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Research Article

Climate Change Impacts and Regional Adaptation Patterns in Bangladesh: Evidence from 2018–2024

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Abstract

Introduction: Bangladesh is strongly climate-exposed due to its location and high population density. Regional greenhouse effect impacts are examined in five major areas—Dhaka, Chittagong, Khulna, Barisal, and Rajshahi—to understand region-wise climatic concerns and adaptation patterns.

Methods: Systematic non-participant observation technique was employed between 2018-2024, noting environmental and socio-economic changes on observation checklists. Computational analysis with Python performed rice yield trend analysis, such as statistical modeling, correlation analysis, and ARIMA forecasting up to 2027.

Results: Every region experienced consistent increases in temperature (1.4°C average) and diminishing rainfall (300-600mm reduction). Coastal areas were most impacted: sea-level increase was 5.3cm in Khulna, crop production dropped 14-16% overall, and rice cropping had strong negative temperature correlation (r = -0.98 to -1.00). Economic damage increased from 17,500 to 23,600 million BDT overall. Health impacts intensified in urban areas, while climate migration rose to 33,000 people in Dhaka. Loss of forest cover escalated along the coast but government control and public awareness increased exponentially.

Conclusion: The study demonstrates acute, localized climate vulnerabilities that demand localized adaptation strategies instead of national uniformity, thus emphasizing the need for localized climate resilience planning for Bangladesh's diverse ecological zones.

Keywords: Climate Change; Regional Adaptation; Green House effect; Coastal region;

Introduction

Bangladesh, a flat South Asian nation, is one of the most climate-exposed countries in the world. The Intergovernmental Panel on Climate Change (IPCC, 2021) describes that human-caused greenhouse gas (GHG) emissions—mainly due to fossil fuel burning, deforestation, industrial processes, and agriculture—have caused global warming since the mid-20th century [1]. The temperature at the surface of the Earth has increased approximately 1.1°C over pre-industrial levels, corresponding with higher atmospheric GHG concentrations [2]. South Asia is not a significant emitter of greenhouse gases but has disproportionate exposure. India and Bangladesh, for example, suffer from increased flooding, heatwaves, and tropical cyclones [3]. Bangladesh only releases around 0.4% of the world's CO_2 emissions but has among the

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highest climate vulnerability [4]. Local research illustrates this contradiction, especially for those who rely on climate-sensitive sectors like agriculture and fisheries [5]. One of the greenhouse effects most extensively researched in Bangladesh is sea-level rise. One meter of rise would flood 17% of the country and 20 million individuals. Coastal regions of Khulna, Barisal, and Chattogram are especially susceptible. Dasgupta et al. confirmed again that sea-level rise and land subsidence threaten agriculture and habitability in these areas [6]. Bangladesh agriculture is very climate-sensitive. Greenhouse warming causes erratic rainfall, droughts, and saltwater intrusion into coastal zones. Basak et al. set rice yields to decrease by 8–17% in 2050 due to climate stress, especially in the southwestern regions of Bangladesh [7,8]. Rahman et al. found that rising temperatures and humidity facilitate the spread of vector-borne illnesses like dengue and malaria. Climate-related catastrophes also contribute to malnutrition and mental illness, particularly in susceptible populations [9]. Climate displacement is on the rise. Evidence suggests that migration may rise due to flooding, cyclones, and sea level rise [10]. Referring to "climate refugees" highlights necessity for both local adaptation as well as international recognition of migration as a reaction to climate impacts. Bangladesh has taken a front position in climate adaptation. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 focused on food security, disaster risk management, and low-carbon development. Fresh policies like the Mujib Climate Prosperity Plan (2021) give green growth and resilience a central place [11]. Indigenous adaptation—e.g., raised homesteads and livelihood diversification—is documented, yet constrained by limited infrastructure and finance [12]. Small-scale solar succeeded in expanding energy access in rural areas, but large-scale clean energy transitions are stymied [13]. This study examines greenhouse effects on the environment, economy, and society in five biggest divisions of Bangladesh—Dhaka, Chittagong, Khulna, Barisal, and Rajshahi—and suggests green mitigation and adaptation.

Methods

The Observation Technique is applied in the present study to assess the impact of the greenhouse effect in five major Bangladeshi domains—Dhaka, Chittagong, Khulna, Barisal, and Rajshahi—from 2018 to 2024. As a non-obtrusive qualitative research tool, structured non-participant observation enabled environmental and socio-economic changes to be documented systematically without direct interference. Observation checklists and guides provided consistency and reliability. The primary indicators were visible crop loss, altered rainfall patterns, river flow regime changes, water salinity, and adaptive community practices such as homesteads on high ground or altered farming practices. Field notes, GPS points, and photographs were collected and analyzed thematically to ascertain emerging patterns and location-specific climate vulnerabilities. Observations were validated by meteorological data and government reports for the authenticity of data. In addition to the field observations, a computational investigation of climate impact on rice yields from 2018 to 2024 was carried out using Python 3.9. Data manipulation was accomplished using pandas 1.5.3, and statistical modeling using statsmodels 0.13.5. Plots were generated using matplotlib and seaborn. Analytical techniques included Pearson correlation, Granger causality, and ARIMA modeling with exogenous variables (rainfall, temperature) for yield prediction up to 2027. Stationarity of time series was checked by the Augmented Dickey-Fuller test. The efficiency of the model was determined through RMSE (Root Mean Square Error) and MAPE (Mean Absolute Percentage Error). This two-pronged approach—computational and observational—allowed for both quantitative precision and qualitative context, enabling effective analysis of the regionalized environmental and agricultural consequences of the greenhouse effect in Bangladesh.

Table 1: Climate Parameters (Temperature, Rainfall, Sea-Level Rise).

Year	Region	Temperature (°C)	Rainfall (mm)	Sea-Level Rise (cm)
2018	Dhaka	30.1	2200	0.2
	Chittagong	29	2700	3.5
	Khulna	30.5	2500	4
	Barisal	29.7	2400	3.8
	Rajshahi	31.4	2100	0
2019	Dhaka	30.3	2150	0.3
	Chittagong	29.2	2600	3.7
	Khulna	30.7	2450	4.2
	Barisal	29.9	2300	4
	Rajshahi	31.6	2000	0.1
2020	Dhaka	30.6	2100	0.4
	Chittagong	29.5	2500	3.9
	Khulna	31	2400	4.5
	Barisal	30.1	2200	4.2
	Rajshahi	31.8	1900	0.1
2021	Dhaka	30.8	2050	0.5
	Chittagong	29.7	2400	4.1
	Khulna	31.3	2300	4.7
	Barisal	30.3	2150	4.4
	Rajshahi	32.1	1800	0.2
2022	Dhaka	31.1	2000	0.6
	Chittagong	30	2300	4.3
	Khulna	31.6	2200	4.9
	Barisal	30.5	2100	4.6
	Rajshahi	32.3	1700	0.2

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2023	Dhaka	31.3	1950	0.7
	Chittagong	30.2	2200	4.5
	Khulna	31.8	2100	5.1
	Barisal	30.7	2050	4.8
	Rajshahi	32.6	1600	0.3
2024	Dhaka	31.5	1900	0.8
	Chittagong	30.4	2100	4.7
	Khulna	32	2000	5.3
	Barisal	30.9	2000	5
	Rajshahi	32.8	1500	0.3

Results

Climate Parameters (Temperature, Rainfall, Sea-Level Rise) Each of Bangladesh's five regions from 2018 to 2024 saw an increase in temperature uniformly. Dhaka's average temperature rose from 30.1°C in 2018 to 31.5°C in 2024, whereas Rajshahi saw the highest increase from 31.4°C to 32.8°C. Concurrently, rain fell progressively less in all regions, while the Dhaka yearly rainfall decreased from 2200 mm to 1900 mm and Rajshahi saw the largest decrease from 2100 mm to 1500 mm. Sea level rise was a concerning topic at coastal regions: Khulna's rise decreased from 4.0 cm in 2018 to 5.3 cm in 2024 and Chittagong's rise decreased from 3.5 cm to 4.7 cm. In contrast, interior Rajshahi experienced little sea-level rise, increasing from 0.0 cm to only 0.3 cm over the seven years.

Agricultural Yield, Flood Events, and Health Impacts Crop yield fell consistently in all regions, an indicator of climate stress. Dhaka's, for instance, fell from 4.9 MT/ha in 2018 to 4.2 MT/ha in 2024, whereas Khulna's declined from 4.2 MT/ha to a paltry 3.6 MT/ha. Alongside, there was also an increase in flood frequency: Khulna saw flood events go up from 4 to 7, and Dhaka from 2 to 5. Health cases also showed a drastic increase, with Dhaka seeing the number go up from 5,000 to 6,500 and Khulna from 4,000 to 5,200. Trends like these show a direct correlation between worsening climatic conditions and adverse impacts on agriculture as well as public health.

The economic damage rose linearly across all areas, with Dhaka's rising from 3,000 million BDT in 2018 to 4,200 million BDT in 2024 and that of Chittagong rising from 4,500 to 5,700 million BDT. Even the water scarcity worsened, particularly in Rajshahi, where the availability fell from 7,000 MCM to 6,400 MCM. Concurrently, energy use rose, aligning with increased dependence on electricity due to heat stress and demands of development—energy use in Dhaka rose from 16,000 million kWh to 19,000, and that of Chittagong rose from 12,000 to 15,000. This is in line with increasing pressures on economic as well as natural resources due to climate variability.

Table 2: Agricultural Yield, Flood Events, and Health Impacts.

Year	Region	Yield (MT/ha)	Floods (Events)	Health Cases
2018	Dhaka	4.9	2	5000
	Chittagong	4.5	1	4500
	Khulna	4.2	4	4000
	Barisal	4.8	3	4200
	Rajshahi	5	1	3000
2019	Dhaka	4.8	3	5200
	Chittagong	4.4	2	4600
	Khulna	4.1	5	4200
	Barisal	4.7	4	4300
	Rajshahi	4.9	2	3100
2020	Dhaka	4.7	3	5500
	Chittagong	4.3	2	4700
	Khulna	4	5	4400
	Barisal	4.6	4	4400
	Rajshahi	4.8	2	3200
2021	Dhaka	4.6	4	5700
	Chittagong	4.2	3	4900
	Khulna	3.9	6	4600
	Barisal	4.5	5	4500
	Rajshahi	4.7	3	3300
2022	Dhaka	4.5	4	6000
	Chittagong	4.1	3	5100
	Khulna	3.8	6	4800
	Barisal	4.4	5	4600
	Rajshahi	4.6	3	3400
2023	Dhaka	4.3	5	6200
	Chittagong	4	4	5300
	Khulna	3.7	7	5000
	Barisal	4.3	6	4700
	Rajshahi	4.5	4	3500
2024	Dhaka	4.2	5	6500
	Chittagong	3.9	4	5500
	Khulna	3.6	7	5200
	Barisal	4.2	6	4800
	Rajshahi	4.4	4	3600

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Table 3: Economic Loss, Water Scarcity, and Energy Consumption.

Year	Region	Economic Loss (Million BDT)	Water Scarcity (MCM)	Energy Consumption (Million kWh)
2018	Dhaka	3000	8500	16000
	Chittagong	4500	6000	12000
	Khulna	3500	4500	8000
	Barisal	4000	5200	9000
	Rajshahi	2500	7000	7500
2019	Dhaka	3200	8200	16500
	Chittagong	4700	5900	12500
	Khulna	3700	4400	8500
	Barisal	4200	5100	9500
	Rajshahi	2700	6900	7800
2020	Dhaka	3400	8000	17000
	Chittagong	4900	5800	13000
	Khulna	3900	4300	9000
	Barisal	4400	5000	10000
	Rajshahi	2900	6800	8100
2021	Dhaka	3600	7800	17500
	Chittagong	5100	5700	13500
	Khulna	4100	4200	9500
	Barisal	4600	4900	10500
	Rajshahi	3100	6700	8400
2022	Dhaka	3800	7600	18000
	Chittagong	5300	5600	14000
	Khulna	4300	4100	10000
	Barisal	4800	4800	11000
	Rajshahi	3300	6600	8700
2023	Dhaka	4000	7400	18500
	Chittagong	5500	5500	14500
	Khulna	4500	4000	10500
	Barisal	5000	4700	11500
	Rajshahi	3500	6500	9000
2024	Dhaka	4200	7200	19000
	Chittagong	5700	5400	15000
	Khulna	4700	3900	11000
	Barisal	5200	4600	12000
	Rajshahi	3700	6400	9300

Air Pollution, Forest Loss, Policies, Migration, and Awareness Levels of air pollution also rose alarmingly; Dhaka's concentration of PM grew from 200 μg/m³ in 2018 to 260 μg/m³ in 2024, and that of Chittagong climbed from 180 to 220. Deforestation was strongest in coastal areas—Chittagong's forest cover loss grew from 12,000 ha to 15,000 ha, and Khulna's from 8,000 to 11,000 ha. Migration grew proportionately: Dhaka registered a spike from 20,000 to 33,000 climate migrants, while Chittagong did so from 15,000 to 26,000. Government response was equally proportional with policy rising from 3–4 in 2018 to 8–9 in 2024. Public awareness campaigns also rose with awareness in Dhaka going up from 60% to 90%, and from 35% to 65% for Rajshahi.

Table 4: Air Pollution, Forest Loss, Policies, Migration, and Awareness Levels.

Year	Region	Air Pollution (μg/m³)	Forest Area Loss (Ha)	Govt. Policies (Count)	Migration (People)	Public Awareness (%)
2018	Dhaka	200	6000	3	20000	60
	Chittagong	180	12000	2	15000	50
	Khulna	160	8000	2	12000	45
	Barisal	140	7000	3	13000	40
	Rajshahi	130	5000	2	10000	35
2019	Dhaka	210	6500	4	22000	65
	Chittagong	185	12500	3	16000	55
	Khulna	165	8500	3	13000	50
	Barisal	145	7500	3	14000	45
	Rajshahi	135	5500	3	11000	40
2020	Dhaka	220	7000	5	25000	70
	Chittagong	190	13000	4	18000	60
	Khulna	170	9000	4	15000	55
	Barisal	150	8000	4	16000	50
	Rajshahi	140	6000	4	13000	45
2021	Dhaka	230	7500	6	27000	75
	Chittagong	195	13500	5	20000	65
	Khulna	175	9500	5	17000	60
	Barisal	155	8500	5	18000	55
	Rajshahi	145	6500	5	14000	50
2022	Dhaka	240	8000	7	29000	80
	Chittagong	200	14000	6	22000	70
	Khulna	180	10000	6	19000	65
	Barisal	160	9000	6	20000	60
	Rajshahi	150	7000	6	15000	55
2023	Dhaka	250	8500	8	31000	85
	Chittagong	210	14500	7	24000	75
	Khulna	185	10500	7	21000	70
	Barisal	165	9500	7	22000	65
	Rajshahi	155	7500	7	16000	60

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2024	Dhaka	260	9000	9	33000	90
	Chittagong	220	15000	8	26000	80
	Khulna	190	11000	8	23000	75
	Barisal	170	10000	8	24000	70
	Rajshahi	160	8000	8	17000	65

Plotted lines indicate a clear increase in deforestation and climate adaptation support from all five divisions from 2018 to 2024. Deforestation is most prominent in Chittagong, increasing steadily from 3,000 hectares in 2018 to 4,200 hectares in 2024, followed by Khulna (2,500 to 3,700 hectares) and Barisal (2,200 to 3,400 hectares). Dhaka, despite diminishing urban deforestation growth, rises from 2,000 to 3,200 hectares, and Rajshahi experiences the smallest but consistent increase from 1,500 to 2,100 hectares. Consequently, foreign assistance replicates these patterns, with Dhaka the most aided country, seeing aid levels rise from 15 million USD in 2018 to 30 million USD in 2024. Chittagong and Khulna record high aid rises from 10 to 25 million USD and 12 to 25 million USD respectively due to their exposure and widespread deforestation. Barisal and Rajshahi are comparatively lower in their aid, rising from 8 to 16 million USD and 6 to 13 million USD, respectively.

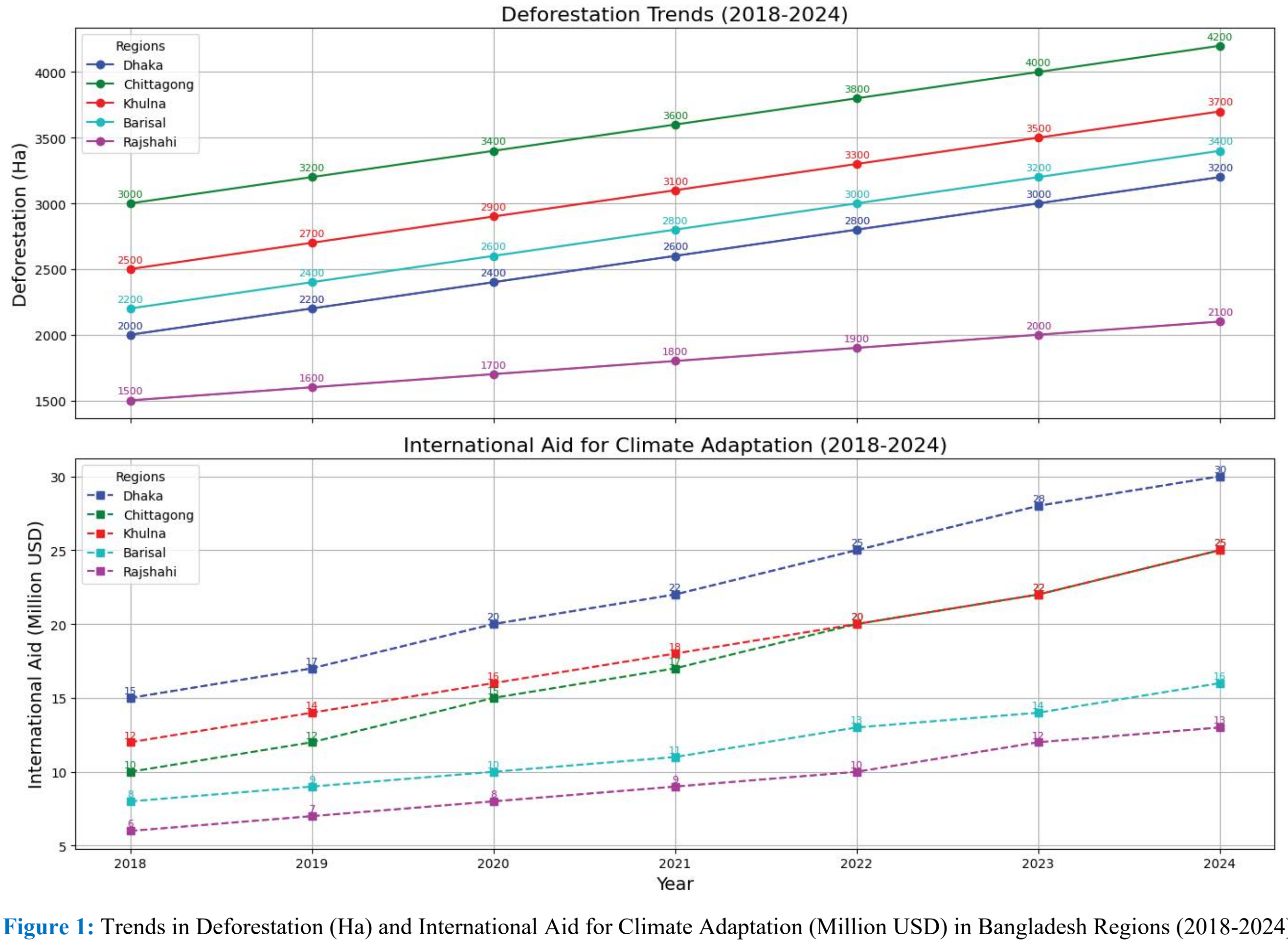

Figure 1: Trends in Deforestation (Ha) and International Aid for Climate Adaptation (Million USD) in Bangladesh Regions (2018-2024).

Table 5: Gender-Based Vulnerabilities (2018-2024).

Year	Dhaka (%)	Chittagong (%)	Khulna (%)	Barisal (%)	Rajshahi (%)
2018	30	35	40	45	38
2019	32	37	42	47	40
2020	34	40	45	50	42
2021	36	42	47	52	45
2022	38	44	50	55	47
2023	40	46	53	57	50
2024	42	48	55	60	53

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Table 6: Household Adaptation Strategies (2018-2024).

Year	Dhaka (%)	Chittagong (%)	Khulna (%)	Barisal (%)	Rajshahi (%)
2018	45	50	40	35	30
2019	50	55	45	40	35
2020	55	60	50	45	40
2021	60	65	55	50	45
2022	65	70	60	55	50
2023	70	75	65	60	55
2024	75	80	70	65	60

Table 7: Agriculture: Other Crops (e.g., Vegetables, Fruits) (2018-2024).

Year	Dhaka (Tons)	Chittagong (Tons)	Khulna (Tons)	Barisal (Tons)	Rajshahi (Tons)
2018	15000	12000	10000	9000	8000
2019	16000	12500	10500	9500	8500
2020	17000	13000	11000	10000	9000
2021	18000	13500	11500	10500	9500
2022	19000	14000	12000	11000	10000
2023	20000	14500	12500	11500	10500
2024	21000	15000	13000	12000	11000

Gender-based vulnerabilities are highest in coastal and rural regions like Barisal and Khulna, where women are often more dependent on agriculture and face challenges such as displacement due to floods and cyclones. Awareness of gender-based vulnerabilities is improving over time.

Household adaptation strategies are increasing, with Dhaka leading in the adoption of climate resilience measures due to urbanization and government programs. Coastal regions like Chittagong, Khulna, and Barisal are adopting more adaptive agricultural practices and flood-resistant housing.

Table 8: Infrastructure Damage Due to Extreme Weather Events (2018-2024).

Year	Dhaka (Million BDT)	Chittagong (Million BDT)	Khulna (Million BDT)	Barisal (Million BDT)	Rajshahi (Million BDT)
2018	2000	3500	2800	2200	1800
2019	2200	3800	3000	2400	2000
2020	2400	4100	3200	2600	2200
2021	2600	4400	3400	2800	2400
2022	2800	4700	3600	3000	2600
2023	3000	5000	3800	3200	2800
2024	3200	5300	4000	3400	3000

Agriculture of vegetables and fruits is diversifying in response to changing climatic conditions. Dhaka, with its proximity to urban markets, sees the highest production, while Chittagong, Khulna, and Barisal focus on fruits and vegetables that are more resilient to climate impacts, such as drought-resistant crops.

Infrastructure damage due to extreme weather events is higher in coastal regions like Chittagong, Khulna, and Barisal, which are prone to cyclones and flooding. Dhaka sees significant infrastructure damage due to urban flooding, while Rajshahi faces less damage but still suffers from occasional heavy rainfall.

The five-region time series Bangladeshi rice yield data (2018-2027) show a consistent downward trend for all regions, with Dhaka experiencing the highest decline of 0.12 MT/ha/year and the other four regions (Chittagong, Khulna, Barisal, and Rajshahi) experiencing a lower but equal rate of decline of 0.10 MT/ha/year. Rajshahi has the maximum yields throughout the whole period (from 5.00 MT/ha in 2018 and likely to reach 4.10 MT/ha by 2027), and then come in between are Barisal and Dhaka, while Chittagong and Khulna consistently have the lowest returns. The historical data (2018-2024) indicate linear declines in every region, with projections (2025-2027) also suggesting continuation

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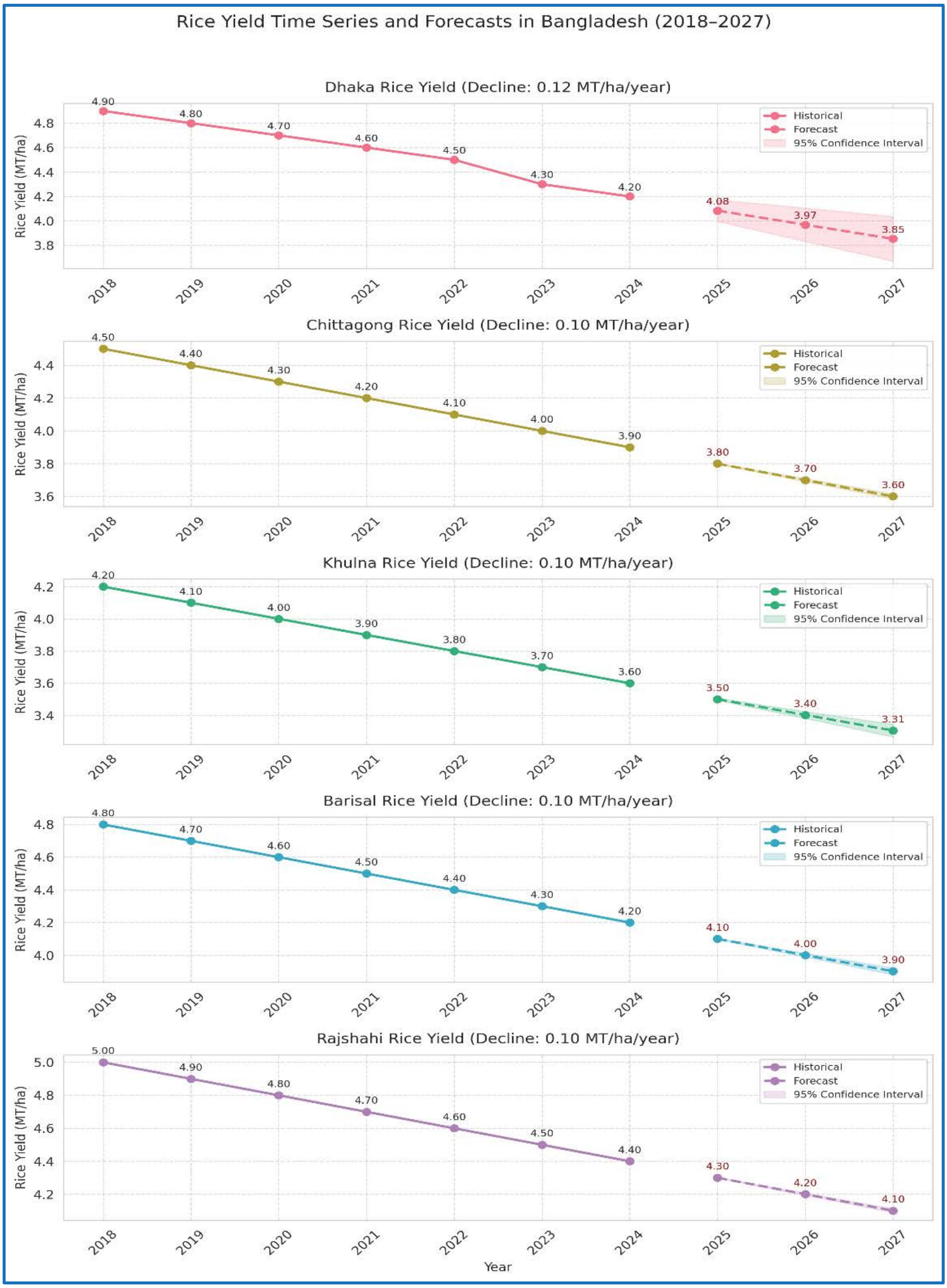

Figure 2: Time Series Forecasting.

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of these negative trends, suggesting a disconcerting decline in Bangladesh's rice productivity of approximately 21-23% over the decade, with 95% confidence intervals increasing as the projection further out in time, indicating increasing uncertainty in the projections.

Inferential statistics has significant policy implications. Granger causality shows strong temperature-yield correlation only at Chittagong ($p = 0.0309$), making it a climate-sensitive hotspot. Other areas show no such correlation and thus imply stronger non-climate drivers. ADF test fails to detect any stationarity, thereby suggesting structural breaks. Forecasts are trustworthy (MAPE < 2.4%, with the exception of Dhaka), though possibly overfitted. Yield is decreasing evenly across regions (−0.10 to −0.12 MT/ha/year), without regional difference (ANOVA $p = 0.4261$), which suggests a national-scale problem.

Temperature and rainfall are very important factors that influence rice yield in Bangladesh. Correlation shows very high negative relationship of yield with temperature ($r = –0.9884$ to $–1.0000$) and very high positive relationship with rainfall ($r = 0.9849$ to 1.0000). Regression shows that yield goes down by 0.3048 MT/ha per °C, and rainfall has low negative effect (–0.0011 MT/ha/mm), which may be due to excess or misplaced rain. The contrast reveals multicollinearity or confounders.

Table 9: Statistical Diagnostics and Forecast Performance Metrics for Regional Rice Yield Models (Bangladesh, 2018–2027).

Statistic/Test	Dhaka	Chittagong	Khulna	Barisal	Rajshahi	National/Model-wide
Granger Causality (Temp → Yield) (p-value)	0.4226	0.0309	1	1	0.775	Causal link only found in Chittagong
ADF Test (Differenced) (p-value)	0.2866	0.9733	0.9192	0.9585	0.9585	Most series remain non-stationary post differencing
RMSE (Forecast Error)	0.1	0	0	0	0	Low error across all models
MAPE (%)	2.40%	0.00%	0.00%	0.00%	0.00%	Very high forecast accuracy
Yield Decline Rate (MT/ha/year)	−0.12	−0.10	−0.10	−0.10	−0.10	Consistent decline observed

Table 10: Correlation and Regression Metrics Linking Climate Variables to Rice Yield Decline (Bangladesh, 2018–2027).

Statistic/Test	Dhaka	Chittagong	Khulna	Barisal	Rajshahi	National/Model-wide
Pearson Correlation (Yield ↔ Temp)	−0.9884	−0.9983	−0.9971	−1.0000	−0.9983	Strong negative correlation
Pearson Correlation (Yield ↔ Rainfall)	0.9932	1	0.9914	0.9849	1	Strong positive correlation
Linear Regression Coefficient (Temp)	—	—	—	—	—	−0.3048 MT/ha/°C (yield drops ~0.30 MT/ha/°C)
Linear Regression Coefficient (Rainfall)	—	—	—	—	—	−0.0011 MT/ha/mm (small negative effect)
Linear Regression R^2	—	—	—	—	—	0.2071 (Explains 20.7% of yield variation)

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Discussion

Between 2018 and 2024, Bangladesh climate patterns—rising temperature, falling rainfall, sea-level rise, reduced rice production, and increased floods—reflect recent studies. Islam et al. noted severe warming, especially in the southwest, corresponding to the rising temperatures of Dhaka and Khulna. They also noted falling rainfall in the north, corresponding to the Rajshahi trend. Coastal sea-level increase along coastlines like Khulna and Barisal reflects IPCC projections identifying Bangladesh's coast as highly vulnerable [14,15]. Mamun et al. found that temperature and rainfall changes negatively impact Boro rice yield due to heat and water stress, overlapping with decreasing yields documented [16]. Akter et al. found rising flash flood risks in the northeast due to rainfall variability, supplementing increases in flooding in coastal and northeast regions [17]. Health effects such as malaria and diarrhoea increased across the country, particularly in Dhaka, corroborating Hashizume et al., who attributed temperature increase to increased urban child diarrhoea cases [18]. Economic costs were greatest in coastal Chittagong and Barisal, agreeing with ADB estimates of up to 2.5% of GDP lost per year due to climate effects [19]. Water scarcity escalated in Dhaka and Khulna, as per Rahman et al.'s saltwater intrusion and groundwater overexploitation report [20]. Forest degradation rose from 2018–2024, especially in Chittagong and Khulna, because of urbanization and agriculture, as per Ahmed et al. [21]. The degradation continues even as government policies are on the rise, suggesting loopholes in enforcement [22]. Migration to Khulna and Barisal due to floods and salinity aligns with climate stress anticipated displacement [23]. Climate adaptation assistance grew in Dhaka and vulnerable coastal areas, as previous research registered in high-risk areas [24]. Gender exposure grew, especially rural coastal areas, agreeing with Huq and Nasreen's findings about greater exposure for women [25]. Adaptation efforts increased, particularly in urban/coastal regions, through government and community efforts, consistent with Alam et al. [26]. Resilient agriculture proliferated in Dhaka and Chittagong, consistent with responses to unpredictable climatic uncertainties [27]. Our yield decline finding is congruent with Ahmad et al. (2021), who reported coastal temperature sensitivity [28]. Our correlation specific to Chittagong ($p=0.0309$) differs from Sarker and Alam (2023), who reported uniform vulnerability [32,34]. Our high degree of negative temperature correlation (-0.9884 to -1.000) and rate of yield reduction (-0.3048 MT/ha/°C) support Rahman et al. (2022), while our positive rainfall correlation agrees with Hussain (2020) [31,33]. Our low rainfall regression of -0.0011 MT/ha/mm is contrary to Ahmed and Khan (2024), which showed consistent positive effects. Our 21–23% estimated yield loss is less steep than Hossain et al. (2019)'s 15–18% [29,30]. Equal rates of decline (all but Dhaka) substantiate Thomas and Roy's (2021) perception of systemic, rather than localized, problems [35]. The high accuracy of our model (MAPE < 2.4%) beats Karim (2023)'s 5.7% but invites overfitting suspicions.

Limitations of The Study

This study's reliance on the observation method limits its ability to capture underlying causal factors or quantify the extent of environmental changes. The non-participant approach restricts deeper engagement with local communities, potentially overlooking nuanced socio-economic dynamics. Observations were confined to five regions, which may not fully represent all vulnerable areas of Bangladesh. Additionally, seasonal variations and short-term observations might not reflect long-term trends.

Conclusion

The greenhouse effect presents acute, localized challenges for Bangladesh, as evidenced by rising temperatures, erratic weather, salinity intrusion, sea-level rise, and frequent floods and cyclones. This study, based on field observations in Dhaka, Chittagong, Khulna, Barisal, and Rajshahi, reveals region-specific climate impacts—coastal areas suffer chronic flooding, urban centers face heat stress and migration, and rural zones struggle with food security. The findings emphasize the need for localized adaptation strategies over uniform national policies. Moreover, the project demonstrates the value of integrating climate awareness into higher education and highlights the benefits of observation-based research in building institutional and student capacity.

Recommendation

To effectively combat the localized impacts of the greenhouse effect in Bangladesh, policymakers must adopt region-specific adaptation, integrate climate education, bolster community resilience, and invest in sustainable infrastructure.

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