A CASE STUDY ON LAND USE AND LAND COVER CHANGES IN SPECIFIC AREAS IN CHATTOGRAM CITY CORPORATION

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ABSTRACT

Chattogram, the port city of Bangladesh, has recently endured severe flooding, flash flooding, and waterlogging during the monsoon season. The aforementioned catastrophes have affected Chattogram for many years and as a result of global warming and climate change, their frequency and severity have increased. Low-lying portions of this coastal city are only 2.5 to 3 meters above sea level, although the average height of high tide is about 5 meters. Floods recently disrupted public life by becoming more bothersome than ever. The city used to have a lot of bodies of water. Water used to be discharged into such bodies of water during high tides and periods of heavy rainfall and low tides it tends to go back to the sea by canals and rivers. However, as the population increased and the city was unintentionally urbanized, canals and rivers were encroached upon and the area of the city increased. Now, extra water from rain and tide cannot drain naturally through the natural drainage system or be absorbed by the land and water bodies. Additionally, the city produces more waste which is deposited in the canals because of the growing population.

The study focuses on the LULC changes within specific areas—Halishahar, Patenga, Double Mooring, and Kotwali—using GIS overlays and Impact Observatory 10m land cover data based on ESA Sentinel-2 imagery. These high-resolution LULC maps capture the dynamic shifts in urban, industrial, and natural landscapes between 2017 and 2022. The analysis extends to understanding the correlation between these changes and atmospheric factors such as temperature and rainfall. Historical data reveal that these areas have experienced significant alterations, especially in built-up areas, green spaces, and water bodies. Urban expansion has encroached upon natural drainage systems, limiting water flow during rainfall and tides. The rise in population contributes to increased waste, affecting canals and exacerbating environmental challenges. This study seeks to comprehensively explore the implications of LULC changes on atmospheric conditions, with a specific focus on temperature variations and shifts in rainfall patterns. By employing advanced GIS techniques and overlay analyses, the research aims to identify the root causes of these changes, providing insights for sustainable urban development and environmental management in Chattogram City.

Keywords: *Land Use - Land Cover, GIS Overlay, Urbanization, Temperature, Rainfall.*

1. INTRODUCTION

Land degradation resulting from the rapid changes in land use and land cover (LULC), driven by both climatic variations and human activities, has become a global concern (Biro et al., 2013; Leh et al., 2013; Liu et al., 2014). While humans have historically modified land for survival, the accelerated pace of exploitation has led to profound alterations in ecosystems and environmental processes at local, regional, and global scales (Vitousek et al., 1997). Spatial detection of land use changes is crucial for developing effective land management and planning strategies, particularly in coastal areas (Muttitanon & Tripathi, 2005; Kashaigilia & Majaliwa, 2013). Bangladesh, home to the world's largest delta, encompasses a coastal area of 47,201 km², constituting approximately 32% of the country's land area (Islam, 2004). The utilization of Landsat data for monitoring urban expansion and associated land cover changes has become a prevalent approach, widely adopted by researchers and practitioners alike (Kalnay and Cai 2003; Carlson and Arthur 2000; Turner et al., 2007). In recent years, Chattogram, the second most populous city in Bangladesh with 1,736 people/km² (Population & Housing Census 2022), has experienced exponential growth. From studies it was identified that urban area/built area was the most dominant land use type resulted from the conversion of agricultural land and rural settlement which increased during the period of 28 years in CMA (Chattogram Metropolitan Area) region with an expansion rate of 2.25% (Roy, S. et. al., 2020). The built-up areas in Chattogram City exhibited a consistent annual growth trend, ranging from 0.42 % to 4.80 % in contrast, waterbodies experienced a declining trend, with an annual decrease ranging from 2.06 % to 5.16 %. Conversely, cropland significantly decreased over the 20 years, with an average yearly decrease ranging from 3.36 % to 22.64 % (Biswas et al., 2023). Serving as the industrial and commercial hub of Bangladesh, Chattogram has undergone significant urbanization, particularly in areas proximate to the export processing zone, the Bay of Bengal, and the Karnaphuli River, which hosts the Chattogram Sea Port. As a result, the city regularly undergoes sever water-logging problems. 22 wards among 41 wards of the city were found as waterlogging-affected, as well as 8.42% of city area has been found to be severely water-logged (Islam et al., 2021). Given this context, the study focuses on areas affected by the observed circumstances, specifically targeting Halishahar, Patenga, Double Mooring, and Kotwali. However, it's crucial to acknowledge that conducting a comprehensive analysis is hindered by limitations in geospatial data quality and availability for urban areas in Bangladesh. The constraints imposed by limited resources have resulted in a scarcity of detailed geospatial data. Spatial information and digital maps of cities are often inadequate, either due to their non-existence or poor quality. In instances where maps are available, they may be outdated or classified as restricted information, posing challenges for public departments in terms of accessibility (Nazem et al., 2015). These constraints underscore the need for careful consideration of data limitations in the study's scope and interpretation of results. The primary objective of this case study is to scrutinize the alterations in land cover within the Halishahar, Patenga, Double Mooring, and Kotwali areas under Chattogram City from 2017 to 2022. The study aims to explore the impacts of these changes, ascertain the trends associated with these transformations, and evaluate their consequences. Additionally, the study will also investigate the average temperature variations resulting from the observed land cover changes. In light of the substantial effects of land-use change on ecological variables and climate change, this study extends its focus to changes in precipitation and temperature. In recent centuries land-use change has had significant effects on ecological variables and climate change (Pawan Thapa, 2021).

2. STUDY AREA

The study was conducted in four specific areas within Chattogram City, namely: (a) Halishahar (22°20′12.12″N 91°46′29.64″E), (b) Patenga (22.2359795°N 91.7868103°E), (c) Double Mooring (22°20.3′N 91°48.5′E), and (d) Kotwali (22°20.3′N 91°50.3′E) (refer to Figure 1). These areas encompass significant commercial and industrial zones. Additionally, their proximity to the Bay of Bengal and Karnaphuli river subjects them to recurrent urban flooding during the monsoon, a consequence of rapid urban growth in the region. Figure 1 depicts the entire Chattogram Metropolitan

Area based on Thana Boundaries, with the areas under investigation (Halishahar, Double Mooring, Kotwali, and Patenga) delineated for reference.

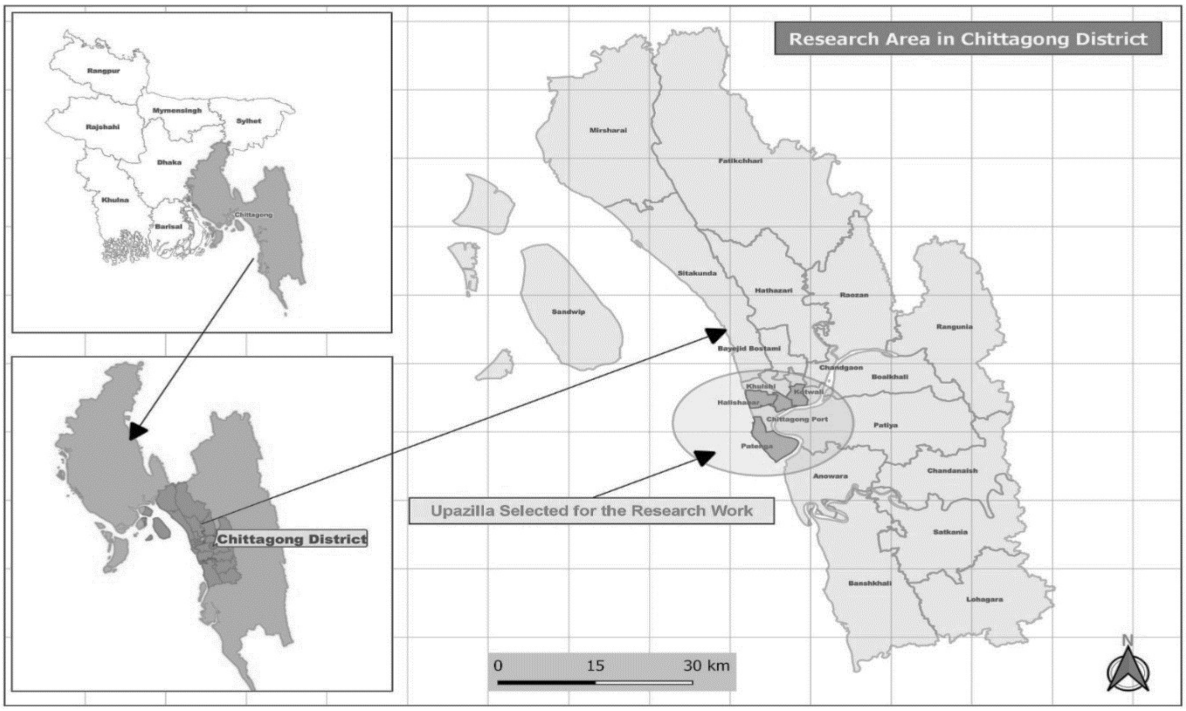

Figure 1: Study Areas: (a) Halishahar, (b) Patenga, (c) Double Mooring and (d) Kotwali.

3. METHODOLOGY

3.1 Data Acquisition and Preparation

The land use and land cover maps for the designated four study regions were acquired from the Impact Observatory 10m land cover maps, accessible through the Land Cover Explorer application. This tool grants entry to 700 distinct 10-meter resolution Geo TIFF files for every year within the Sentinel-2 Land Use/Land Cover map, collaboratively generated by Esri, Microsoft, and Impact Observatory. Developed from ESA Sentinel-2 imagery, the map constitutes a compilation of forecasts for nine land use/land cover categories for each year, encompassing the period from 2017 to 2021. This comprehensive cartographic resource proves invaluable for scrutinizing diverse land use/land cover configurations. These maps, derived from ESA Sentinel-2 imagery at a 10-meter resolution, present amalgamated forecasts of Land Use and Land Cover (LULC) across nine distinct categories, resulting in comprehensive LULC maps. The anticipated data adheres to the Universal Transverse Mercator (UTM) with a Mosaic Projection in WGS84. Within the scope of this case study and for the designated regions, the ascertained LULC classes encompass Bare Ground, Built Area, Crops, Flooded Vegetation, Rangeland, Trees, and Water, spanning the period from 2017 to 2022. Table 1 provides a detailed depiction of these categorized LULC classes.

Table 1: LULC Classes.

Land Cover Classes	Description
Bare Ground	Areas of rock or soil with very sparse to no vegetation for the entire year; large areas of sand with little to no vegetation; examples: exposed rock or soil, desert, dry salt flats, dry lake beds
Built Area	Artificial, impervious surfaces in the form of individual features, parts of features, or tight clusters of features with little to no mixed vegetation or bare ground.
Crops	Humans planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, and fallow plots of parcelled land.

Flooded Vegetation	Areas of vegetation with obvious intermixing of water throughout the majority of the given period; mostly herbaceous (non-woody) vegetation and/or scattered tree (mangrove)/scrub/shrub cover.
Rangeland	Healthy, closely packed vegetation that is predominantly dense, short (under 5m) woody shrubs with very little to no mixed grass or bare ground cover.

Additionally, in conjunction with the LULC change projection, an examination of alterations in other meteorological parameters, such as temperature and rainfall, for the designated areas was conducted. This meteorological data was sourced from the Bangladesh Meteorological Department and aligned with the LULC data for comprehensive analysis.

3.2 Schematic Diagram for LULC Map Generation

The process of image classification entails the conversion of multi-band raster imagery into a single-band raster with various categorical classes corresponding to different types of land cover. There are two primary methodologies for classifying a multi-band raster image: supervised and unsupervised classification. In supervised classification, the image is categorized using spectral signatures, i.e., reflectance values, derived from training samples. These samples consist of polygons representing distinct areas of different land cover types targeted for classification. Conversely, the unsupervised classification method employed by the Land Cover Exploration source identifies spectral classes or clusters within the multi-band image. Following cluster identification, the classification of each cluster into specific land cover categories (e.g., water, bare earth, dry soil, etc.) is conducted. The schematic diagram in Figure 2 illustrates the stepwise process of obtaining the Land Use/Land Cover (LULC) maps.

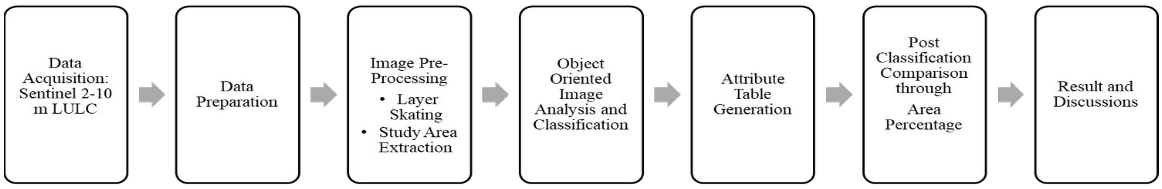

Figure 2: Schematic Diagram for LULC Map Generation.

4. RESULT AND ANALYSIS

4.1 Variation in LULC-Generated Maps and Data

In general, being the commercial and industrial hub for Bangladesh, Chattogram has seen rapid urbanization and industrialization resulting in significant land use changes. The distribution of land use/land cover change for 2017-2019 is demonstrated in Figure 3 and Figure 4 demonstrates the same for 2018-2022:

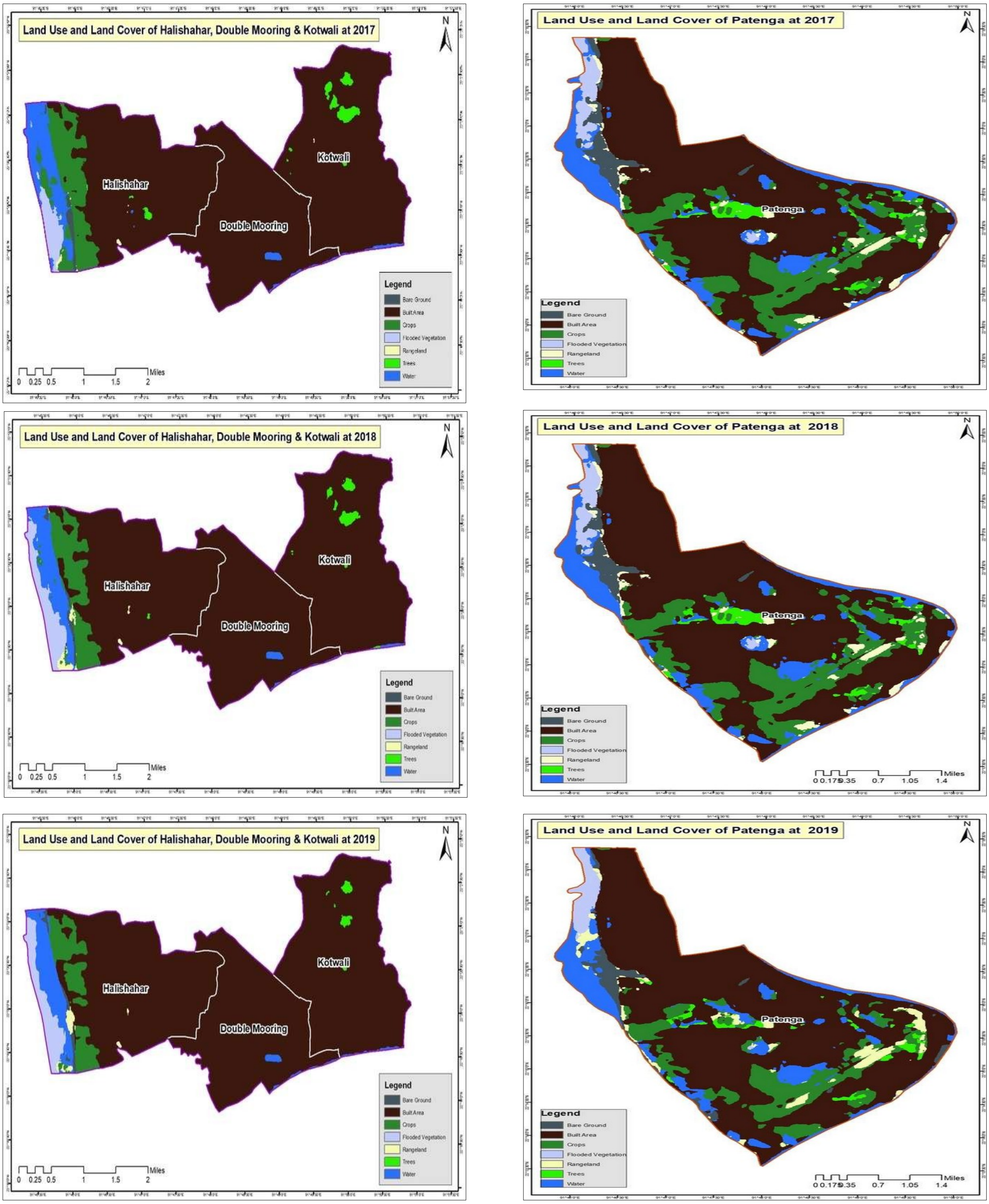

Figure 3: Land Use / Land Cover Maps for Halishahar, Double Mooring, Kotwali, and Patenga from 2017 to 2019.

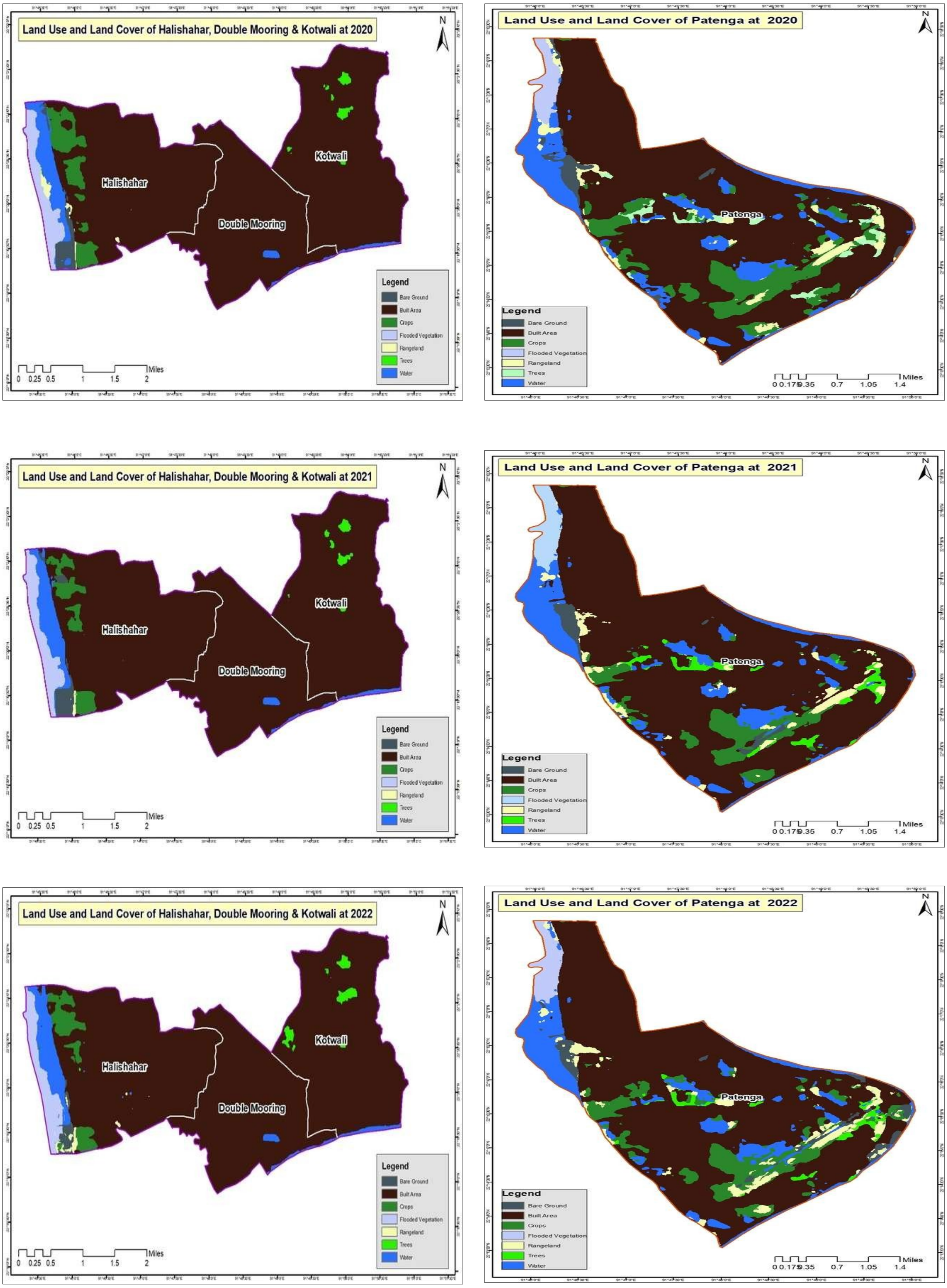

Figure 4: Land Use / Land Cover Maps for Halishahar, Double Mooring, Kotwali, and Patenga from 2020 to 2022.

4.2 LULC Data Analysis

Table 2 depicts the changes in land use and land cover across Halishahar (HL), Double Mooring (DM), and Kotwali (KT) during the specified study years. In 2017, about 84.16% of the total area in these regions was marked as built-up, indicating the growth of residential and industrial areas. Only 5.065% was designated as water bodies, showing the impact of urbanization, and there was a decrease in crop-covered areas. By 2018, the land covered by trees dropped by 0.777%, while the built-up area increased to 85.24%. This suggests an ongoing trend of urbanization and a decrease in green spaces. The reduction in tree-covered areas could be due to increased urban development, where green spaces are cleared for construction. The rise in built-up areas may be driven by population growth and economic activities, leading to the need for more urban space. These changes align with global urbanization trends, reflecting societal and economic shifts in these regions.

Table 2: Land Use and Land Cover of Halishahar, Double Mooring & Kotwali in Different LULC Classes.

Land Use and Land Cover of HL, DM & KT							
Land Use Categories							
Years	**Crops (%)**	**Rangeland (%)**	**Water (%)**	**Trees (%)**	**Built Area (%)**	**Flooded Vegetation (%)**	**Bare Ground (%)**
2017	7.201	0.125	5.065	1.15	84.165	1.793	0.51
2018	5.621	0.473	4.493	0.777	85.24	3.015	0.389
2019	4.738	0.467	4.502	0.429	86.227	3.15	0.496
2020	3.763	0.409	3.84	0.575	86.906	3.197	1.318
2021	2.473	0.1	3.931	0.568	88.436	3.31	1.191
2022	2.729	0.373	4.194	0.915	87.814	3.345	0.63

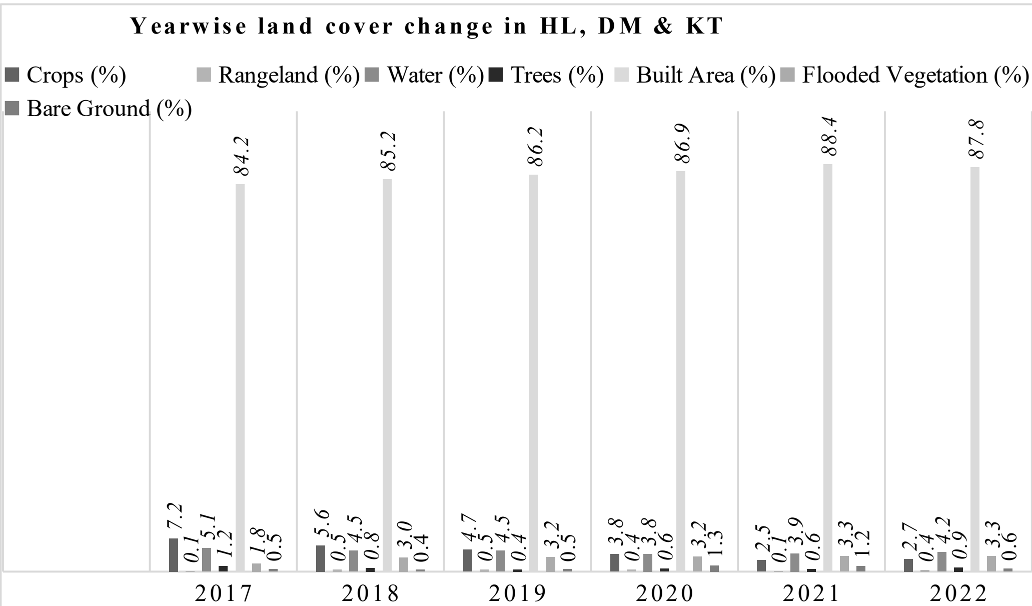

Figure 5: Year-wise land cover change in Halishahar, Double Mooring, and Kotwali.

In 2019, the predominant land use in the studied areas was in the built-up category, covering 86.227% of the total area. This expansion in built-up areas coincided with a decrease in crop land, which accounted for 4.738% of the city. The continuous urban expansion further contributed to a reduction in tree-covered areas. In 2020, there was a notable decline in the extent of water bodies, decreasing to 3.84% from the previous year. Similarly, the area dedicated to crops diminished, registering at 3.763%. By 2021, land use was predominantly characterized by built-up areas, covering about 88.436% of the total area. Like previous years, the coverage of areas with trees remained relatively low at 0.568%. Water bodies covered 4.194% of the land, while the area dedicated to crops decreased to 2.729% in 2022. This trend underscores the continued impact of urban expansion on land use patterns in the specified regions. Table 3 provides an overview of the Land Use Categories for Patenga (PT) in 2017, indicating that water bodies covered 10.876% of the total area, while built-up areas accounted for 62.514%. Situated away from the main city, Patenga exhibited a relatively lower proportion of built-up areas compared to the city centre. In 2018, a small portion of the land, 2.077%, was covered by trees, while crop areas reduced to 13.27%. From 2019 to 2022, there was a consistent expansion of built-up areas in Patenga, accompanied by a simultaneous decline in crop areas. In 2022, the area dedicated to crops was 9.102%, water-covered areas constituted 11.231%, areas covered by trees were 2.289%, and built-up areas reached 68.847%. This pattern reflects the ongoing urbanization and changes in land use dynamics in the Patenga region over the specified years.

Table 3: Land Use and Land Cover of Patenga in Different LULC Classes.

Land Use Land Cover of PT							
Land Use Categories							
Years	**Crops (%)**	**Rangeland (%)**	**Water (%)**	**Trees (%)**	**Built Area (%)**	**Flooded Vegetation (%)**	**Bare Ground (%)**
2017	15.883	2.753	10.876	2.267	62.514	2.669	3.032
2018	13.27	2.84	10.742	2.077	66.04	2.581	2.443
2019	11.906	3.544	10.787	1.569	66.733	2.587	2.867
2020	10.695	3.326	11.288	2.011	68.274	2.406	1.996
2021	6.623	2.936	11.337	2.289	72.247	2.775	1.786
2022	9.102	4.493	11.231	1.457	68.847	2.615	2.254

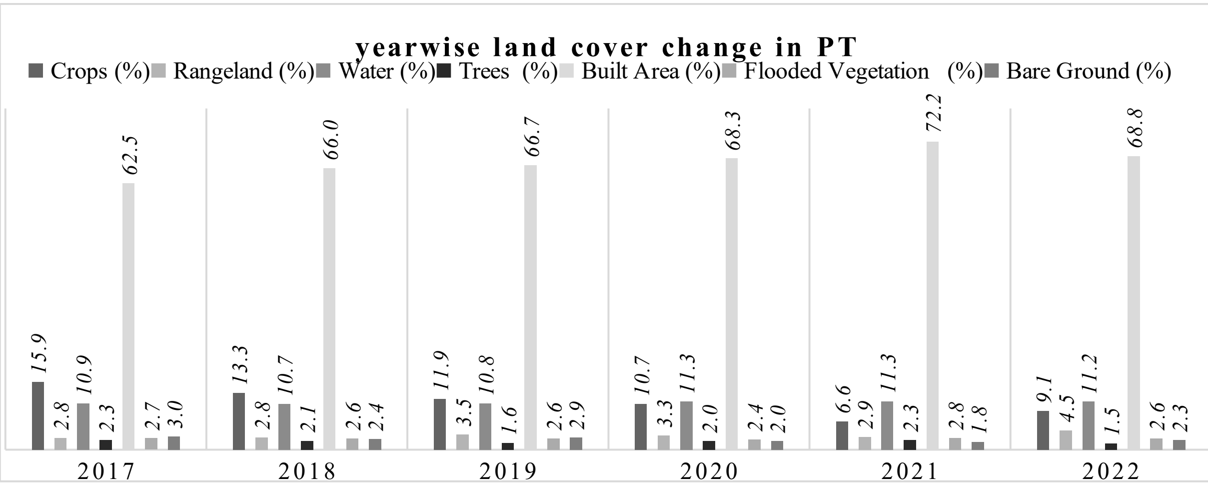

Figure 6: Year-wise land cover change in Patenga.

Table 4: Land Use and Land Cover % change with Base Year 2017 for Built Area, Crops and Water Body

Land Use Land Cover												
Years	**Built Area (%)**		**Crops (%)**		**Water (%)**		**Increase/ Decrease Based on Base Year 2017**					
							Built Area (%)		**Crops (%)**		**Water (%)**	
	PT	**HL, DM & KT**	**PT**	**HL, DM & KT**	**PT**	**HL, DM & KT**	**PT**	**HL, DM & KT**	**PT**	**HL, DM & KT**	**PT**	**HL, DM & KT**
2017	62.514	84.165	15.883	7.201	10.876	5.065						
2018	66.04	85.24	13.27	5.621	10.742	4.493	3.53 (+)	1.075 (+)	2.613 (-)	1.58 (-)	0.134 (-)	0.572 (-)
2019	66.73	86.22	11.90	4.73	10.78	4.50	4.22	2.062	3.977	2.463	0.089	0.563

	3	7	6	8	7	2	(+)	(+)	(-)	(-)	(-)	(-)
2020	68.274	86.906	10.695	3.763	11.288	3.84	5.67 (+)	2.741 (+)	5.188 (-)	3.438 (-)	0.412 (+)	1.225 (-)
2021	72.247	88.436	6.623	2.473	11.337	3.931	9.73(+)	4.271(+)	9.26(-)	4.728 (-)	0.461(+)	1.134 (-)
2022	68.847	87.814	9.102	2.729	11.231	4.194	6.33 (+)	3.649 (+)	6.781 (-)	4.472 (-)	0.355 (+)	0.871 (-)

4.3 Meteorological Data Analysis

The meteorological data analysed in this study, focusing on precipitation and temperature, were sourced from the Bangladesh Meteorological Department Database.

Table 5 presents the average temperature changes in the study area from 2017 to 2022, considering both the average maximum and minimum temperatures over the 12 months. In 2017, the average maximum temperature was recorded at 33.9°C, while the average minimum temperature was 19.4°C. Subsequently, there was a marginal decline of 0.3°C in the average maximum temperature in 2018. However, in 2019, there was an increase to 34.4°C, representing a rise of 0.5°C from 2017. The average maximum temperature consistently exceeded 34°C in the subsequent four years (2019 to 2022). The average minimum temperature remained constant at 19.4°C in both 2017 and 2018, but it began to increase from 2019 onwards. The highest values were observed between 2019 and 2022. Focusing on the months of March through May, traditionally the warmest period, the average maximum temperature exhibited a regular pattern that aligned with the overall trend observed from 2019 to 2022. This consistent change in temperature trends is attributed to the evolving land cover in the research area, emphasizing the interconnectedness between land use changes and meteorological patterns.

Table 5: Maximum and Minimum Temperature of Study Areas.

Maximum and Minimum Temperature of Study Areas				
Time	**Average maximum temperature of 12 months (°C)**	**Average maximum temperature from March to May (°C)**	**Average minimum temperature of 12 months (°C)**	**Average minimum temperature of January, February, November and December (°C)**
2017	33.9	34.3	19.4	14.9
2018	33.6	34.9	19.4	13.4
2019	34.4	35.5	19.8	13.2
2020	33.8	35.7	19.5	13.3
2021	34.9	37.8	20.0	14.2
2022	34.1	34.5	19.6	14.6

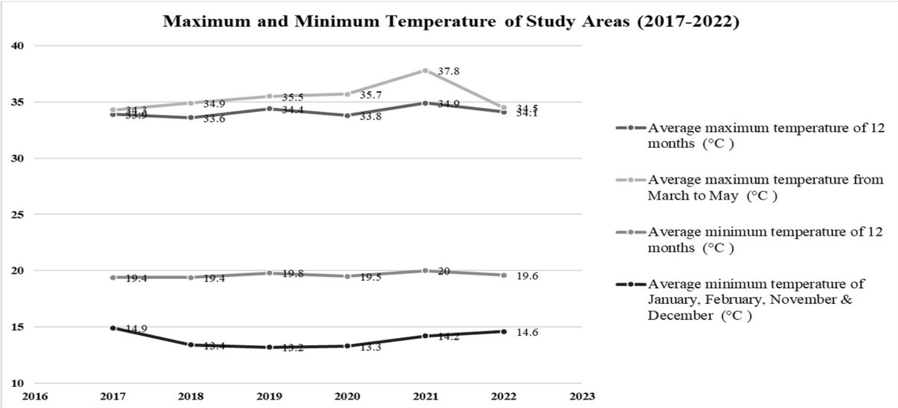

Figure 7: Maximum and Minimum Temperature of Study Areas.

Table 6 presents a nuanced analysis of the average precipitation levels in the study areas over the years 2017 to 2022, both for the entire year and during the monsoon season. In 2017, the annual average precipitation was recorded at 312.6 mm, reflecting a typical year. However, during the monsoon season of the same year, there was a substantial increase to 611.8 mm, indicating a heightened intensity of rainfall during this period. In the subsequent years, a noticeable decline in overall precipitation is evident. Despite a relative increase in 2021, with precipitation reaching 285.3 mm, a significant departure from the 2017 levels, the year 2022 witnessed a remarkable drop to 160.8 mm. This substantial decrease, almost halving the recorded value from 2017, suggests a noteworthy shift in precipitation patterns over the study period. Similarly, examining the average precipitation during the monsoon season unveils a parallel trend. In 2021, precipitation reached its zenith at 639.4 mm, representing the highest recorded rainfall during the specified years. In contrast, 2022 experienced the lowest levels, indicating a considerable decrease. This detailed examination of precipitation patterns provides valuable insights into the dynamics of the local climate.

Table 6: Precipitation of Study Areas.

Precipitation of Study Areas		
Years	**Average Precipitation of 12 months (mm)**	**Average Precipitation from June to October (mm)**
2017	312.6	611.8
2018	229.3	450.6
2019	251.0	490.6
2020	233.3	474.4
2021	285.3	639.4
2022	160.8	301.8

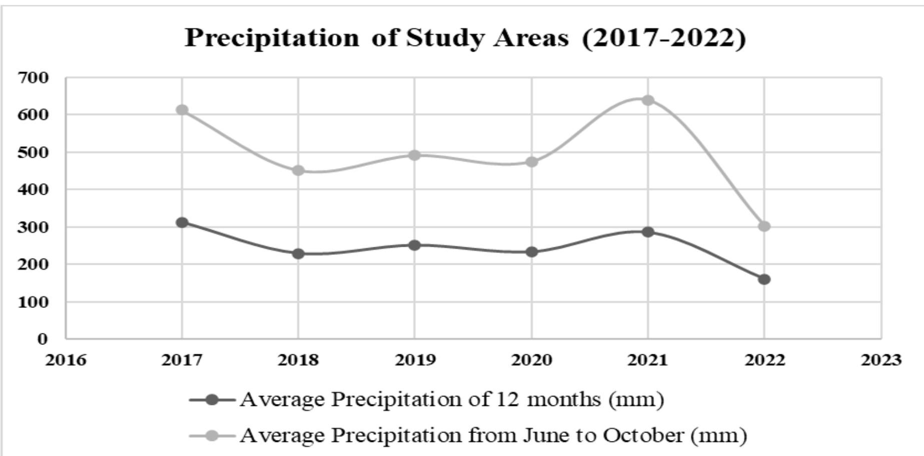

Figure 8: Year Wise Precipitation of Study Areas.

CONCLUSIONS

5.1 Discussion

Urbanization, industrialization, and population density in metropolitan areas are key drivers of land use change, leading to a spectrum of environmental, social, and economic challenges. This phenomenon is evident in Halishahar, Patenga, Double Mooring, and Kotwali, where substantial urban expansion has altered land use and cover. A six-year study reveals the unplanned conversion of land into built-up areas, resulting in a reduction of spaces dedicated to crops, trees, and water bodies. This rapid and uncontrolled transformation contributes to climate deterioration, as highlighted by the key factors of temperature and precipitation in this study. Several recommendations about this study are suggested for effective implementation by policymakers.

5.2 Policy Recommendations

As per the Water Act 2013, it is prohibited to construct any structure in a water body, whether on the bank or not, without the authorization of the competent authority. This includes filling the water body, removing soil or sand from it, obstructing the natural flow of water, or attempting to change its course. The investigators propose prioritizing the preservation and good maintenance of localized water bodies to ensure their cleanliness and uninterrupted flow. Establish a network of connections between local waterways and the main major waterways to ensure a well-functioning and effective drainage system. Recommend that the local government strategically suitably design the city, using local culture, to create a visually appealing and environmentally friendly environment, while also ensuring efficient drainage systems.

5.3 Limitations

As per the study (Rwanga, et al 2017) the general accuracy in land use and land cover (LULC) classification is 81.7%, accompanied by a kappa coefficient (K) of 0.722. Although the kappa coefficient falls under the substantial category, suggesting room for improvement, it remains suitable for subsequent research endeavours. This variation might have come for our study area which could be identified after the calculation. The heightened utilization of remote sensing data and techniques has significantly expedited geospatial processes, enhancing their speed and efficacy. However, this increased complexity concurrently introduces elevated prospects for errors. In our study, we acknowledge this as a limitation.

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REFERENCES

BBS. (2022). *Population and Housing Census 2022: Preliminary Report*. Dhaka: Bangladesh Bureau of Statistics.

Bhatti, J. S., Fleming, R. L., Foster, N. W., Meng, F. R., Bourque, C. P. A., & Arp, P. A. (2000). Simulations of pre-and post-harvest soil temperature, soil moisture, and snowpack for jack pine: comparison with field observations. *Forest Ecology and Management, 138*(1-3), 413-426.

Biro, K., Pradhan, B., Buchroithner, M., & Makeschin, F. (2013). Land use/land cover change analysis and its impact on soil properties in the northern part of Gadarif region, Sudan. *Land Degradation & Development, 24(1),* 90-102.

Biswas, J., Jobaer, M. A., Haque, S. F., Shozib, M. S. I., & Limon, Z. A. (2023). Mapping and monitoring land use land cover dynamics employing Google Earth Engine and machine learning algorithms on Chattogram, Bangladesh. *Heliyon,* 9(11).

Carlson, T. N., & Arthur, S. T. (2000). The impact of land use—land cover changes due to urbanization on surface microclimate and hydrology: a satellite perspective. *Global and planetary change, 25(1-2)*, 49-65.

Hassan, M. M., & Nazem, M. N. I. (2016). Examination of land use/land cover changes, urban growth dynamics, and environmental sustainability in Chittagong city, Bangladesh. *Environment, development and sustainability*, *18*, 697-716.

Islam, M. R. (2004). *Where land meets the sea: a profile of the coastal zone of Bangladesh*. University Press.

Islam, M. R., & Raja, D. R. (2021). Waterlogging risk assessment: An undervalued disaster risk in coastal urban community of Chattogram, Bangladesh. *Earth, 2(1),* 151-173.

Kashaigili, J. J., & Majaliwa, A. M. (2013). Implications of land use and land cover changes on hydrological regimes of the Malagarasi River, Tanzania. *Journal of Agricultural Science and Applications, 2(1)*, 45-50.

Kalnay, E., & Cai, M. (2003). Impact of urbanization and land-use change on climate. *Nature, 423*(6939), 528-531.

Leh, M., Bajwa, S., & Chaubey, I. (2013). Impact of land use change on erosion risk: an integrated remote sensing, geographic information system and modeling methodology. *Land Degradation & Development, 24(5)*, 409-421.

Liu, Z., Yao, Z., Huang, H., Wu, S., & Liu, G. (2014). Land use and climate changes and their impacts on runoff in the Yarlung Zangbo river basin, China. *Land Degradation & Development, 25(3)*, 203-215.

Muttitanon, W., & Tripathi, N. K. (2005). Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. *International Journal of Remote Sensing, 26(11)*, 2311-2323.

Roy, S., Pandit, S., Eva, E. A., Bagmar, M. S. H., Papia, M., Banik, L., ... & Razi, M. A. (2020). Examining the nexus between land surface temperature and urban growth in Chattogram Metropolitan Area of Bangladesh using long term Landsat series data. *Urban Climate, 32*, 100593.

Rwanga, Sophia S, Nadambuki, J. M. (2017). Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS.

Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences, 104*(52), 20666-20671.

Thapa, P. (2021). The relationship between land use and climate change: A case study of Nepal. *The Nature, Causes, Effects and Mitigation of Climate Change on the Environment*.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science, 277*(5325), 494-499.

WARPO (2013), *Bangladesh Water Act*. Water Resources Planning organization, Ministry of Water Resources.