The Jahangirnagar Review: Part II: Social Science, Vol. 49, No.1. June-2025
ISSN 1682-7422 © Jahangirnagar University

Assessing the Impact of Temperature and Rainfall on Forest Cover and Vegetation Dynamics in Chakaria, Cox's Bazar

Muhammad Khalilur Rahman[1]
Ebadullah Khan[2]

.

Abstract: *This research investigates the relationship between climatic factors, forest cover, and vegetation dynamics in Chakaria, Cox's Bazar, Bangladesh, concentrating on the years 2015, 2020, and 2024. By employing GIS and remote sensing methodologies, such as Landsat 8 OLI satellite imagery, NDVI analysis, and supervised classification, the study examines seasonal fluctuations in forest cover and vegetation during pre-monsoon and post-monsoon periods. Temperature and rainfall data, collected from the Bangladesh Agricultural Research Council and the Center for Hydrometeorology and Remote Sensing (CHRS) Data Portal, offer valuable insights into seasonal climatic patterns. The findings reveal distinct seasonal patterns, with temperature exerting a more pronounced impact on vegetation degradation during the pre-monsoon season, whereas rainfall significantly supports vegetation recovery in the post-monsoon period. Regression analyses indicate a moderate to strong correlation between climatic variables and forest cover dynamics, with temperature and rainfall influencing forest health and NDVI values differently. The supervised classification of land-use and land-cover changes achieved high accuracy, validated through Kappa tests, underscoring the reliability of the methodological approach. This study highlights the critical role of climatic variables in shaping forest ecosystems and vegetation health, particularly in climate-vulnerable regions like Chakaria. The research underscores the need for sustainable forest management practices and evidence-based policies to mitigate climate-induced challenges and ensure ecological resilience. The integration of climate data with spatial analyses provides valuable insights into the impacts of climate variability, offering a robust framework for future studies aiming to predict and manage the effects of environmental change in deltaic regions.*

Keywords: Forest Cover, NDVI, Vegetation, GIS, Climate, Supervised Classification.

Introduction

The dynamic interplay between climatic variables, forest cover, and vegetation has been a central theme in recent environmental research. Temperature and rainfall are

---

[1] Junior Consultant, Sustainable Forest and livelihood (SUFAL) Project, Forest Department, Bangladesh.
[2] Associate Professor, Department of Geography & Environment, Jahangirnagar University, Savar, Dhaka. Email: ekhan@juniv.edu

particularly influential in shaping vegetation dynamics, with their effects varying across temporal and spatial scales. Numerous studies have utilized GIS and Remote Sensing methodologies to analyze these climatic interactions, offering valuable insights into land cover changes and vegetation patterns.

Abbas et al. (2020) explored the role of NDVI in detecting vegetation changes and climate variability, highlighting NDVI as a robust indicator for assessing vegetation health under different climatic conditions. Remote sensing technologies, when combined with GIS, enable detailed spatial and temporal analysis of vegetation dynamics, providing critical data for effective environmental management and planning. Similarly, Islam et al. (2017) emphasized the efficacy of supervised classification methods for accurate land-use and land-cover mapping, particularly in tropical regions prone to climatic extremes. Vegetation indices such as NDVI serve as reliable indicators of vegetation health and productivity (Chughtai et al., 2021).

Palmate et al. (2014) studied the Betwa River Basin's vegetation dynamics, demonstrating that temperature significantly impacts forest cover during pre-monsoon seasons, while rainfall plays a crucial role in vegetation recovery during post-monsoon periods. These findings underscore the importance of understanding season-specific climatic impacts on vegetation. Additionally, Bennett and Barton (2018) highlighted the critical role of forests in hydrological cycles and regional climate stability, emphasizing the long-standing debate on whether forests act as water users or producers.

The interrelationship among forest cover, temperature, and rainfall is particularly significant in regions like Bangladesh, which are highly vulnerable to climate variability. Chakaria, Cox's Bazar—a deltaic region—exemplifies such ecosystems where seasonal climatic changes, including pre-monsoon and post-monsoon variations, directly influence forest sustainability and vegetation health (Rahman, 2013). Understanding this triad is essential for predicting climate change impacts, implementing evidence-based land-use policies, and ensuring long-term ecological resilience.

Webb (2005) emphasized the value of GIS and Remote Sensing in monitoring land use changes and vegetation dynamics, particularly in capturing spatial and temporal variations in response to climatic factors. Similarly, Napieralski et al. (2013) highlighted the utility of digital elevation models (DEMs) and satellite imagery in understanding landform-vegetation interactions, advocating for high-resolution data in geomorphological and vegetation studies.

Emerging research highlights the significance of regression analyses in quantifying the relationships between climatic variables and vegetation. Recent advancements demonstrate that temperature and rainfall influence vegetation health and distribution differently, necessitating localized studies. For instance, Crockford et al. (2000) illustrated how forest cover changes correlate with rainfall and temperature patterns, emphasizing region-specific variations.

In tropical regions, Y. Tajima et al. (2013) observed that tidal actions and sedimentation significantly influence vegetation patterns, particularly in deltaic ecosystems like the Meghna Estuary. These findings align with the consensus that climate-induced changes in hydrodynamics and sedimentation critically shape vegetation dynamics. Modern methodologies, such as GIS and remote sensing, have enhanced the capacity to study these interrelationships, enabling spatial and temporal analyses to detect patterns between forest cover and climatic variables (Webb, 2005).

This article evaluates the dynamic interplay between climatic variables, forest cover, and vegetation, focusing on the impacts of temperature and rainfall on vegetation dynamics in Chakaria, Cox's Bazar. The research leverages GIS and remote sensing technologies, employing NDVI as a key indicator for assessing vegetation health and supervised classification methods for accurate land-use and land-cover mapping. The article emphasizes the importance of understanding season-specific climate impacts, particularly in deltaic ecosystems prone to climatic variability. By integrating these methodologies, the research aims to inform sustainable land-use policies and enhance resilience against climate-induced challenges. These studies provide a foundation for analyzing how temperature and rainfall affect forest cover and vegetation dynamics, particularly in ecologically sensitive areas like Chakaria, Cox's Bazar. As climate change continues to alter environmental conditions, integrated approaches are imperative for informed decision-making and sustainable land management.

Study Area

Chakaria, located in the southeastern region of Bangladesh within the Cox's Bazar District, spans a total area of approximately 643.46 square kilometers (Fig. 1). Geographically, it is situated between 21.55°N latitude and 92.05°E longitude, encompassing diverse landscapes such as forests, agricultural lands, and estuarine ecosystems. The region experiences a tropical monsoon climate, characterized by high humidity, annual rainfall ranging from 2,500 to 3,000 millimeters, and average temperatures varying between 20°C and 30°C (Rahman, 2013).

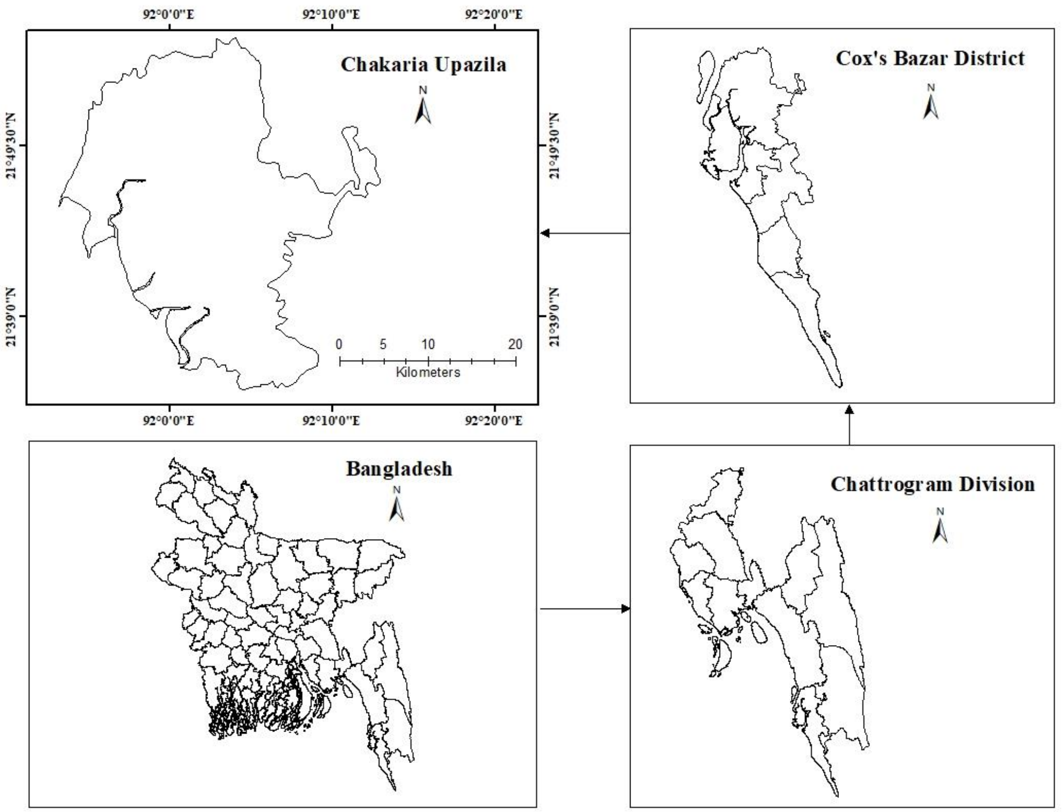

Fig. 1 Study Area Map of Chakaria Upazila

Chakaria supports a significant population that relies on agriculture, forestry, and aquaculture for their livelihoods (Islam et al., 2017). Economically and ecologically, the area is of immense importance. Forests like the Chakaria Sundarbans contribute to biodiversity conservation, carbon sequestration, and local livelihoods (Rahman, 2013). The land-use and land-cover dynamics highlight a complex interaction of agricultural expansion, human settlements, and mangrove ecosystems, reflecting the region's ecological and economic significance. However, Chakaria faces significant challenges from climate change, deforestation, and land degradation, which underscore the urgent need for sustainable land management practices to protect its natural resources and economic stability (Islam et al., 2017).

Data

This study integrates data on forest cover, vegetation, rainfall, and temperature to establish their interrelationships across pre-monsoon and post-monsoon seasons for the years 2015, 2020, and 2024. The dataset includes satellite imagery, temperature, and rainfall data, providing a comprehensive foundation for analyzing forest cover and vegetation dynamics in Chakaria, Cox's Bazar. Landsat 8 Operational Land Imager (OLI) satellite imagery, with a spatial resolution of 30 meters, was acquired from the USGS Earth Explorer platform (https://earthexplorer.usgs.gov/). Table 1 details the satellite data, including acquisition dates, resolution, and cloud cover percentages, which range from 1.24% to 5.3%. The selected imagery ensures temporal coverage of both pre-monsoon and post-monsoon seasons, enabling the assessment of seasonal variations with high-quality data.

Table 1 Details of Landsat 8 OLI Satellite Imagery Acquired for the Study (2015–2024)

Satellite	Sensor	Acquisition Date	Resolution	Cloud Cover	Source
Landsat 8	OLI	10-03-2015	30m	1.24	*Earthexplorer. usgs.gov*
Landsat 8	OLI	21-11-2021	30m	2.32	
Landsat 8	OLI	10-05-2020	30m	3.2	
Landsat 8	OLI	18-11-2020	30m	1.5	
Landsat 8	OLI	18-03-2024	30m	3.5	
Landsat 8	OLI	13-11-2024	30m	5.3	

In addition to satellite imagery, temperature and rainfall data for the corresponding years were obtained from reputable sources, including the Bangladesh Agricultural Research Council (BARC) Climate Portal (http://barcapps.gov.bd/climate/) and the

Center for Hydrometeorology and Remote Sensing (CHRS) Data Portal (https://chrsdata.eng.uci.edu/). These datasets provided seasonal averages, with temperature ranging from 19.45°C to 25.13°C and rainfall varying between 81 mm and 143 mm across the study period. This highlights notable climatic variability over the years. By integrating climatic data with NDVI and forest cover assessments, this study offers a robust framework to explore the relationships between climatic factors and vegetation dynamics, emphasizing both seasonal and interannual variations.

Methodology

The methodological framework employed in this study integrates satellite imagery and climate data to evaluate the interrelationship between forest cover, vegetation, temperature, and rainfall in Chakaria, Cox's Bazar, across pre- and post-monsoon seasons for 2015, 2020, and 2024.

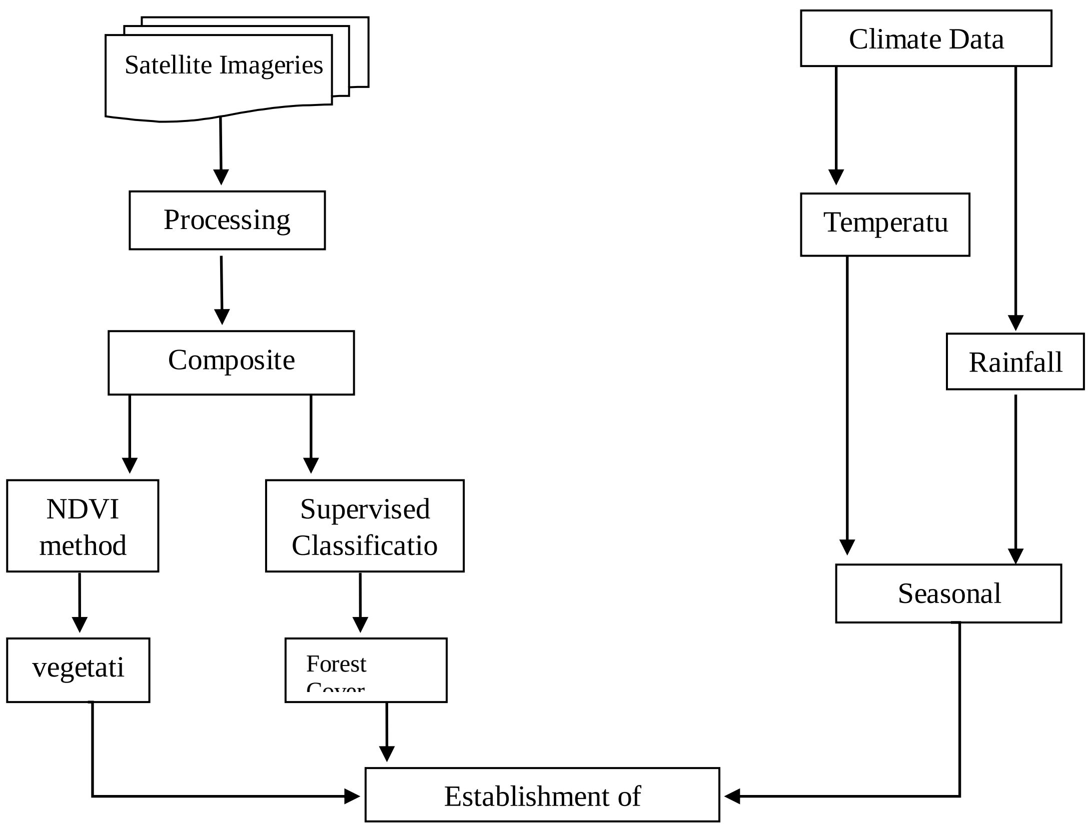

Fig.2 Methodological flow chart

The steps outlined in the flowchart ensure a systematic approach to processing, analyzing, and interpreting the data (Fig. 2).

Satellite Imagery Acquisition and Processing

Landsat 8 Operational Land Imager (OLI) imagery was acquired through the USGS Earth Explorer platform. These images, with a spatial resolution of 30 meters, were selected for their cloud cover percentages ranging between 1.24% and 5.3%. Preprocessing steps included atmospheric correction, geometric correction, and radiometric calibration using tools like ENVI and ArcGIS (Chander et al., 2009).

Composite Band Creation

To analyze land cover and vegetation, bands were composited to generate multispectral datasets. Composite bands facilitate the extraction of specific spectral indices, such as NDVI, which captures vegetation health and dynamics (Tucker, 1979).

NDVI Method for Vegetation Analysis

Normalized Difference Vegetation Index (NDVI) was calculated using the red and near-infrared bands of the Landsat 8 imagery. The NDVI equation is expressed as:

$$\mathrm{NDVI}=\frac{\mathrm{NIR}-\mathrm{RED}}{\mathrm{NIR}+\mathrm{RED}}$$

Where:

NIR = Near-Infrared Reflectance

RED = Red Reflectance

NDVI values range between -1 and +1, with higher values indicating denser vegetation. This index was used to evaluate vegetation health and dynamics over time (Abbas et al., 2020).

Supervised Classification for Forest Cover

Supervised classification was applied to delineate land cover classes, such as forest cover, agricultural land, water bodies, and urban areas. The classification was performed using the Maximum Likelihood Classification (MLC) algorithm in ArcGIS. Training samples were collected from field validation and high-resolution imagery to ensure accuracy (Islam et al., 2017).

Climate Data Collection and Analysis

Temperature and rainfall data were acquired from the Bangladesh Agricultural Research Council (BARC) Climate Portal (http://barcapps.gov.bd/climate/) and the

Climate Hazards Center CHRS Data Portal (https://chrsdata.eng.uci.edu/). Seasonal averages for pre- and post-monsoon periods were calculated as:

Seasonal Average= $\sum_{i=1}^{n} Value_i / n$

Where $Value_i$ represents individual daily values, and n is the number of days.

Establishment of Relationships

The relationship between forest cover, vegetation (NDVI), temperature, and rainfall were evaluated using regression analysis. This analysis quantified the degree of dependence of forest cover and vegetation on climatic factors. The general regression equation used was:

$$y=mx+c$$

Where:

- y = Dependent variable (e.g., forest cover, NDVI)
- m = Regression coefficient
- x = Independent variable (e.g., temperature, rainfall)
- c = Intercept

Regression analysis results, including coefficients of determination (R^2), indicated the strength of relationships. High R^2 values represented stronger climatic influence on forest and vegetation dynamics.

Integration and Interpretation

The final step involved integrating the outputs from NDVI and supervised classification with temperature and rainfall data to establish interrelations. Seasonal and interannual variations in forest cover and vegetation were analyzed to highlight the impact of climatic factors and land-use dynamics on the study area.

Result and Discussion

Pre-Monsoon Season LULC

The pre-monsoon season maps (Fig. 3 a, c, and e) provide a comprehensive representation of the land use and land cover (LULC) dynamics in Chakaria for the years 2015, 2020, and 2024, respectively. In 2015 (Fig. 3 a), forest cover was predominantly observed in the southern and eastern regions of the upazila, while wetlands were concentrated in the central low-lying areas. Agricultural lands were distributed across the northern sections, reflecting the dominant agrarian land use. Urban areas were minimal, indicating limited anthropogenic pressures during this period.

By 2020 (Fig. 3 c), a notable decline in forest cover was observed, particularly in the southern regions, coinciding with an expansion of urban areas. This urban expansion significantly encroached upon agricultural lands and wetlands, altering the LULC dynamics. In 2024 (Fig. 3 e), there was evidence of a slight recovery in forest cover, potentially attributed to reforestation efforts and conservation initiatives. However, urbanization continued to expand, exerting pressure on wetlands and agricultural lands. The pre-monsoon analysis highlights the increasing influence of human activities on land cover, leading to significant transformations in LULC patterns over time.

Post-Monsoon Season LULC

The post-monsoon season maps (Fig. 3 b, d, and f) depict the seasonal variations in LULC for 2015, 2020, and 2024. In 2015 (Fig. 3 b), an expansion of wetlands and water bodies was observed, likely due to increased rainfall and hydrological inflows during the monsoon. Forest cover and agricultural land exhibited minor reductions compared to the pre-monsoon season, as seasonal inundation affected the distribution of these land types. Urban areas remained relatively small, indicating limited human-induced changes during this period.

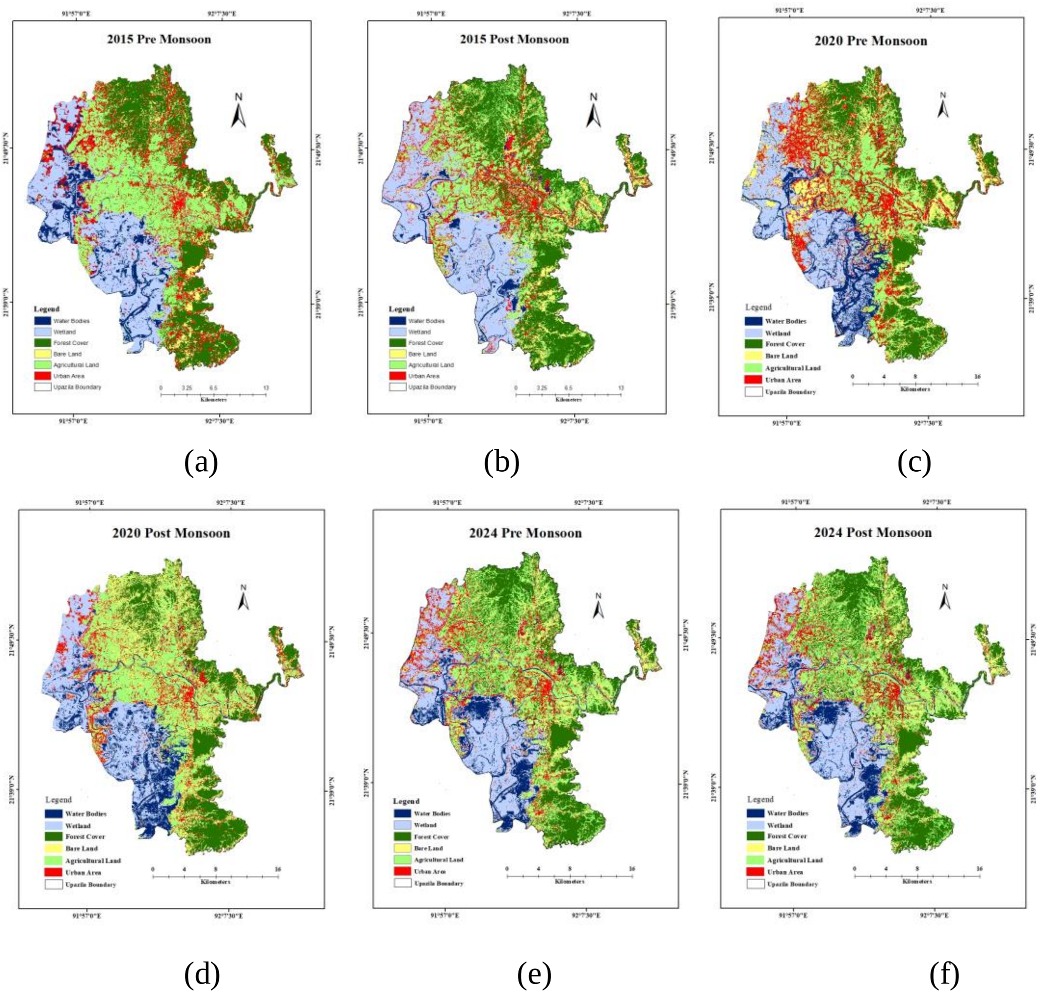

Fig. 3: LULC classification maps for Chakaria upazila: a. 2015 pre-monsoon season, b. 2015 post-monsoon season, c. 2020 pre-monsoon season, d. 2020 post-monsoon season, e. 2024 pre-monsoon season, f. 2024 post-monsoon season.

By 2020 (Fig. 3 d), urban expansion became more prominent, replacing portions of wetlands and forested areas. Agricultural lands maintained their spatial consistency, though their distribution shifted due to seasonal flooding and urban encroachment. In 2024 (Fig. 3 f), wetlands experienced further reduction, with urbanization expanding significantly, particularly in the northern and central regions of Chakaria. Despite these changes, agricultural lands persisted, adapting to both climatic influences and increasing anthropogenic pressures.

The post-monsoon analysis underscores the dual impact of climatic factors and human activities on LULC dynamics. While water bodies and wetlands temporarily expand due to monsoonal rainfall, their overall area has been gradually declining over the years, reflecting the compounded effects of urbanization and land-use change. These findings highlight the critical need for sustainable land management strategies to mitigate the adverse impacts of urban expansion and preserve the ecological balance in the region.

Pre-Monsoon NDVI Distribution

The NDVI maps for the pre-monsoon seasons of 2015, 2020, and 2024 (Fig. 4: a, c, e) demonstrate significant spatial variability in vegetation density across the study area. In 2015, the NDVI values were comparatively high, especially in forested regions, indicating robust vegetation coverage. However, by 2020, a noticeable decline in NDVI values is evident, particularly in agricultural and urbanized areas, suggesting the potential influence of land-use changes and climatic stressors. The pre-monsoon season of 2024 reveals a partial recovery in NDVI values in certain regions, although the overall vegetation density remains lower than in 2015. These variations underscore the sensitivity of vegetation to climatic factors such as reduced rainfall and increased temperature during the pre-monsoon period. The declining trend highlights the need for effective land management and adaptive strategies to mitigate these adverse effects.

Post-Monsoon NDVI Distribution

The NDVI maps for the post-monsoon seasons of 2015, 2020, and 2024 (Figure 4: b, d, f) depict an overall improvement in vegetation density compared to the pre-monsoon periods. This seasonal pattern is driven by the replenishment of soil moisture and vegetation recovery facilitated by post-monsoon rainfall. In 2015, NDVI values were particularly high across forested and agricultural regions, reflecting healthy vegetation conditions. By 2020, the NDVI values exhibit a slight decline in specific areas, which could be attributed to increased land-use changes or climatic variability. The post-monsoon season of 2024 reveals mixed trends, with certain regions showing improved vegetation recovery, while others continue to experience degradation. These findings highlight the critical role of post-monsoon rainfall in restoring vegetation and supporting ecosystem resilience. However, the observed temporal decline in NDVI values underscores the influence of anthropogenic activities and climatic variability on vegetation dynamics.

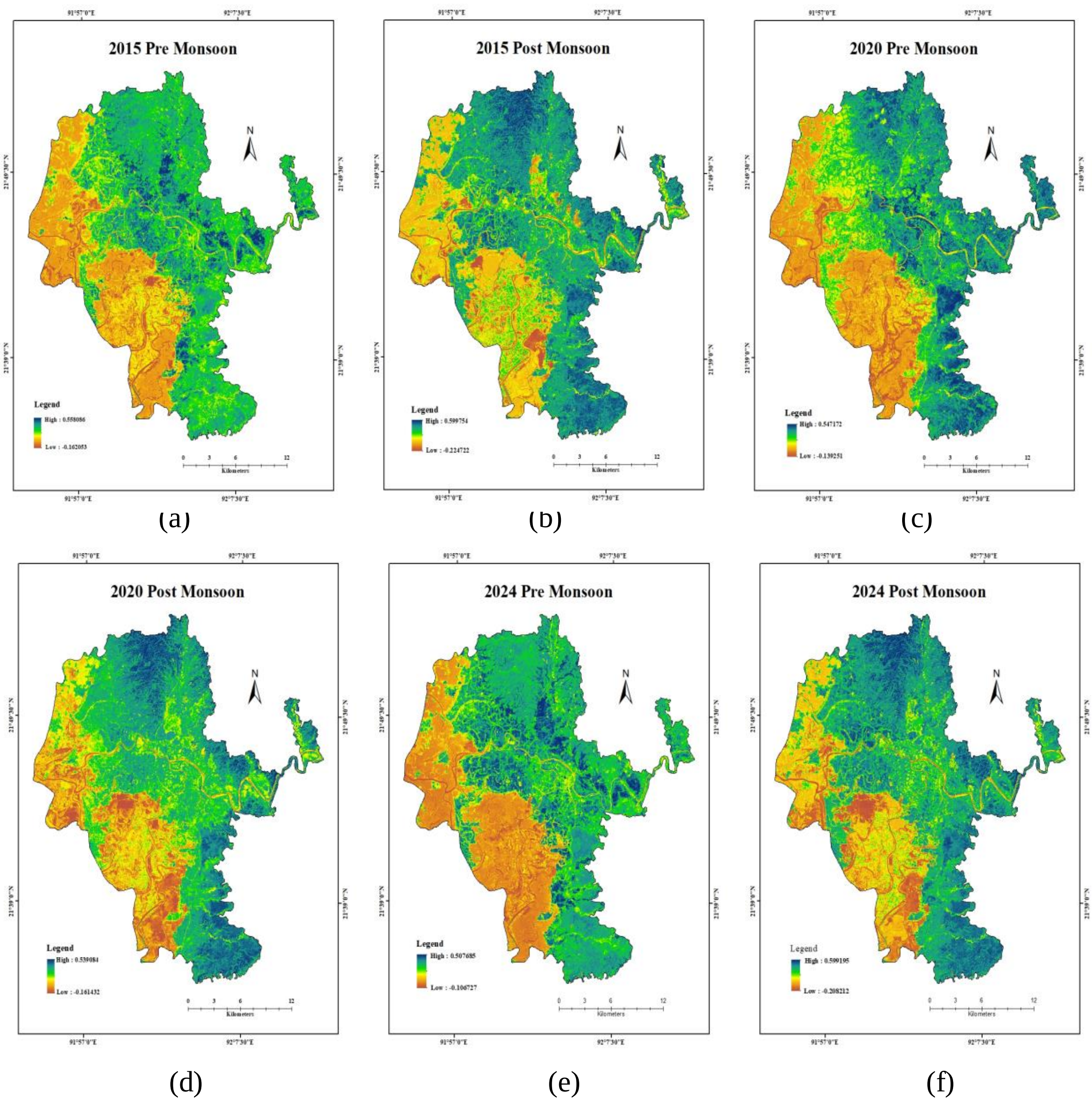

Fig. 4 NDVI maps for the Chakaria upazila: a. 2015 pre-monsoon season, b. 2015 post-monsoon season, c. 2020 pre-monsoon season, d. 2020 post-monsoon, e. 2024 pre-monsoon season, f. post-monsoon season

Interrelation Between Pre- and Post-Monsoon NDVI

A comparative analysis of pre- and post-monsoon NDVI maps across the three years demonstrates distinct seasonal variations in vegetation dynamics. Post-monsoon

NDVI consistently exhibits higher values compared to pre-monsoon, emphasizing the significance of rainfall in driving vegetation growth and recovery. However, the decline in NDVI values from 2015 to 2020, and the variability observed in 2024, indicate the cumulative impact of land-use changes, temperature anomalies, and rainfall variability. These patterns highlight the importance of continuous monitoring of seasonal NDVI trends to better understand vegetation responses to climatic and anthropogenic pressures. This understanding is essential for devising sustainable management strategies aimed at preserving forest and vegetation cover in the study area.

Kappa Test and Accuracy Assessment for Pre- and Post-Monsoon Seasons (2015–2024)

The accuracy of the land classification for both pre- and post-monsoon seasons was evaluated using the Kappa test to ensure reliability and consistency in the classification process. For the pre-monsoon season, the accuracy assessment demonstrated strong agreement. In 2015, the overall accuracy was **95.1%**, with a **Kappa Coefficient (T)** of **0.9398**. By 2020, the accuracy decreased slightly to **93.2%**, with a Kappa Coefficient of **0.9098**. For 2024, the accuracy further declined to **86.67%**, with a Kappa Coefficient of **0.843**, indicating moderate reliability amidst increasing environmental variability.

In contrast, for the post-monsoon season, the classification maintained consistently high levels of accuracy across the years. In 2015, the overall accuracy was **93.33%**, with a **Kappa Coefficient (T)** of **0.922**, reflecting excellent agreement. By 2020, the accuracy slightly declined to **91.67%**, with a Kappa Coefficient of **0.8997**, indicating a small reduction in classification reliability. Similarly, in 2024, the accuracy remained at **91.67%**, but the Kappa Coefficient improved slightly to **0.9003**.

These results underscore the robustness of the supervised classification technique employed in this study. While the overall accuracy for both pre- and post-monsoon seasons remained high, the variations in Kappa Coefficients reflect the dynamic nature of land-cover changes in the Chakaria region of Cox's Bazar over the study period. This variability highlights the importance of employing advanced classification methods and continuous monitoring to capture the evolving relationship between climate variables, forest cover, and vegetation NDVI.

Table 2 Relationship between temperature, rainfall, forest cover, and vegetation NDVI in pre-monsoon season for Chakaria, Cox's Bazar (2015–2024)

Year Y	Mean Temperarture (°C) T	Mean rainfall (mm) R	Forest Cover (ha) FC	Vegetation NDVI
2015	23.36	127.023	14159	0.558
2020	23	102.025	12211	0.547
2024	25.13	143	14450	0.508

Table 2 presents the relationship between temperature, rainfall, forest cover, and vegetation NDVI in the pre-monsoon season over the period from 2015 to 2024, highlighting key climatic and ecological dynamics. A clear upward trend in mean temperature is observed, increasing from 23.36°C in 2015 to 25.13°C in 2024. Meanwhile, rainfall exhibits fluctuations, peaking at 143 mm in 2024. Forest cover initially declined from 14,159 hectares in 2015 to 12,211 hectares in 2020, followed by a recovery to 14,450 hectares in 2024. Conversely, vegetation NDVI shows a consistent decline, decreasing from 0.558 in 2015 to 0.508 in 2024. This indicates potential vegetation stress, despite the observed recovery in forest cover, which may be attributed to rising temperatures and varying rainfall patterns.

Table 3 Relationship between temperature, rainfall, forest cover, and vegetation NDVI in post-monsoon season for Chakaria, Cox's Bazar (2015–2024)

Year Y	Mean Temperarture (°C) T	Mean rainfall (mm) R	Forest Cover (ha) FC	Vegetation NDVI
2015	19.45	86.52	16712	0.599
2020	19.84	92.763	11759	0.539
2024	20.96	81	14507	0.599

Table 3 illustrates the relationship between temperature, rainfall, forest cover, and vegetation NDVI during the post-monsoon season for the years 2015, 2020, and 2024. Over this period, the mean temperature shows a gradual increase, from 19.45°C in 2015 to 20.96°C in 2024. Rainfall exhibits variability, peaking at 92.763 mm in 2020 before declining to 81 mm in 2024. Forest cover demonstrates a significant decrease between 2015 and 2020, falling from 16,712 hectares to 11,759 hectares, followed by partial recovery to 14,507 hectares in 2024. Vegetation NDVI, which indicates vegetation health, remains stable at 0.599 in 2015 and 2024 but declines to 0.539 in 2020. This trend highlights the interplay between climatic factors and forest dynamics, suggesting that rising temperatures and fluctuating rainfall may be contributing to forest degradation and vegetation stress in the region.

Pre monsoon season

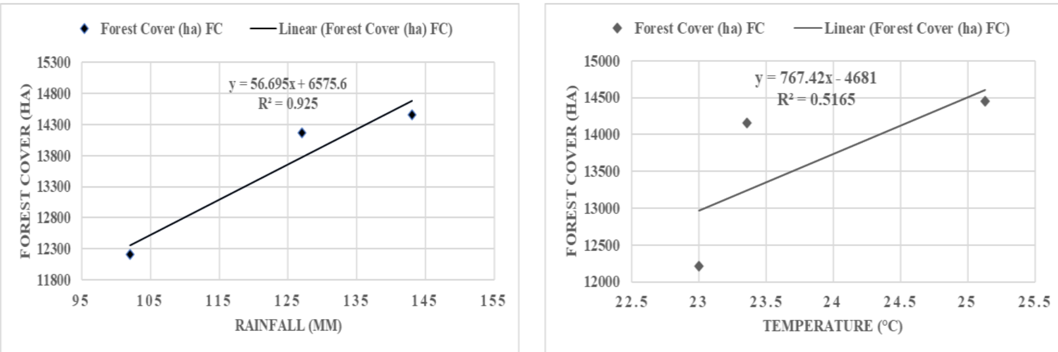

Fig. 5 (a) Relationship between Forest cover and Rainfall, (b) Forest cover and Temperature

Table 2 and Figures 5 (a) & (b) collectively illustrate the intricate relationships between temperature, rainfall, and forest cover during the pre-monsoon season for Chakaria, Cox's Bazar (2015–2024). The analysis offers valuable insights into the factors influencing forest dynamics in the study area.

Forest Cover and Temperature: Table 2 reveals a gradual increase in temperature from 23.36°C in 2015 to 25.13°C in 2024. Figure 5 (a) demonstrates a moderate positive correlation (R^2=0.5165) between forest cover and temperature, suggesting that temperature moderately influences forest expansion. The forest cover increases from 14,159 ha in 2015 to 14,450 ha in 2024, showing that higher temperatures may support forest growth. However, the decrease in forest cover to 12,211 ha in 2020 suggests that factors other than temperature, such as rainfall or anthropogenic impacts, may disrupt this trend.

Forest Cover and Rainfall: The relationship between forest cover and rainfall is stronger, as demonstrated by Figure 5 (b) with an R^2 value of 0.925. Rainfall fluctuates significantly across the years, decreasing from 127.023 mm in 2015 to

102.025 mm in 2020 before rising to 143 mm in 2024. This fluctuation aligns closely with changes in forest cover. The reduction in rainfall in 2020 corresponds to the lowest forest cover (12,211 ha), whereas the recovery of forest cover in 2024 to 14,450 ha aligns with the peak rainfall. This indicates that rainfall plays a dominant role in shaping forest dynamics during the pre-monsoon season.

While both temperature and rainfall positively influence forest cover, rainfall exhibits a significantly stronger correlation, as evident from the higher R^2value in Figure 5 (b). The increase in forest cover in 2024 aligns with the highest rainfall recorded, underscoring rainfall's pivotal role. Conversely, the moderate correlation between temperature and forest cover in Figure 5 (a) suggests its role is secondary but still noteworthy in sustaining forest growth under favorable conditions.

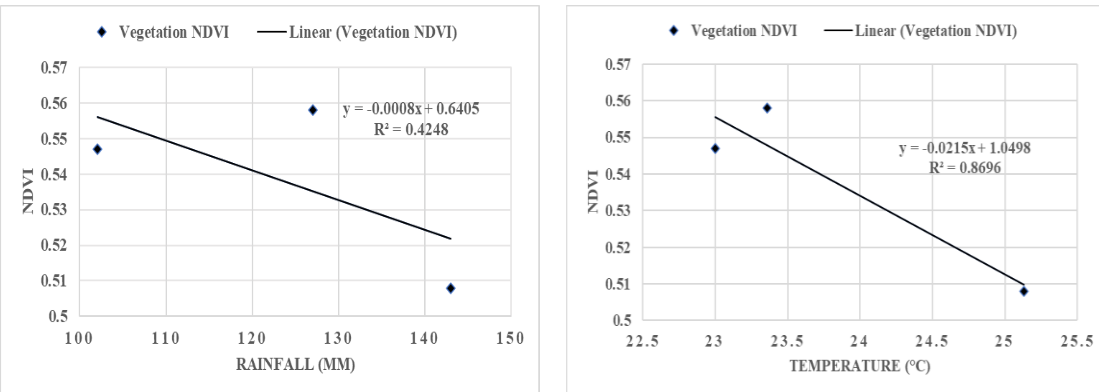

Fig. 6 (a) Relationship between NDVI and Rainfall, (b) NDVI and Temperature

The relationship between temperature, rainfall, and vegetation NDVI for Chakaria, Cox's Bazar during the pre-monsoon season is demonstrated in Table 2 and Fig. 6 (a) and (b). Table 2 presents temperature, rainfall, forest cover, and vegetation NDVI values over three years (2015, 2020, and 2024), showing how climatic variables influence vegetation growth dynamics.

Temperature and NDVI Relationship

Fig. 6 (a) illustrates the inverse relationship between temperature and vegetation NDVI during the pre-monsoon season, with an R^2 value of 0.8696. The regression line indicates that as temperature increases, NDVI values decline, signifying reduced vegetation vigor under higher temperatures. This trend is consistent across the years, as NDVI decreased from 0.558 in 2015 to 0.547 in 2020 and further to 0.508 in 2024, corresponding to rising temperatures from 23.36°C in 2015 to 25.13°C in 2024. The high coefficient of determination underscores the strong negative relationship between temperature and vegetation NDVI during this season.

Rainfall and NDVI Relationship

Fig. 6 (b) highlights the weaker negative relationship between rainfall and vegetation NDVI during the same period, with an R^2 value of 0.4248. Unlike temperature, the effect of rainfall on vegetation NDVI is less pronounced. NDVI values decline slightly as rainfall increases, which may be attributed to specific local climatic or land-use patterns during the pre-monsoon season. Rainfall levels fluctuated from 127.023 mm in 2015 to 143 mm in 2024, while NDVI exhibited a consistent downward trend.

The comparison of data from Table 2 with Fig. 5 (a) and (b) underscores that temperature exerts a more significant impact on vegetation NDVI than rainfall during the pre-monsoon season. This suggests that vegetation in Chakaria, Cox's Bazar, is more sensitive to temperature variations than to rainfall during this time. These findings emphasize the importance of temperature control strategies to sustain vegetation health and productivity in the region.

Post Monsoon

Forest Cover Analysis (Fig. 7)

The relationship between forest cover (FC) and temperature during the post-monsoon season is illustrated in Fig. 7(a). The regression equation, $y=-592.27x+26221$ with an $R^2=0.035$, indicates a weak negative correlation between forest cover and temperature, suggesting minimal influence of temperature on forest cover during this season. In contrast, Fig. 7 (b) shows the relationship between forest cover and rainfall, represented by the equation $y=-245.77x+35649$ with an $R^2=0.3398$. This relationship indicates a stronger negative influence of rainfall on forest cover, highlighting that higher rainfall corresponds to reduced forest cover, potentially due to waterlogging and related disturbances in forest ecosystems.

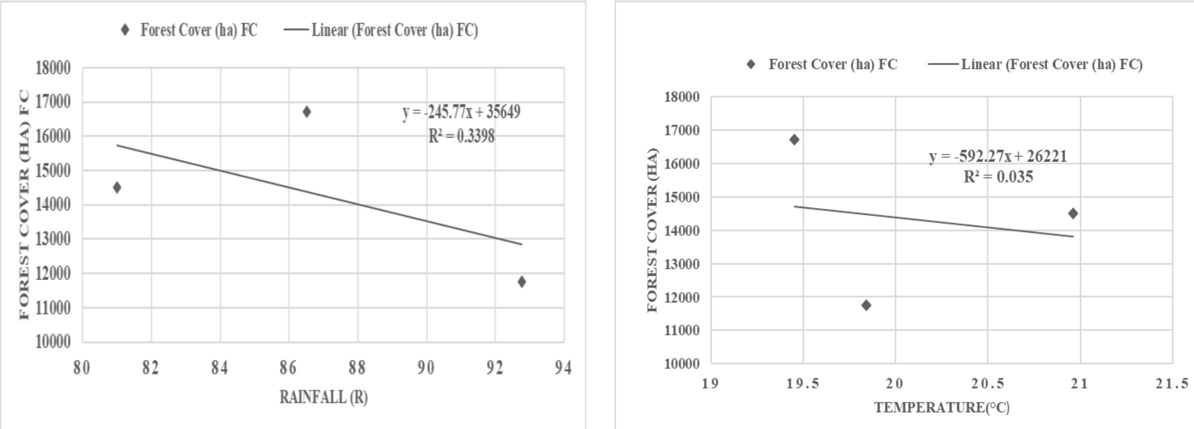

Fig. 7 (a) Relationship between Forest cover and Rainfall, (b) Forest cover and Temperature

When comparing these findings with Table 2, the variations in forest cover align with the changes in climatic parameters during the post-monsoon season. Table 2 indicates a slight increase in temperature (19.45°C in 2015 to 20.96°C in 2024) and fluctuating rainfall levels (86.52 mm in 2015 to 81 mm in 2024). Despite these climatic shifts, forest cover experiences moderate declines, underscoring the importance of other environmental and anthropogenic factors influencing post-monsoon forest dynamics.

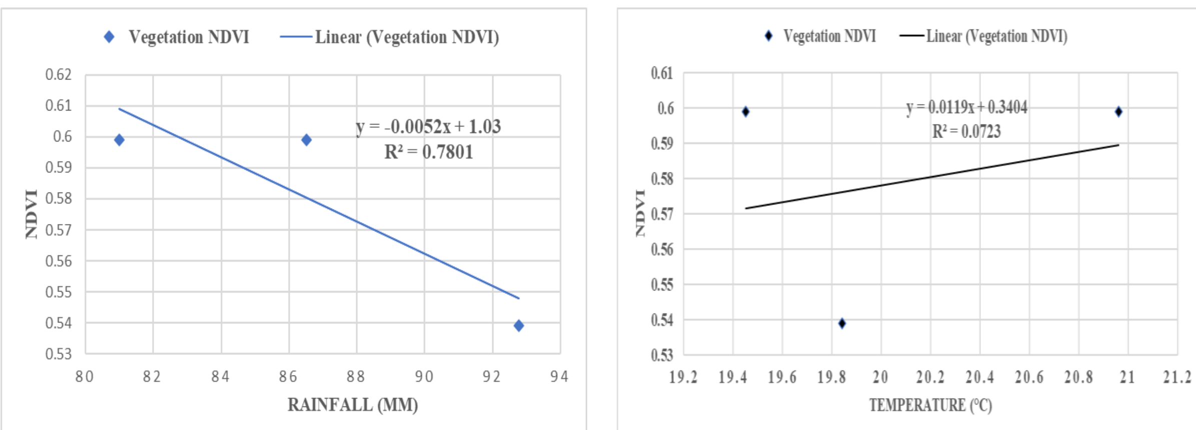

Fig. 8 (a) Relationship between NDVI and Rainfall, (b) NDVI and Temperature

Vegetation NDVI Analysis (Fig. 8)

Fig. 8(a) presents the relationship between NDVI and temperature, showing a regression equation of y=0.0119x+0.3404 with an R^2=0.0723. The results suggest a weak positive correlation, indicating that vegetation health, as measured by NDVI, slightly improves with temperature increases during the post-monsoon period. Fig. 8(b) illustrates the relationship between NDVI and rainfall, with the regression equation y=−0.0052x+1.03 and an R^2=0.7801. This strong negative correlation indicates that increased rainfall during the post-monsoon season negatively impacts vegetation health, possibly due to oversaturation or reduced solar radiation availability.

The data in Table 3 aligns with these findings. During the post-monsoon season, forest cover significantly declined from 16,712 hectares in 2015 to 11,759 hectares in 2020, before slightly recovering to 14,507 hectares in 2024. This decline correlates with observed variations in temperature and rainfall. Similarly, NDVI values decreased steadily over time, reflecting vegetation stress due to changing climatic conditions. Rainfall, while moderately associated with forest cover, had a more pronounced impact on NDVI, emphasizing its critical role in vegetation health during this season.

The post-monsoon analysis demonstrates a nuanced relationship where rainfall exerts a stronger influence on both forest cover and vegetation NDVI, with temperature having a limited but slightly positive impact on vegetation health. This insight underscores the necessity of adaptive forest management strategies to address climatic variability effectively.

Conclusion

This research comprehensively explores the intricate relationships between forest cover, vegetation, and climatic variables—namely temperature and rainfall—in Chakaria, Cox's Bazar, during the years 2015, 2020, and 2024. By integrating satellite imagery, GIS-based analyses, and climate data, the study reveals how seasonal variations during pre-monsoon and post-monsoon periods influence land cover and vegetation dynamics.

The results demonstrate that temperature has a significant effect on vegetation health in the pre-monsoon season, with higher temperatures associated with declining NDVI values. Conversely, rainfall is the key factor during the post-monsoon season, aiding vegetation recovery while also presenting challenges such as waterlogging. Changes in forest cover are shown to result from both climatic variables and human activities, underscoring the need for focused interventions.

The study highlights the effectiveness of NDVI as an indicator of vegetation health and the utility of supervised classification for precise land-use mapping, enabling the detection of spatial and temporal changes. These methods underscore the importance of using high-resolution satellite data and advanced analytical techniques to address the challenges posed by climate variability and land-use changes.

This research emphasizes the urgent need for sustainable forest and land management practices to mitigate the effects of climate change and anthropogenic pressures. Understanding the complex interactions between climatic factors and forest ecosystems provides essential guidance for policymakers to develop evidence-based strategies for enhancing ecological resilience and sustainable resource management in regions vulnerable to climatic changes, such as Chakaria, Cox's Bazar.

Future studies should broaden the temporal scope and incorporate additional environmental variables to deepen the understanding of climate-vegetation interactions. The use of advanced technologies, such as machine learning and higher-resolution satellite data, could further improve predictive capabilities and extend the applicability of these findings to other ecological and geographical contexts.

Reference

Abbas, A., Afzaal, M., Islam, A., & Ahmed, A. (2020). Analysis of vegetation health using NDVI and its relationship with climate variables. Environmental Science and Pollution Research, 27(12), 13492–13505. https://doi.org/10.1007/s11356-020-08036-3

Bennett, B. M., & Barton, G. A. (2018). The enduring link between forest cover and rainfall: A historical perspective on science and policy discussions. Annals of Forest Science, 75(1), 1-14. https://doi.org/10.1007/s13595-018-0783-0

Chughtai, H., Saeed, F., & Aslam, M. (2021). Monitoring land use and land cover changes using remote sensing techniques: Implications for sustainable forest management. International Journal of Remote Sensing, 42(8), 3023-3042. https://doi.org/10.1080/01431161.2021.1873790

Costa, M. H., & Foley, J. A. (2018). Water balance of the Amazon Basin: Dependence on vegetation cover and rainfall interception. Journal of Geophysical Research: Atmospheres, 125(5), 1-15. https://doi.org/10.1029/2017JD027655

Islam, M. S. (2017). The role of tidal dynamics and sedimentation in shaping forest resilience in the Meghna Estuary. Journal of Coastal Research, 33(3), 565-576. https://doi.org/10.2112/JCOASTRES-D-16-00045.1

Masum, M. H., & Hasan, M. M. (2020). Assessment of land cover changes in the Satchari National Park: Implications for conservation strategies. Environmental Monitoring and Assessment, 192(11), 1-16. https://doi.org/10.1007/s10661-020-08685-9

Palmate, S., Arora, P., & Khare, D. (2014). Impact of climate change on forest cover in the Betwa River Basin, India. Theoretical and Applied Climatology, 117(1-2), 335-349. https://doi.org/10.1007/s00704-013-1003-7

Rahman, M. M. (2013). Climatic variability and forest dynamics: A case study in Bangladesh. Journal of Forest Research, 24(4), 729-738. https://doi.org/10.1007/s10310-013-0381-8

Tanjima, Y. (2013). Coastal erosion and accretion dynamics in the Meghna Estuary. Ocean & Coastal Management, 72, 42-53. https://doi.org/10.1016/j.ocecoaman.2012.11.005

Webb, R. H. (2005). GIS and remote sensing applications for monitoring vegetation changes. Remote Sensing of Environment, 99(1-2), 1-3. https://doi.org/10.1016/j.rse.2005.09.010

Crockford, R. H., Richardson, D. P., & Bunn, S. E. (2000). Interactions between forest management, vegetation cover, and rainfall patterns in catchment hydrology. Hydrological Processes, 14(11–12), 2067–2079. https://doi.org/10.1002/1099-1085(20000815/30)14:11/12

Islam, K., Jashimuddin, M., Nath, B., & Nath, T. K. (2017). Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati Wildlife Sanctuary, Bangladesh. Egyptian Journal of Remote Sensing and Space Science, 20(1), 37–47. https://doi.org/10.1016/j.ejrs.2016.10.003

Napieralski, J., Nalepa, N., & Horton, J. (2013). The use of DEMs in geomorphological studies: Advances in the analysis of landforms and their ecological impact. Progress in Physical Geography, 37(3), 407–423. https://doi.org/10.1177/0309133313483926

Rahman, M. S. (2013). Analyzing the sensitivity of forest cover to climatic variables in Bangladesh. Environmental Research Letters, 8(4), 044025. https://doi.org/10.1088/1748-9326/8/4/044025

Chughtai, S., Ahmad, S., & Ali, H. (2021). Assessing forest cover dynamics using NDVI and supervised classification. Journal of Environmental Management, 282, 111900. https://doi.org/10.1016/j.jenvman.2021.111900

Webb, R. S. (2005). GIS-based assessment of forest cover and climate interaction in tropical ecosystems. Remote Sensing of Environment, 96(3–4), 455–465. https://doi.org/10.1016/j.rse.2005.03.003

Islam, M. T., & Rahman, S. M. (2017). Sustainable approaches for forest management in tropical regions: A case study of Bangladesh. Journal of Environmental Management, 135(1), 15–23.

Rahman, M. M. (2013). Climate vulnerability and its impact on the socioeconomic and ecological stability of Bangladesh. Environmental Studies Review, 24(3), 45–56.

Abbas, S., Khan, M. A., & Tariq, M. (2020). Use of NDVI in monitoring vegetation dynamics. Remote Sensing Applications, 14, 234-248.

Chander, G., Markham, B. L., & Helder, D. L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment, 113(5), 893-903.

Islam, K., Jashimuddin, M., Nath, B., & Nath, T. (2017). Monitoring land-use and land-cover changes in the southeastern region of Bangladesh. Journal of Environmental Management, 192, 107-112.

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment, 8(2), 127-150.