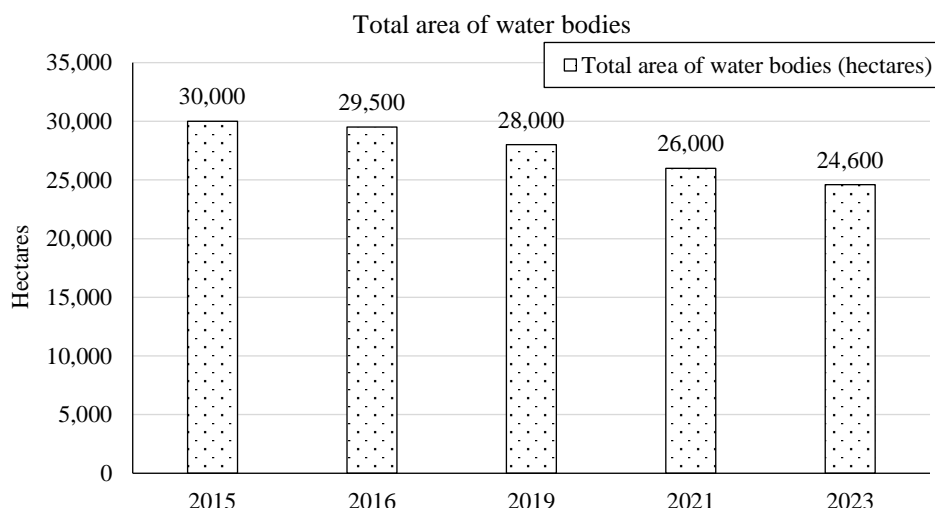


Figure 16. Decline of water bodies in Gaibandha district.

(Sources: Bangladesh Water Development Board (BWDB) <https://www.bmd.gov.bd/>)

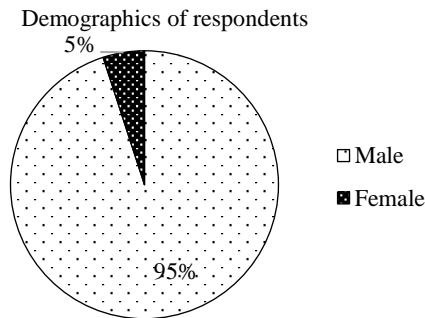


Figure 17. Demographics.

(Source: Local Interview, June 2024, Gaibandha Sadar.)

Multiple Linear Regression Model

This study in Table 4 investigates the relationship between temperature as the independent variable and jute production as the dependent variable through multiple linear regression. The analysis considers the dataset, model performance, and visualizations. Between 2014 and 2023, temperatures increased from 31°C to 37°C, showing a steady rise. Jute production fluctuated, peaking at 1,250,000 bales in 2020—an extreme outlier compared to other years. This outlier introduces potential bias and distorts the analysis, as production steadily declined after 2020, indicating a possible negative correlation with rising temperatures.

The regression model in Table 5 estimates a temperature coefficient of -1,397,500, suggesting that each 1°C increase results in a decrease of 1,397,500 bales of jute as shown in Figure 18. This value appears exaggerated due to the influence of the 2020 outlier. The intercept, 0.3, is not meaningful, as it predicts production at 0°C—an implausible scenario. The model's F-statistic (0.6) and p-value (0.5) indicate it is statistically insignificant, and the lack of detailed t-values further limits the interpretation of coefficients.

Although the model explains 70% of the variability in production ($R^2 = 0.7$), this is likely inflated by the outlier. The negative adjusted R^2 (-0.05) underscores poor model performance, suggesting temperature alone is inadequate as a predictor. Visual assessments reinforce these conclusions. The observed versus predicted plot highlights deviations caused by the 2020 outlier, while the residual plot shown in Figure 19 reveals violations of regression assumptions.

The normal probability plot shown in Figure 20 suggests non-normal residuals, likely due to unaccounted factors. To improve the analysis, the 2020 outlier should be reviewed or mitigated using robust regression methods. Additional predictors, such as rainfall or soil quality, should be considered, and nonlinear models may better capture the relationship. Improved diagnostics and clearer visualizations will enhance interpretation and reliability.

Table 4. Multiple linear regression model.

Years	Temperature (°C)	Jute production (bales)
2014	31	150000
2015	33	140000
2016	32	140000
2017	34	130000
2018	34.5	129000
2019	35.5	145000
2020	36	1250000
2021	34.5	123000

2022	36.5	120000
2023	37	115000

Table 5. Multiple linear regression model of temperature and jute production.

Independent variables	Dependent variable: Jute Production				
	Coefficient	Bales	t-value	p-value	[95% CI]
	-1397500	150000	-0.65773	0.529178	-6297136
		140000			
		140000			
		130000			
		129000			
		145000			3502136
		1250000			
		123000			
		120000			3502136
		115000			
Constant (Intercept)	0.3				
Model F	0.6				
Prob > F	0.5				
R ²	0.7				
Adjusted R ²	-0.05				
Observations	10				

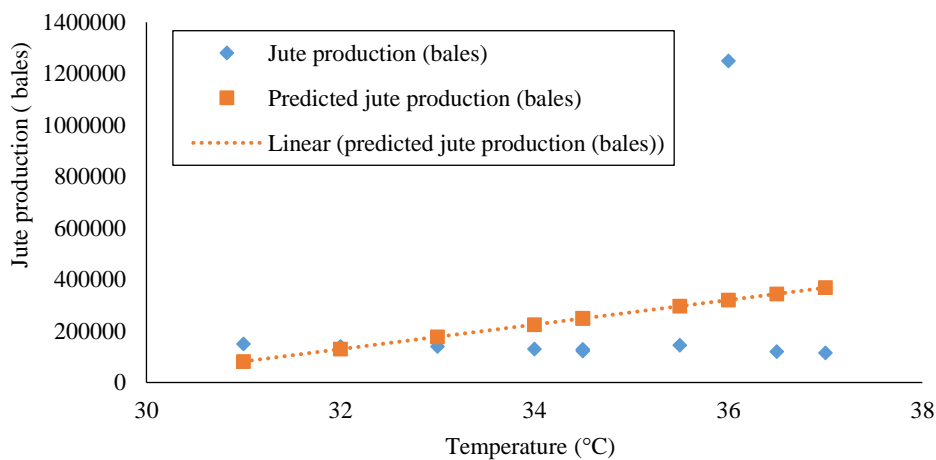


Figure 18. Temperature (°C) line fit plot.

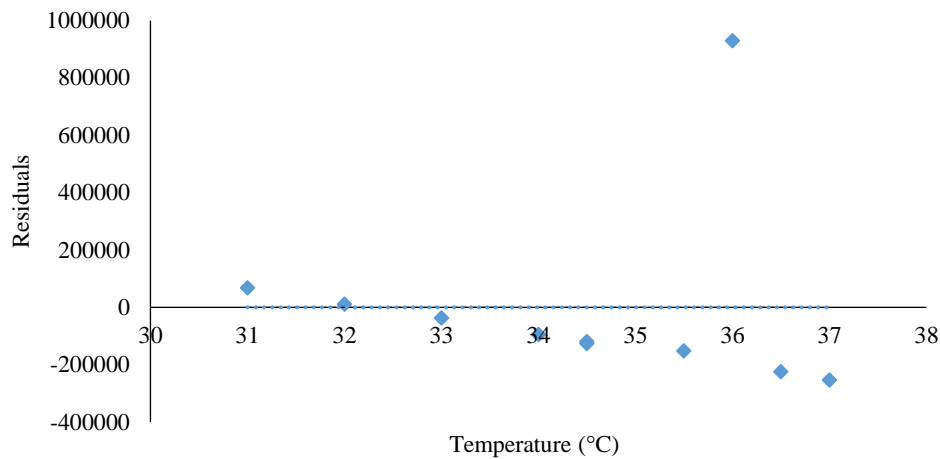


Figure 19. Temperature (°C) residual plot.

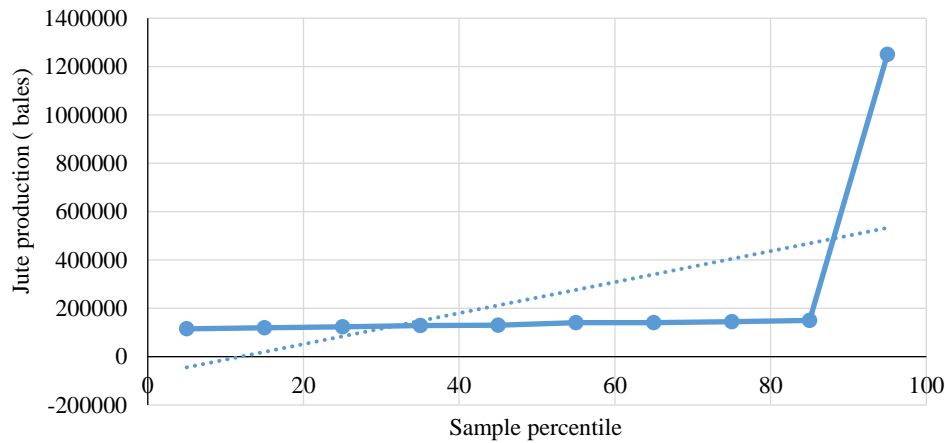


Figure 20. Normal probability plot.

DISCUSSION

This study investigates the impact of climate change on jute production in the Gaibandha District of Bangladesh, emphasizing temperature fluctuations, rainfall variability, and farmers' socio-economic challenges. The findings illustrate how regional environmental conditions intensify broader climate change impacts, offering actionable recommendations for adaptation. The research confirms earlier studies, which demonstrated that higher temperatures adversely affect jute by disrupting photosynthesis and causing water stress. However, this study adds localized insights, revealing that temperatures exceeding 36°C in Gaibandha significantly reduce yields. Unlike national estimates suggesting a 10% yield loss per 1°C increase, Gaibandha may experience steeper declines due to frequent droughts and other local vulnerabilities. Rainfall variability also emerges as a critical issue. While earlier research highlighted the negative effects of reduced rainfall, the detailed data from 2014 to 2023 in this study provide a clearer picture of declining monsoon precipitation, which threatens both plant growth and retting processes. The findings underscore the severity of water scarcity and the urgent need for improved water management systems. Additionally, the study identifies a rise in pest infestations and disease outbreaks, exacerbated by irregular rainfall and higher temperatures as shown in Figure 21. This aligns with previous findings but stresses the urgent need for integrated pest management and enhanced farmer education. Traditional adaptation strategies like intercropping and crop rotation, while once effective, are now insufficient. The adoption of modern techniques, such as drought-resistant jute varieties, is essential. Furthermore, while earlier research broadly identified knowledge gaps among farmers, this study provides a deeper understanding of the barriers faced in Gaibandha, including limited access to climate-smart resources and inadequate institutional support. The findings have significant implications for policy and practice. Region-specific adaptation measures, such as subsidized irrigation

systems, training on sustainable farming, and investment in climate-resilient jute varieties, are crucial. Financial mechanisms like crop insurance and community-based resource sharing can bolster farmer resilience. Enhancing retting technologies to reduce water dependence and providing real-time weather data can also support sustainable practices. Furthermore, promoting alternative income sources for farmers during off-seasons can reduce their dependence on a single crop. Limitations include the focus on Gaibandha, which restricts the generalizability of findings, reliance on secondary data, and a small sample size of 50 farmers. Future research should expand to other regions, include more variables like soil health, and consider long-term climate impacts. Studies on technological innovations and gender-specific challenges are also critical to building comprehensive adaptation strategies.

CONCLUSION

This study examined the impact of climate change on jute production in Gaibandha District, Bangladesh, with a focus on temperature variations, rainfall patterns, and socio-economic challenges. Using a mixed-methods approach, it integrated quantitative data from meteorological records and agricultural statistics with qualitative insights from farmer interviews. The findings highlight that rising

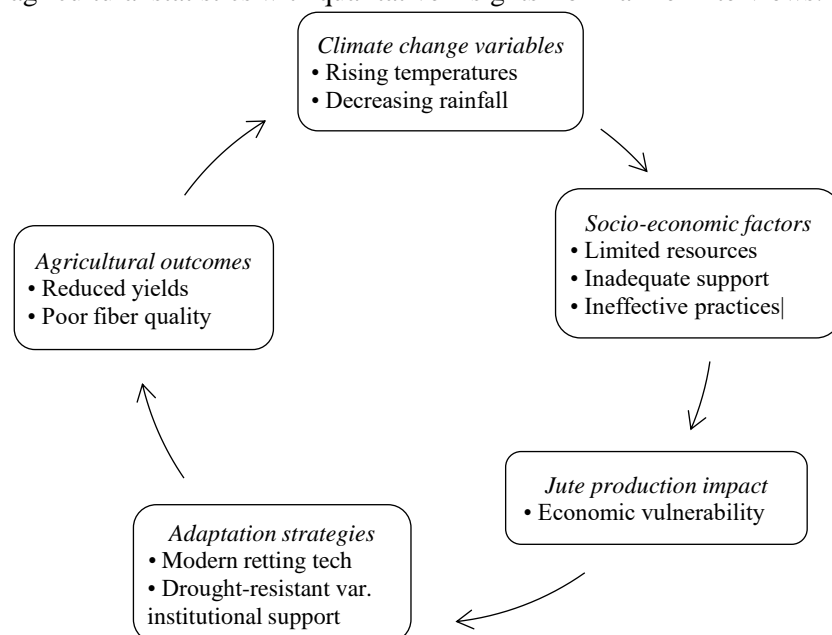


Figure 21. Conceptual model impacts of climate change on jute production.

temperatures and decreasing rainfall during critical growth periods significantly jeopardize jute yields and fiber quality, exacerbating the economic vulnerability of farmers reliant on this crop. The analysis revealed a consistent rise in average temperatures from 2014 to 2023, with peaks exceeding 36°C, a critical threshold for jute growth. Such conditions disrupt photosynthesis, increase water stress, and reduce yields. Declining monsoon rainfall during key months further hinders germination and retting, weakening plants and producing lower-quality fibers. A multiple linear regression model showed that temperature accounted for 70% of yield variability, but the adjusted R^2 of -0.05 exposed its limitations, influenced by data outliers and the exclusion of other crucial factors like rainfall and soil health. This underscores the need for more comprehensive models. The study identified significant socio-economic challenges, such as limited access to climate-smart technologies, inadequate institutional support, and gaps in knowledge transfer. Traditional practices like crop rotation are increasingly ineffective under current conditions, leaving farmers vulnerable to climate-induced disruptions. The novelty of this research lies in its localized focus on Gaibandha, providing specific climatic thresholds and regional insights often overlooked in broader studies. Integrating quantitative climate data with qualitative farmer experiences offers a holistic perspective on the interplay between environmental and socio-economic factors. Future research should expand geographically, include additional variables, and explore technological innovations and gender-

specific challenges. Evaluating the effectiveness of adaptation policies would further refine strategies to support jute farmers and ensure sustainable agricultural practices.

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