Romanian Journal of Ecology & Environmental Chemistry, 6(2), 2024
https://doi.org/10.21698/rjeec.2024.211

Article

Ecological imbalance on the area of Shapahar Upazila, Naogaon district over three decades (1993÷2023) and prediction trend next ten years: a GIS approach

MD NAZMUL HOSSAIN[1], AHAMMODULLAH HASAN[2,3]*, JANNATUL ADNAN[4], TASMIA JAHIN MIM[5], ARMAN HOSSAIN[6], MD ARIFUL MOLLA[7], MD NOOR HOSSAIN[8], HABIB IBNE JAHAN[9], ABDULLA AL MAMUN[10]

[1]*Department of Environmental Science, Stamford University, Dhaka, 51 Siddheswari Rd, Dhaka 1217 env.sub642@gmail.com, Bangladesh.*
[2]*Department of Mathematics, Islamic University, Kushtia-7003, ahammodullah.iu@gmail.com, Bangladesh*
[3]*Department of Mathematics, Milestone College, Uttara Model Town, Sector-15 Uttara, ahammodullah.iu@gmail.com, Bangladesh.*
[4]*Department of Chemistry, Chowmuhani Govt. S A College, Chowmuhani, Begumganj, Road No. 13, Chowmuhani 3821, Noakhali-3831,* jannatuladnan41@gmail.com, *Bangladesh.*
[5]*Department of Biotechnology, BRAC University, Kha 224 Bir Uttam Rafiqul Islam Avenue, Merul Badda, Dhaka, tasmiajahin23@gmail.com, Bangladesh.*
[6]*Department of Environmental Sciences, Jahangirnagar University, Pathalia Union, Savar Upazila, Dhaka-1342, sahriararman@gmail.com, Bangladesh.*
[7]*Department of Environment Science & Disaster Management, Jagannath University, 9-10 Chittaranjan Ave, Dhaka 1100, mmarifulislam22@gmail.com, Bangladesh.*
[8]*Deptartmentof Centre for Advanced Research in Sciences (CARS), University of Dhaka, Shahbag, Dhaka, 1000, drhossain.n@gmail.com, Bangladesh.*
[9]*Institute of Disaster and Vulnerability Studies, University of Dhaka, Shahbag, Dhaka, 1000, habibjahan@gmail.com, Bangladesh.*
[10]*Department of Mathematics, Milestone College, Uttara Model Town, Sector-15 Uttara, mamun.kokok@gmail.com, Bangladesh.*
**Corresponding author: ahammodullah.iu@gmail.com*

Received:	*Accepted:*	*Published:*
09.07.2024	*12.12.2024*	*23.12.2024*

Abstract
This study analyzes land cover changes over three decades (1993-2023) in Shapahar Upazila using Geographic Information Systems (GIS) and remote sensing techniques. The analysis reveals significant shifts in vegetation, water bodies, bare soil, and settlement areas, correlating these changes with shifts in temperature and precipitation. Predictions for the next ten years (2024-2033) indicate a significant increase in vegetation cover. The findings highlight the importance of sustainable land management practices and policies to mitigate ecological imbalances. Utilizing GIS strategies, remote sensing statistics, and meteorological datasets, we examine the converting patterns of four key land cover sorts: water bodies, vegetation area, bare soil, and settlement area. This paper also links Land use and Land cover (LULC) with other temperature and precipitation facts to understand the ability correlations and conjuring factors of LULC change. The analysis suggests that LULC has modified in numerous ways over time, including urbanization developments, flora enlargement, changes within the extent of water bodies, and corresponding adjustments in temperature and moisture patterns. Combining an analysis of specific percent changes in land cover types between consecutive years with the calculation of temperature and precipitation changes helps to understand the relationship between multiple environmental parameters influencing the landscape of Shapahar Upazila. Our study provides additional information regarding the changes in environmental conditions and landscape dynamics in the region and gives contextual information to help land managers, stakeholders, and policymakers understand the current trends in the area and develop climate mitigation and adaptation policies for sustainable development.

Keywords: *LULC change, spatial-temporal dynamics, Shapahar Upazila, GIS, remote sensing, climate change, land use planning, sustainable development*

INTRODUCTION

This research examines the relationships between land use and land cover (LULC) changes and climatic variables from 1993 to 2023 in Shapahar Upazila, Bangladesh. Despite extensive studies on global climate change impacts, limited attention has been given to rural areas like Shapahar, which are experiencing significant ecological transformations. This study aims to fill that gap by investigating how changes in land cover correlate with variations in temperature and precipitation. These modifications affect human health and well-being as well as the average sustainability of agricultural and water consumption [1]. Correspondingly, we have witnessed varied types of such transformations that involve intensive agricultural production, growing urban development, and turning to different natures' management practices that have redesigned the landscape and changed its ecological and climate norms [2]. Researchers from all over the world have found that local climate is being influenced to a great extent by land cover changes – such as deforestation and urbanization – that cause changes in the surface albedo, the amount of evapotranspiration, and the overall energy balance of that area [3, 4]. Deforestation most often results in less evapotranspiration. Consequently, soil moisture and the amount of available water drops, which in turn initiates an increase in land surface temperatures that may create weather conditions different from before [5÷9]. Nevertheless, cities can form a typical feature of the urban heat island, bringing temperatures in urban areas much higher than in their rural surroundings, which also can affect local weather conditions, especially the rainfalls [10÷12]. In this aspect, the research is seen as specialized in pointing out the effects of human activities that entail cropland cultivation and concreting, which have led to large area reduction. This, in turn, brought about an imbalance in local weather [13÷15]. The major part of the analysis was achieved by the integration of GIS tools and remote sensing, where the categories of land cover and the fluctuations in temperatures and fluctuations in rainfall patterns were observed [16]. The way land cover changes interact with its climatic variables like temperature and precipitation play an important role in local environmental sustainability and stability [17, 18]. The normally raised question is the relationship of local environmental processes within the framework of the general atmospheric dynamics, which is determined by their dependence or, on the contrary, the impact of underlying local climate conditions on a wider spectrum of atmospheric changes [19, 20]. Summing up the results of the run of the past study will arguably help environmental governance in the region impacted by the international environmental change, rationalization of the adaptive practices, and improvement of regulations in this area [21].

MATERIALS AND METHODS

Study area

Shapahar Upazila is situated in Bangladesh, in the Naogaon District in its northern part, and it is recognized by its socioeconomically diverse community (fig.1). The upazila covers an area of about 244.48 square kilometers and is subdivided into several unions, each contributing to its vibrancy.

The regional economy is primarily agrarian based and farming remains the most profitable business. Rice, jute, wheat, and sugarcane are popular shade-growing crops in the fertile lands. A link provided by the transportation infrastructure of Shapahar further facilitates the movement of goods and people in the area. Schools, Colleges, hospitals, and Clinics, all depend on the social fabric of the upazila, enabling its people's lives.

Shapahar Upazila is a culturally prosperous area that has local festivals and rites. These different festivals and rites show domestic beliefs and ethnic groups in the region. They create ecological richness with their rivers and wetlands, which makes it much more interesting. At the same time, the livelihoods and conservation efforts of biodiversity are supported by this phenomenon. Turning a blind eye to the difficulties including poverty, Shapahar Upazila holds the potential to be a growth and development platform for the people involved. Consequently, it assures a bright future for its inhabitants.

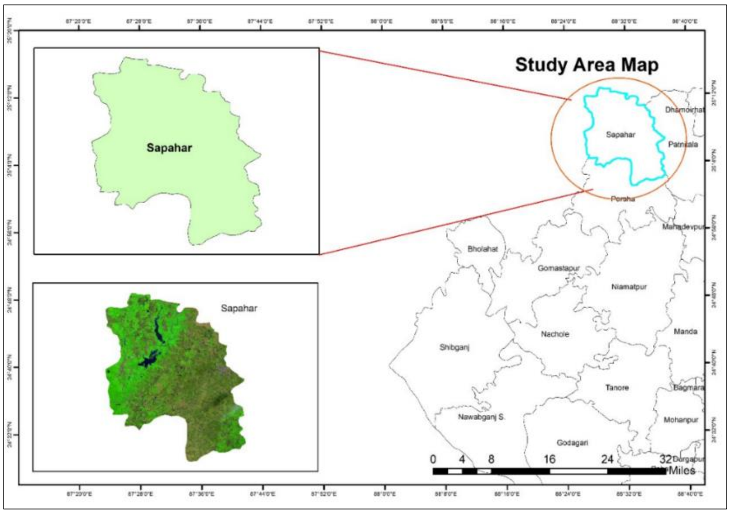

Fig. 1. Study area map of Shapahar Upazila

The regional economy is primarily agrarian based and farming remains the most profitable business. Rice, jute, wheat, and sugarcane are popular shade-growing crops in the fertile lands. A link provided by the transportation infrastructure of Shapahar further facilitates the movement of goods and people in the area. Schools, Colleges, hospitals, and Clinics, all depend on the social fabric of the upazila, enabling its people's lives.

Shapahar Upazila is a culturally prosperous area that has local festivals and rites. These different festivals and rites show domestic beliefs and ethnic groups in the region. They create ecological richness with their rivers and wetlands, which makes it much more interesting. At the same time, the livelihoods and conservation efforts of biodiversity are supported by this phenomenon. Turning a blind eye to the difficulties including poverty, Shapahar Upazila holds the potential to be a growth and development platform for the people involved. Consequently, it assures a bright future for its inhabitants.

Satellite image sourcing processes

Satellite imagery was obtained from the United States Geological Survey (USGS) Earth Explorer for the years 1993, 2003, 2013, and 2023 (fig. 2). These images were processed using remote sensing techniques and classified through supervised classification methods to differentiate between land cover types, including water, vegetation, bare soil, and settlements. Validation of classification accuracy was achieved through ground-truth data collected via GPS. While the cloud-free Landsat images can be obtained from USGS Earth Explorer, it is extremely challenging and a continuous interval from one Landsat image to the next is impossible. By doing this, the cloudless images were taken in the summer periods of the year which is (March, April). This method is consistent with the remote sensing methodologies used previously in Bangladesh summer Landsat images which have a fair amount of cloud cover. Precisely because the study site was mainly constructed of long timber trees, seasonal modifications, including shifts in sun sensor geometry, appeared inconsequential. Researchers used ground trothing, which is the precise determination of land cover types and classes, and GPS-based data as the basis for the land use/land cover classification. These grades represent the set of images that were used in the train NN in the impact area of Shapahar Upazila.

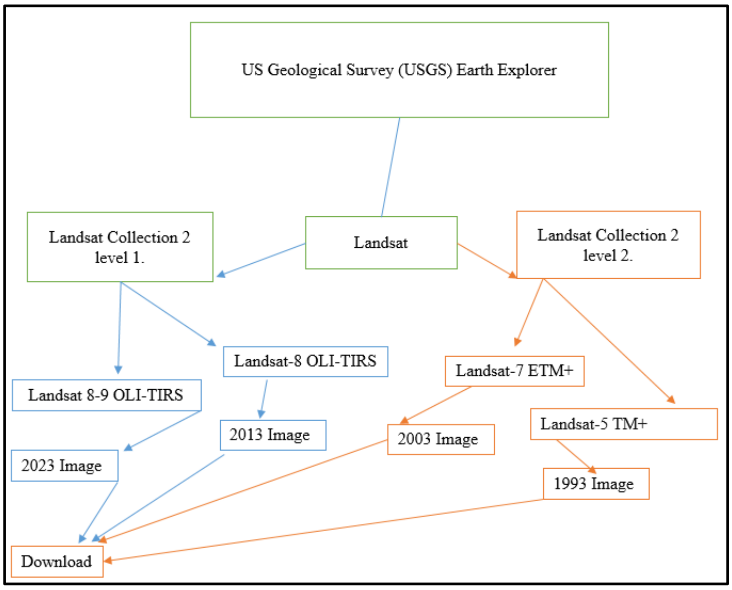

Fig. 2. Satellite Image Sourcing Processing

Table 1 presents information on satellite imagery acquired from various Landsat missions namely Landsat 5, Landsat 7, and Landsat 8, and in near-future spacecraft, Landsat 8-9. Data for the years 1993, 2003, 2013, and 2023 is included in each column, with the satellite sensor, path/row, cloud coverage %, acquisition date, pixel size, and Landsat scene ID on each row.

Table 1. Features of Landsat satellite images

Satellite	Sensor	Path/ Row	Cloud Cover	Acquisition Date	Resolution	LANDSAT_SCENE_ID	Downloaded (Year)
Landsat-8-9	OLI-TIRS	136/45	0.00	23-04-2023	30m	LC08_L1TP_139042_20230423_20230423_02_RT	2023
Landsat-8	OLI-TIRS	136/45	0.00	22-04-2013	30m	LC08_L1TP_138043_20130422_20200911_02_T1	2013
Landsat-7	ETM+	136/45	0.00	4-04-2003	30m	LT05_L1TP_139043_20030404_20200902_02_T1	2003
Landsat-5	TM	136/45	0.00	30-4-1993	30m	LT05_L1TP_139043_19930430_20200915_02_T1	1993

Satellite images process

Figure 3 represents the satellite image processing method, where the final LULC map is presented in the flowchart.

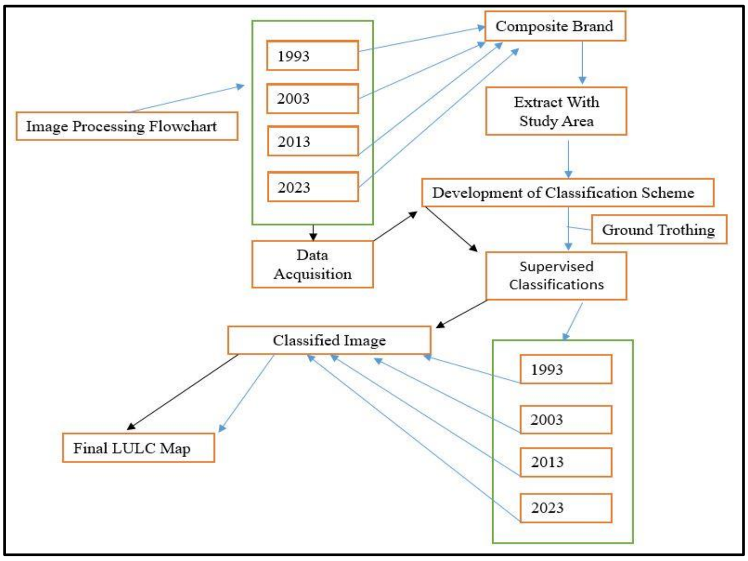

Fig. 3. Satellite image processing

Temperature data process

Temperature minimum, temperature maximum, and precipitation data were collected from NASA POWER and then calculated data by Microsoft Excel. The data were collected yearly and converted it monthly and then created the chart and table using Microsoft Excel.

Table 2 shows the category and definition of water with vegetation, settlement, and bare soil. The classes for the LULC category are Water (rivers, ponds, lakes), Vegetation Cover (moderately vegetated areas), Settlement (commercial and residential regions), and Bare Soil (unused agricultural land). These classes assist in classifying distinctive land kinds based totally on their characteristics, together with water bodies, vegetation density, human settlements, and bare ground.

Table 2. Considered LULC classes of Shapahar Upazila.

SL	Category	Definitions
1	Water	Rivers, ponds, lakes, reservoirs, and other areas with flowing water
2	Vegetation's Cover	Sparsely vegetated areas with 2-10% canopy cover, rural homesteads, and rural vegetation.
3	Settlement	Commercial and residential areas, transportation, industrial infrastructures, and brickfields
4	Bare Soil	Unused agricultural land, loose and shifting sand, bare soil, and agriculturally unsuitable areas

Calculations Percentage Change

In the study, the percentage were calculated, change for each land cover type across all the years, then computed the change from one year to the next for each land cover type and calculated the percentage change. Furthermore, for each type of land cover, was set the direction of change (either increase or decrease).

The percentage change was estimated using formula:

$$\% \text{ Change} = (\text{final value} - \text{initial value}) \times 100/ \text{ initial value} \quad (1)$$

If the final value is greater than the initial value, the direction of change is "Increase." If the final value is less than the initial value, the direction of change is "Decrease.

RESULT AND DISCUSSION

The LULC change analysis

The LULC maps illustrate significant shifts between 1993 and 2023. Notably, vegetation cover has dramatically increased, while bare soil areas have significantly declined. The transition from bare soil to vegetation can be attributed to expanded agricultural practices, particularly mango cultivation, which has become economically beneficial for local farmers. However, this increase in vegetation raises concerns about groundwater depletion, underscoring the need for sustainable agricultural practices. Fig. 4. shows how the given parameters have changed during the 10-year frames, hence showing graphs of bare soil and settlement close to the waterbody while the cover of the vegetation region is trendless upward, which may signify the transformation of the environment with an increase in natural coverage and decrease in urbanization.

Temporal Land Cover Dataset (1993÷2023)

Fig. 5. shows that the observed data and a temporal shift in land cover from 1993 to 2023. This data collection describes the changes in LULC during the time range; hence, changes manifest in the parameters, like vegetation, water bodies, bare soil, and settlement patterns.

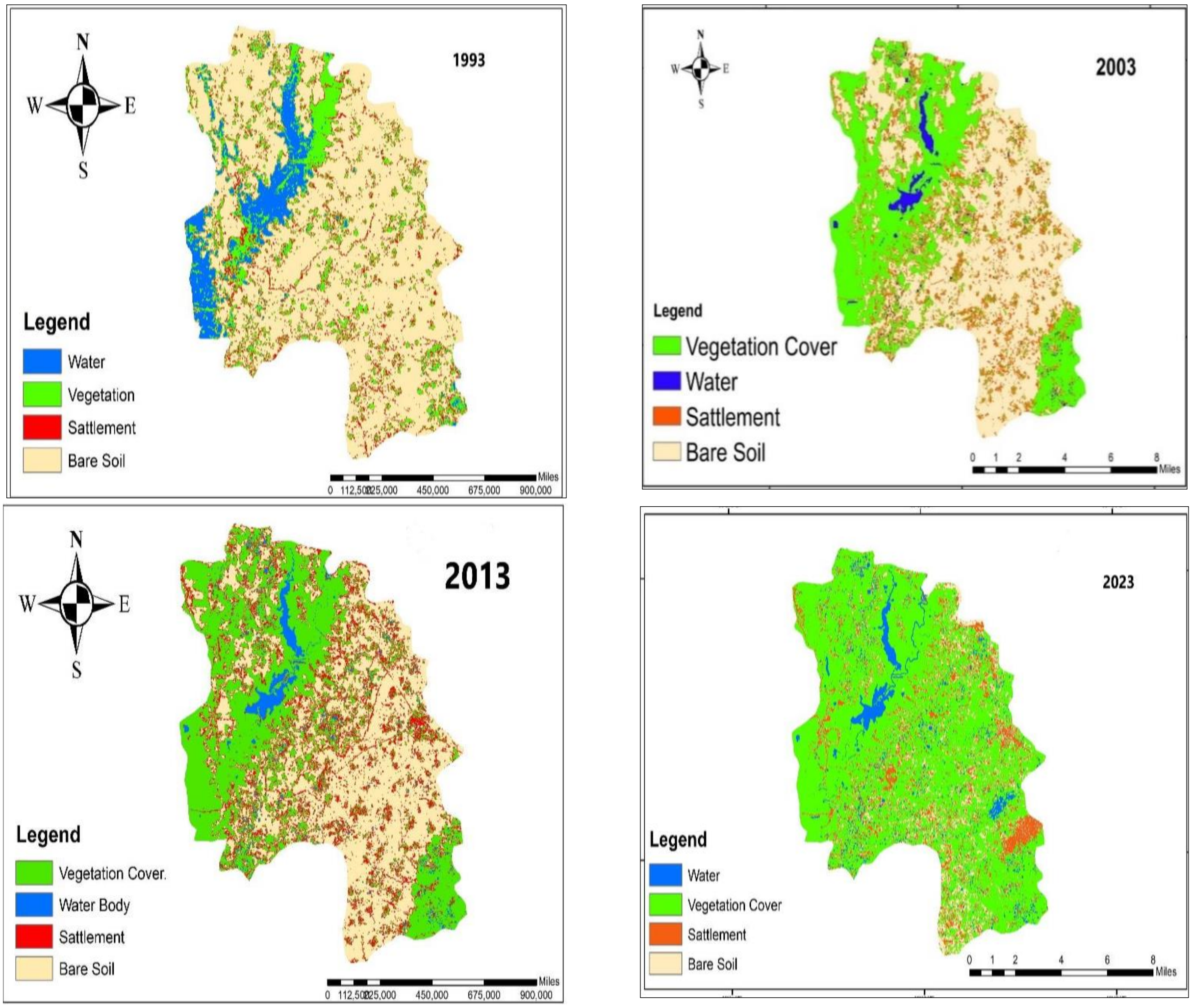

Fig. 4. LULC Maps (1993, 2003, 2013, 2023)

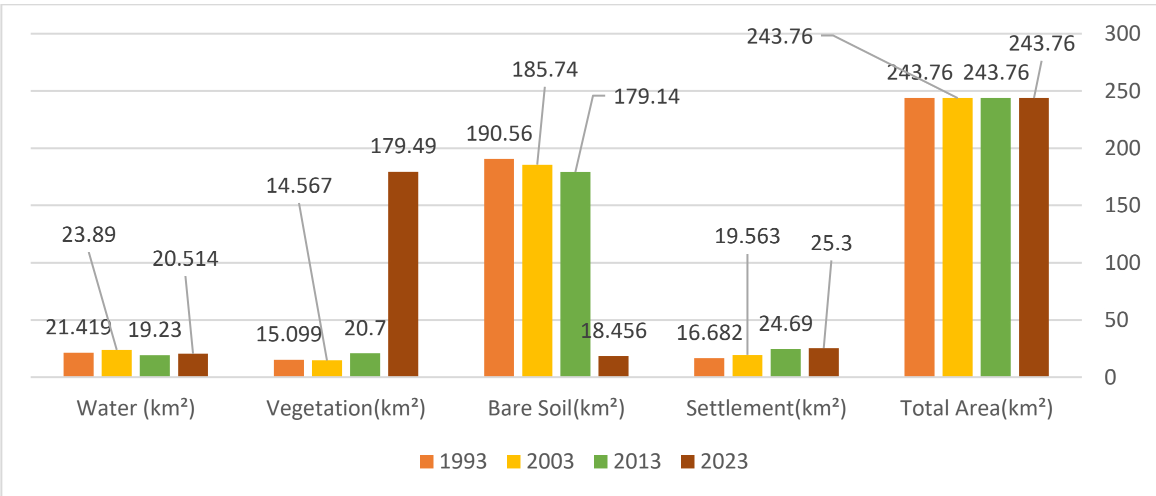

Fig. 5. Temporal LULC Dataset (1993÷2023)

Annual percentage LULC over four decades (1993÷2023)

Fig.6. presents an imagined changing season from the year 1993 to 2023 by depicting various items relevant to vegetation, water bodies, bare soil, and settlements. The assessment of land cover modifications highlights sizeable shifts in diverse classes over the favored period. While water bodies skilled a mild decrease of 4.22%, vegetation cover with a growth of 1089.05% In assessment, bare soil areas exhibited a huge decline of 90.34%. Settlement zones displayed a significant increase, showing a growth of 51.67%. These findings underscore the dynamic modifications in LULC kinds,

emphasizing the importance of expertise and tracking environmental shifts for knowledgeable choice-making and sustainable land control practices.

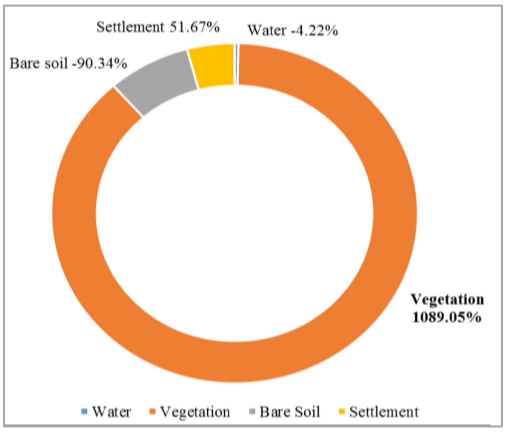

Fig. 6. Annual percentage LULC over four decades (1993÷2023)

Summary of land cover changes over three time periods, from 1993 to 2023

Table 3 present the annual percentage change in LULC from 1993 to 2023. Over these 30 years, significant shifts in land cover dynamics are observed across four key categories: water, vegetation, bare soil, and settlement area. Table 3 shows a high-quality increase of 11.51% in water bodies from 1993 to 2003, followed by a super decline of 19.57% from 2003 to 2013, earlier than rebounding with a 6.68% increase from 2013 to 2023. In contrast, Vegetation covers initially reduced with the aid of 3.52% from 1993 to 2003 however, it witnessed a fantastic surge of 41.97% from 2003 to 2013, observed by using an exceptional growth of 765.29% from 2013 to 2023. The region blanketed through bare soil confirmed regular declines at some point, with decreases of 2.52%, 3.56%, and a massive 89.73% from 1993 to 2003, 2003 to 2013, and 2013 to 2023 respectively. Settlement regions tested regular boom, with increases of 17.28%, 26.14%, and a couple of 2.47% over the identical durations. These tendencies offer valuable insights into lengthy-term land cover dynamics, reflecting phenomena, urbanization, vegetation growth, and adjustments in water bodies and bare soil regions.

Table 3. Annual percentage change in LULC from 1993 to 2023

Category	1993-2003 (%)	2003-2013 (%)	2013-2023 (%)	Change Direction
Water	+11.51	-19.57	+6.68	Increase, Decrease, Increase
Vegetation	-3.52	+41.97	+765.29	Decrease, Increase, Increase
Bare Soil	-2.52	-3.56	-89.73	Decrease, Decrease, Decrease
Settlement	+17.28	+26.14	+2.47	Increase, Increase, Increase

Trends of temperature and precipitation from 1993 to 2023

Temperature and precipitation facts from 1993 to 2023 offer important new insights into long-term climate trends, as shown in figures 7, 8, 9, and 10. Maximum temperatures are growing year over year, being especially excessive in the wintry weather months in June and July. The highest temperatures recorded in 2003 and 2013 surpassed 38ºC, while between 1993 and 2023, temperatures will increase by up to 25ºC.

On the other hand, minimum temperatures have also increased over time, with a minimum in 2023 and 1993. Rainfall amounts vary widely, with some years, such as 1993, receiving little rainfall, some falling, and others, such as 2003 and 2023, getting more. August 2023 recorded the highest precipitation, with 11 mm. This shift highlights the dynamic nature of climate systems and the importance of long-term data analysis for understanding and adapting to a changing climate.

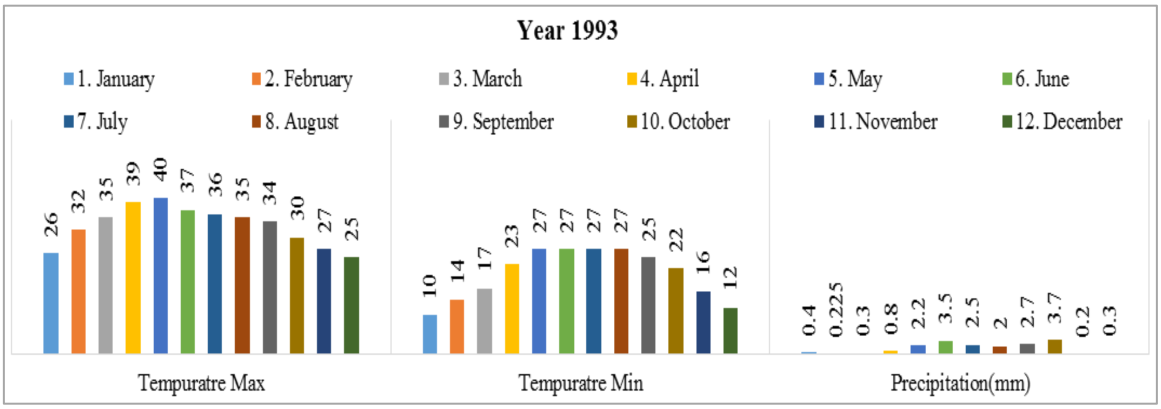

Fig. 7. Trends of temperature and precipitation (1993)

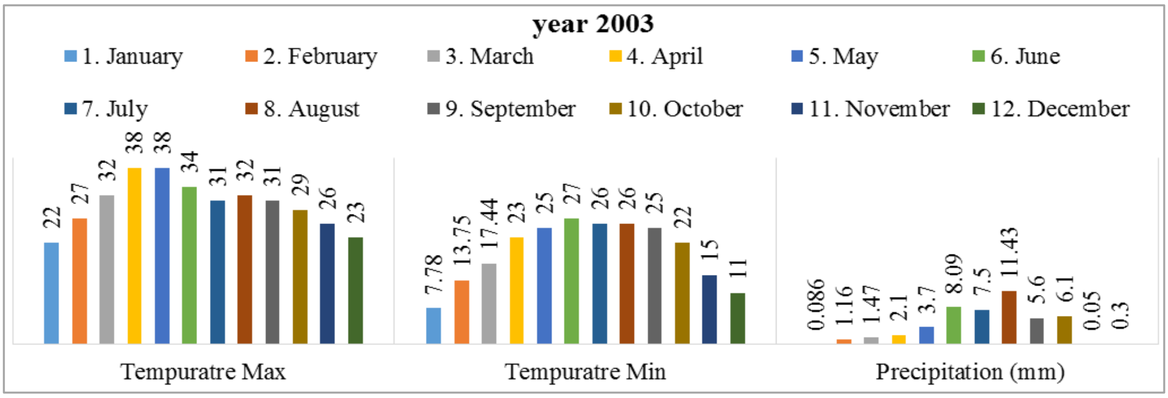

Fig. 8. Trends of temperature and precipitation (2003)

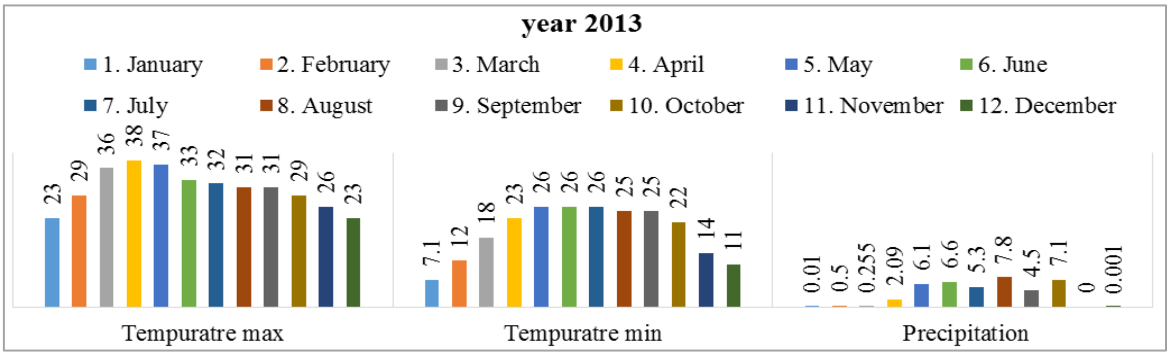

Fig. 9. Trends of temperature and precipitation (2013)

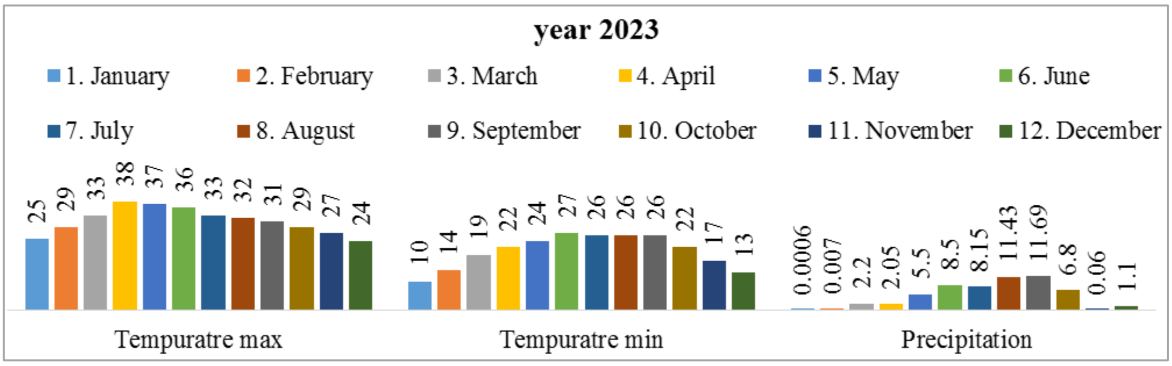

Fig. 10. Trends of temperature and precipitation (2023)

Table 4 shows the annual averages for the following: maximum temperature, minimum temperature, precipitation, and the years 1993, 2003, 2013, and 2023. In 1993, the average maximum temperature was 31.92°C, the minimum temperature was 20.42°C, and the average rainfall was 1.82 mm. In 2003, the average maximum temperature increased marginally to 32.51°C over the next decade, while the average minimum temperature decreased to 19.65 °C. Notably, precipitation increased to 4.43 mm, almost double that of 1993. However, the maximum and minimum temperatures in 2013 were reduced to 30.83°C and 18.06°C, respectively. Despite this cooling trend, 4.01 mm.

Table 4. Yearly average weather data

Year	Average Max Temperature (°C)	Average Min Temperature (°C)	Average Precipitation (mm)
1993	31.92	20.42	1.82
2003	32.51	19.65	4.43
2013	30.83	18.06	4.01
2023	30.83	18.65	4.50

In 2023, the average maximum temperature reached 30.83°C, while the average minimum temperature rises to 18.65°C. This means a slight increase in temperature. Also, slightly more than 4.50 mm of rain fell. Overall, these results highlight the dynamic nature of climate during the years under study, reflecting changes in precipitation and temperature.

The percentage deviations between the parameters are shown in Table 5. For the years 1993–2003, 2003–2013, and 2013–2023, examining the annual percentage change over the four years from 1993 to 2023 shows some interesting trends in climate, with the highest temperature showing a slight increase of about 1.85% in 1993 and 2003 and a sharp decline of about 5.18% between 2003 and 2003 in 2013.

Table 5. Yearly change percentages in weather parameters

Year	Max Temperature (%)	Min Temperature (%)	Precipitation (%)
1993-2003	1.85	-3.77	143.96
2003-2013	-5.18	-8.09	-9.48
2013-2023	0.00	3.26	12.22

It should be noted that there was no change in the maximum temperature from 2013 to 2023. On the other hand, the minimum temperature decreased gradually in time by about 3.77% between 1993 and 2003 and then fell again to about 8.09% between 2003 and 2013.

However, there was some improvement, with an increase of 3.26% from 2013 to 2023. The largest changes were observed in the drought pattern, with a remarkable rise of 143.96% from 1993 to 2003 and a decrease of 9.48% from 2003 to 2013. There was a noticeable 12.22% increase in rainfall between 2013 and 2023, indicating that rainfall varies with time. These programs highlight the dynamic nature of weather events and the importance of long-term weather monitoring for accurate meteorology and forecasting.

LULC, temperature and precipitation dataset with relationship

Table 6 shows several correlations between LULC changes and temperature and precipitation patterns. The distribution of bare soil area, vegetation cover, waterbody, and settlement area, as well as the average maximum and lowest temperatures and precipitation, have all changed significantly throughout time. The highest area in 1993 was 21.419 in the water, 15.099 in the vegetation cover, 190.56 in the bare soil area, and 17.682 in the settlement area. There was an average of 1.82 inches of precipitation, with a maximum temperature of 31.92°C and a low temperature of 20.42°C.

The vegetation cover increased to 15.567 and the waterbody to 24.89 by 2003. The settlement area increased to 19,563, while the bare soil area fell to 185.74. With a greater average precipitation of 4.43, the average maximum temperature increased to 32.51°C and the average minimum temperature decreased to 19.65°C.

The waterbody dropped to 19.23 in 2013, and the amount of vegetation grew to 20.7. The settlement area increased to 24.69 while the bare soil area decreased to 179.14. With an average precipitation of 4.01, the average lowest temperature was 18.06°C and the average maximum temperature dropped to 30.83°C.

Table 6. Correlation between LULC changes and temperature and precipitation patterns

Year	Water Area	Vegetation Cover	Bare Soil Area	Settlement Area	Average Max Temperature (°C)	Average Min Temperature (°C)	Average Precipitation (mm)
1993	21.419	15.099	190.56	17.682	31.92	20.42	1.82
2003	24.89	15.567	185.74	19.563	32.51	19.65	4.43
2013	19.23	20.70	179.14	24.69	30.83	18.06	4.01
2023	20.514	179.49	19.456	25.30	30.83	18.65	4.50

By 2023, the vegetation cover had reached an all-time high of 179.49, while the waterbody had expanded once more to 20.514. The settlement area increased to 25.3, while the bare soil area decreased dramatically to 19.456. There was an average of 30.83°C for the maximum temperature, 18.65°C for the minimum, and 4.5 inches of precipitation on average.

In conclusion, there has been a constant shift in the distribution of land areas, with bare soil and settlement areas declining and water and vegetation cover rising. There is a varied pattern to temperature trends, while precipitation has usually increased over time.

Predicted changes in land cover over the next 10 Years

In the upcoming 10 years, the predicted land cover changes are presented in table 7 suggest that the trends identified are based on the data from 1993, 2003, 2013 to 2023. The provided data outlines the anticipated changes in land cover percentages over the next decade, spanning from 2024 to 2033. Predictions suggest a notable shift towards increased vegetation cover in Shapahar Upazila. Starting from a modest 6.9% in 2024, the vegetation percentage is forecasted to rise substantially to 44.7% by 2033. This significant projected increase of 37.8% over the specified period reflects potential ecological transformations within the region. While other land cover categories such as water, bare soil, and settlement also exhibit fluctuations, it is the remarkable surge in vegetation cover that stands out as the dominant trend. These projections underscore the evolving landscape dynamics and hint at potential environmental and socioeconomic implications for Shapahar Upazila in the coming years.

Table 7. Predicted Changes in Land Cover Over the Next 10 Years.

Year	Water (%)	Vegetation (%)	Bare Soil (%)	Settlement (%)
2024	5.15	6.9	-98.03	2.72
2025	6.82	11.1	-106.01	5.33
2026	8.5	15.3	-114.0	7.95
2027	10.18	19.5	-121.98	10.57
2028	11.86	23.7	-129.96	13.19
2029	13.54	27.9	-137.94	15.81
2030	15.22	32.1	-145.92	18.43
2031	16.9	36.3	-153.9	21.05
2032	18.58	40.5	-161.88	23.67
2033	20.26	44.7	-169.86	26.29

Main reason of rapid vegetation cover changes in the studied area

The Barind area lies in some parts of the Naogaon district of Bangladesh, so the soil type and texture of that area are slightly different. The temperature of the Barind area is usually 25÷30ºC; for this reason, fruit trees grow well in that area. As the soil in the Barind area has low waterlogging and the temperature is good for fruit cultivation, farmers have taken advantage of this opportunity to plant fruit trees in large numbers. Between 2013 and 2023, more trees have been planted in the central Sapahar area. Among them is the mango tree, which is very popular there. One of the reasons for planting this mango tree is the temperature and soil quality of the Sapahar area. On the other hand, as mango cultivation became profitable, farmers started planting more mango trees in the Shapahar area. Because of that, it can be seen that there has been a massive change in the land cover in the Shapahar area, becoming a greener area day by day. The mango cultivation is the main reason for the rapid change of the aria.

CONCLUSION

This study reveals substantial ecological changes in Shapahar Upazila over the past three decades, with a projected increase in vegetation cover for the next ten years. While this is promising for biodiversity, it poses challenges for water resource management. Policymakers should prioritize sustainable land management practices and invest in water conservation measures to address these ecological challenges effectively. The findings underscore the significance of information on the complicated courting among environmental elements and land cover modifications for informed selection-making in land use coverage and sustainable development plans. However, the satellite data used in this investigation has a resolution of 30 m. It may be appropriate for small-scale studies but isn't ideal for detailed investigations. Because better-resolution photos are expensive, the study has to be done with free Landsat images of medium quality. It had some ramifications in terms of accuracy. The most urban green space is seen during the wet season because the leaves appear greener than they do throughout the winter. However, it was unable to locate anticipated data from the wet season due to the dim surroundings. Instead, the information was gathered between late March and early April. Under the shade of the forest canopy, built-up areas are sometimes overlooked. Because the smallest pixel size is 30 m, small-scale green spaces cannot be observed, hence many rooftop gardens or roadside plants may have been missed from the research, resulting in mistakes. These were the study's limitations. Addressing demanding situations together with water useful resource control and groundwater depletion calls for proactive measures, together with the implementation of artificial water reservoirs and the promotion of sustainable agricultural practices. By integrating revolutionary solutions and careful control strategies, the location can efficiently deal with environmentally demanding situations even by selling resilience and conservation.

RECOMMENDATION

Because of transpiration and evapotranspiration techniques, the overabundance of plant cover in the Barind area indicates a higher demand for water resources. With potentially confined floor water availability, groundwater turns into important for maintaining vegetation increase. However, excessive extraction may additionally lead to groundwater depletion and detrimental effects on ecosystems and groups counting on it [8]. To deal with this, artificial recharge methods consisting of reservoirs can be implemented at some point in the wet season to store water to be used all through drier periods [9]. Additionally, selling sustainable agricultural practices by imparting laws and training on reducing chemical usage can help mitigate poor environmental influences [11÷13]. In Shapahar, the uneven terrain leads to water scarcity, especially in summer despite high rainfall due to abundant vegetation. To address this, reservoirs should be built to store water from the rainy season for year-round use. Given the high vegetation cover, effective water management and drainage systems are crucial [14, 15]. However, this vegetation also contributes to high pesticide usage, polluting water and soil. Enforcing strict regulations on pesticide use and promoting organic alternatives can mitigate environmental damage and protect marine ecosystems.

Lastly, it is advocated to put into effect synthetic water reservoirs for managing water resources, mainly at some stage in dry seasons, and to inspire sustainable agricultural practices to maintain the stability among flora cover and groundwater availability at the same time as minimizing chemical usage.

REFERENCES

[1] AHSAN, M.N., WARNER, J., Int. J. Disaster Risk Reduct., **8**, 2014, p. 32, https://doi.org/10.1016/j.ijdrr.2013.12.009.

[2] ZAEHRINGER, J.G., SCHWILCH, G., ANDRIAMIHAJ, O.R., RAMAMONJISO, B., MESSERL, P., Ecosyst. Serv., **5**, 2017, p.140, https://doi.org/10.1016/j.ecoser.2017.04.004.

[3] BONAN, G.B., Science, **32**, 2008, p. 1444, https://doi.org/10.1126/science.1155121.

[4] BHATT, R., HOSSAIN, A., Advanced Evapotranspiration Methods and Applications, IntechOpen, London, UK, 2019, https://doi.org/10.5772/intechopen.83707.
[5] ZHANG, X., CHEN, S., SUN, H., WANG, Y., SHAO, L., Field Crops Res., **114**, no. 1, 2009, p.75, https://doi.org/10.1016/j.fcr.2009.07.006.
[6] KALNAY, E., CAI, M., Nature, **423**, 2003, p. 528, https://doi.org/10.1038/nature01675.
[7] KOGUT, P., EOS Data Analytics, https://eos.com/blog/sustainable-agriculture/ [21.03.2024].
[8] KHORRAMI, M., MALEKMOHAMMADI, B., Sci. Total Environ., **799**, 2021, https://doi.org/10.1016/j.scitotenv.2021.149304.
[9] OKE, T.R., Quart. J. R. Met. Soc., **108, no.** 455, 1982, p.1, https://doi.org/10.1002/qj.49710845502.
[10] SCHENK, E.R., DONNEL, F., SPRINGER, A.E., STEVENS, L.E., Ecol. Eng., **145**, 2020, https://doi.org/10.1016/j.ecoleng.2019.105701.
[11] SULTANA, R., IRFANULLAH, H.M., SELIM, S.A., BUDRUDZAMAN, M., Environ. Chall., **11**, 2023, https://doi.org/10.1016/j.envc.2023.100707.
[12] TURNER, B.L., LAMBIN, E.F., REENBERG, A., Proc. Natl. Acad. Sci. USA, **104**, no. 52, 2007, p. 20666, https://doi.org/10.1073/pnas.0704119104.
[13] CHISHOL,R.A.,Ecol.Econo.,**69**,2010,p.19731987, https://doi.org/10.1016/j.ecolecon.2010.0.13.
[14] VERBURG, P.H., CROSSMAN, N., ELLIS, E.C., HEINIMANN, A., HOSTERN, P., MERTZ, O., NAGENDRA, H., SIKOR, T., ERB, K.H., GOLUBIEVSKI, N., GRAU, R., GROVE, M., KONATE, S., MEYFROIDT, P., PARKER, D.C., CHOWDHURY, R.R., SHIBATA, H., THOMSON, A., ZHEN, L., Anthropocene, **12**, 2015, p.29, https://doi.org/10.1016/j.ancene.2015.09.004.
[15] ZHANG, X., XIE, B., ZHOU, K., LI, J., YUAN, C., XIAO, J., XIE, J., Ecol. Indic., **158**, 2024, https://doi.org/10.1016/j.ecolind.2023.111524.
[16] SEYAM, M.M.H., HAQUE, M.R., RAHMAN, M.M., Case Stud. Chem. Environ. Eng., **7**, 2023, https://doi.org/10.1016/j.cscee.2022.100293.
[17] FUSSEL, H.M., Glob. Environ. Change, **17**, no. 2, 2007, p.155, https://doi.org/10.1016/j.gloenvcha.2006.05.002
[18] O'BRIEN, K.L., EICHENKO, R.M., Glob. Environ. Change, **10**, no. 3, 2000, p.221, https://doi.org/10.1016/S0959-3780(00)00021-2.
[19] BONTE, B., THERVILLE, C., BOUSQUET, F., SIMI, C., ABRAMI, G., GUERBOIS, C., FRITZ, H., BARRETEAU, O., DHENAIN, S., MATHEVET, R., chapter 9 in Ecosystem and Territorial Resilience. A Geoprospective Approach, Elsevier, 2021, p. 247-278, https://doi.org/10.1016/B978-0-12-818215-4.00009-2.
[20] LUERS, A.L., LOBELL, D.B., SKLAR, L.S., ADDAMS, C.L., MATSON, P.A., Glob. Environ. Change, **13**, no. 4, 2003, p. 255, https://doi.org/10.1016/S0959-3780(03)00054-2.
[21] LOBELL, D.B., ASNER, G.P., ORTIZ-MONASTERIO, J.I., BENNING, T.L., Agric. Ecosyst. Environ., **94**, no. 2, 2003, p. 205-220, https://doi.org/10.1016/S0167-8809(02)00021-X.

Citation: Hossain, N.H. Hasan, A., Adnan, J., Mim, T.J., Hossain, A., Molla, A., Hossain, N., Jahan, H.I., Al Mamu, A., Ecological imbalance on the area of Shapahar Upazila, Naogaon district over three decades (1993÷2023) and prediction trend next ten years: a GIS approach, *Rom. J. Ecol. Environ. Chem.*, **2024**, 6, no.2, pp. 109÷120.