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Research Article

HUMAN INTERVENTION INDUCED LAND USE LAND COVER CHANGES IN THE CHALAN BEEL AREA OF BANGLADESH

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ABSTRACT

ChalanBeel, one of the major inland depressions of marshy character, is in the vulnerable condition due to various human interventions. The number of population of the ChalanBeel area has increased manifold in the recent years. To accommodate the increasing population, huge Beel areas were drained out and reclaimed by the locals. Roads, highways, embankments, bridges, culverts and other infrastructures were developed in this area. Due to increase of agricultural practices, the number of wetlands reduced over the period of time. Overfishing, pollution, unplanned infrastructures, lack of institutional coordination, lack of public awareness, etc. have become responsible for environmental degradation in this area. The present paper assesses the human intervention induced land use land cover changes in the ChalanBeel area. This study was conducted based on both primary and secondary data. Primary data was collected from field survey through interviewing the locals and the secondary data was collected from various published and online sources as well as satellite images were used to identify the land use land cover changes. The study reveals that built-up areas increased from 40.87 sq. km to 144.06 sq. km. and water bodies declined from 258.65 sq. km. to 90.63 sq. km in between 2003 and 2023, and the low-lying areas remained nearly same in that period. Land use land cover changes have significant impacts on the local people's lives and livelihoods. It is important to reduce the human intervention induced land use land cover changes to ensure the planned growth of the surveyed areas.

Keywords: *human intervention, environmental consequences, socioeconomic impact, wetland, chalanbeel, Bangladesh*

Introduction

Over the past few decades, land use and land cover change have become one of the major concerns for many countries of the world (Mou *et al.*, 2023). Human interventions are major contributor to this change, with wetlands being among the most affected. A wide range of human interventions have altered the functionality of wetlands and are considered responsible for their

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degradation (O'Connell 2003; Sievers *et al.*, 2018). Wetlands, which make up 6.4 percent of the planet's land area, are essential ecosystems having crucial impacts on both peoples' well-being and environmental sustainability (Islam and Kitazawa, 2013). Wetlands are among the most significant ecosystem type on the planet. They account for 47 percent of all ecosystem values worldwide (Hu *et al*., 2017) and wetlands with high ecological productivity offer a wide range of ecosystem services that outperform those provided by terrestrial systems (Gardner and Finlayson, 2018). In addition, wetlands offer numerous benefits and contribute substantially to a country's economic development (Ramsar Convention Bureau, 1971).

Over 50 percent of Bangladesh's land areas might be considered as wetlands under the definition provided by the Ramsar convention (Thompson, 2008; Al-Amin *et al*., 2021).Wetlands of Bangladesh can be classified into many varieties, such as Haors, Baors, Swamps, Beels etc., each of which makes a distinct contribution to the country's ecological and socio-economic systems. They also have distinct cultural values. A Beel is a shallow water body or a kind of wetland, usually forms in the low-lying areas in Bangladesh. It is a little saucer-shaped depression with a marshy character which collects surface runoff during the rainy seasons and some of them frequently dries up in winter (Hossain *et al*., 2009), and it is playing an important role in surrounding ecosystems. Despite their significance, wetlands of Bangladesh are being degraded rapidly due to the increasing pressures of population growth (Akhter *et al*., 2018). With some natural processes, a variety of human intervention-induced causes such as overexploitation or overfishing, pollution, poorly constructed infrastructures, lack of institutional coordination, mismanagement and inadequate public awareness are responsible for the reduction of wetland resources, resulting in degradation (Byomkesh *et al*., 2009; Azmery *et al*., 2023).

The ChalanBeel, located in the northwest region of Bangladesh, is the largest and one of the most notable wetlands of the country, particularly in northern Bangladesh (Islam, 2020). The area comprises a series of interconnected depressions through channels and rivers, creating a large water body which spans around 375 sq. km. during the monsoon season (Hossain *et al*., 2009).It covers four adjacent districts: Rajshahi, Pabna, Sirajganj, and Natore; and connects numerous smaller waterways that join and flow southward, eventually draining into the Padma and Brahmaputra rivers (Rahman *et al.*, 2022). The Beel has long offered a variety of benefits to the local communities. It has a distinctive ecosystem that supports the local economy and provides fresh water to thousands of dwellers (Nurullah, 2024). ChalanBeel offers agriculture, cattle grazing, and fishing; and its diversified population also contributes to its cultural importance. During the rainy season, the Beel fills with water, creating a fish breeding habitat for both villagers and fishermen (Galib *et al.*, 2009). The Beel has been historically crucial for supporting the livelihoods of around five million people (Sayeed *et al*., 2015).

Over the previous few decades, many types of human activities, such as agricultural activities, water management projects, development of infrastructures etc. have considerably affected the land use land cover of this area. The total area of the wetland is shrinking rapidly, spanning only 10 Upazilasat present (Hossain *et al.*, 2009). Embankments, dams, highways, and railway lines have interrupted water flows, combined with the impacts of global climate change, resulting in a loss in natural resources and negatively affecting the livelihoods of approximately five million people (Hossain *et al.*, 2009; Kibria and Haroon, 2017). These changes have caused severe environmental and socio-economic consequences in the present area. Due to its declining resistance, the wetland is experiencing environmental deterioration, which has an effect on the socioeconomic circumstances of the local population (Nurullah and Sarker, 2020; Shahidullah *et al*., 2020; Parvez and Mohsin, 2022).

Although several studies were conducted on the ChalanBeel area on various aspects, it is important to examine the role of human intervention on land use land cover changes in the ChalanBeel area of Bangladesh, and the present study is emphasizing more on this aspect.

Materials and Methods

Study Area

ChalanBeel covers eight upazilas in three northern districts, including Ullapara, Raiganj, and Tarash Upazilas of Sirajganj District, Chatmohar, Bhangura, and Fridpur Upazilas of Pabna, and Singra and Gurudaspur Upazilas of Natore, is the most significant wetland in the country. During the monsoon, it is made up of a collection of beels that are connected to one another by a number of waterways. It plays an important role to the country's socio-economic systems and ecological development. The blue color area represented the present area of ChalanBeel occupying a large portion of Sirajgonj, Pabna, Natore and some parts of Rajshahi, Bogura and Naogaon District (Figure 1).

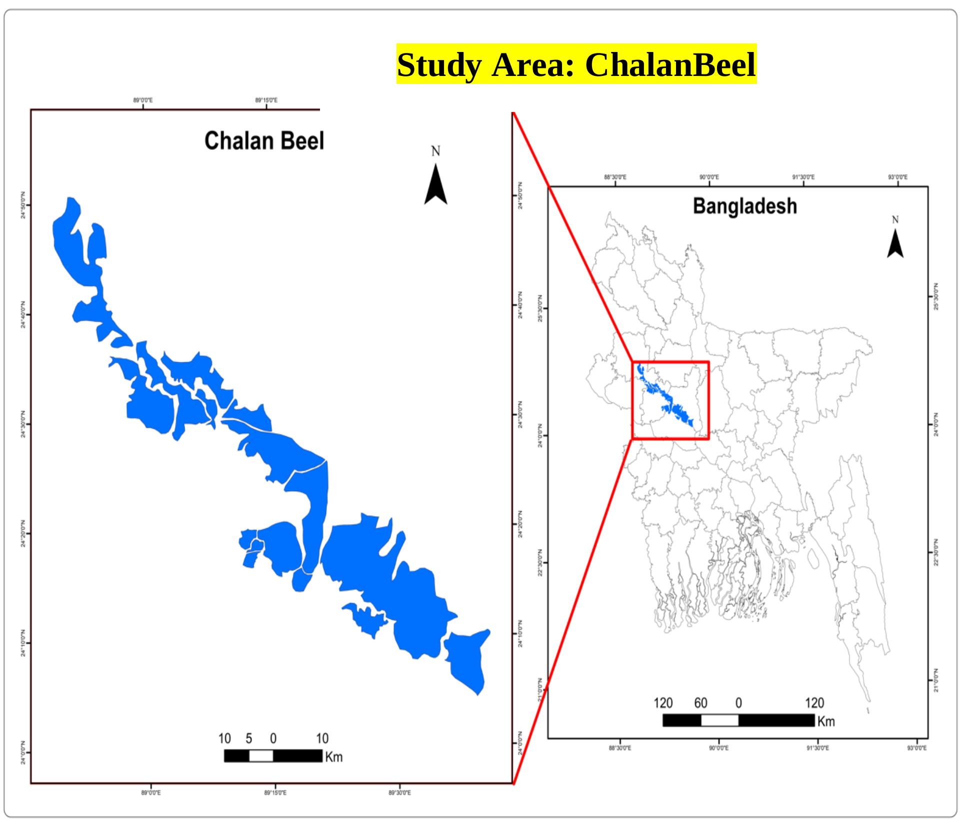

Figure 1: Location of ChalanBeel Area in Bangladesh

Sample Size Selection

The surveyed households were randomly selected from the population of the selected villages of Udhunia Union of Ullahpara Upazila under the Sirajgonj district of Bangladesh. The sample size for this study was calculated by using Yamane's formula (Yamane, 1967), considering the number of households in the study villages. The formula is as follows:

$$n = N / (1 + N \times e^2)$$

Here,n represents the sample size (number of households chosen for interviews),

N stands for the total households in the study areas, and

e indicates the level of error.

To ensure a reliable sample size determination, a confidence level of 93 percent and a precision level of 7.5 percent were used. The total population of Udhunia was 3274 and the number of households was 791. Based on the population of the selected village, the sample size (n) for this study was 146. Rounding to the nearest whole number, the calculated sample size (n) is 150.

Data Collection Techniques

This study followed both primary and secondary data collection methods to investigate human intervention and its environmental consequences in the study area. Primary data was collected through field surveys that included direct observation, questionnaire surveys, and Focus Group Discussions (FGDs) with the relevant stakeholders, including school teachers, farmers, fishers, and local knowledgeable persons. Reconnaissance surveys were conducted in various sites of ChalanBeel, including Singra, HaltiBeel, RoktodoherBeel, and BilashiBeel in 2023, to analyze the socioeconomic and environmental consequences of human interferences. Semi-structured open-ended questionnaires were used and distributed to the surveyed households to collect the primary data. A pilot survey of the questionnaire was undertaken to ensure clarity and relevance, with appropriate revisions made prior to the complete survey. Furthermore, satellite image analysis was performed for mapping and examining land use changes of the surveyed areas. Secondary data was gathered from a variety of published and unpublished sources, including Bangladesh Bureau of Statistics (BBS) documents, journal articles, and reports of relevant governmental and non-governmental organizations (NGOs) publications. Furthermore, satellite images and maps were used to supplement the findings of primary data collected from the field.

Data Analysis Techniques

The collected primary and secondary data were analyzed utilizing a number of software such as ArcGIS 10.8, Google Earth Pro, SPSS, and Microsoft Excel. ArcGIS 10.8 was used to analyze satellite images of the ChalanBeel area over a 20-year period, from 2003 to 2023. Satellite photos were obtained from the USGS Earth Explorer website, using Landsat 7 for 2003 and Landsat 8 for 2013 and 2023. ERDAS Imagine was used for pre-processing to reduce noise and haze in these photographs, which were taken in January during the dry season to minimize cloud cover and highlight permanent water features. When the land use and land cover map of three different years were prepared, further statistical analysis were conducted to anticipate the differences. Furthermore, all acquired data was examined statistically, and the results were presented as tables, graphs, diagrams, and maps to effectively communicate the research findings.

Research Design

The following diagram represents the research methodology of the present study:

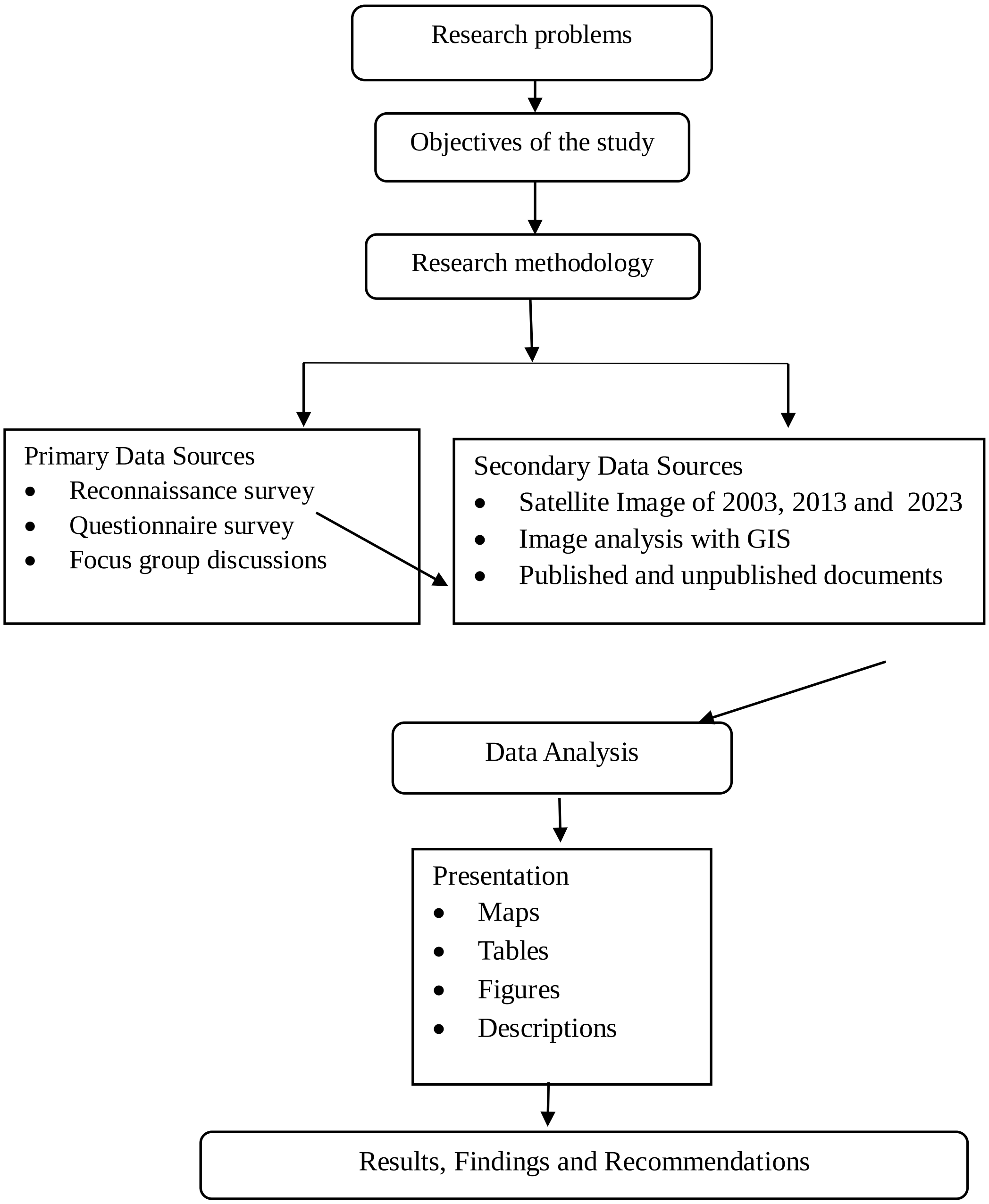

Figure 2: Research Design

Results and Discussion

The demographic characteristics of the surveyed respondents selected from the study area to know their views regarding the human intervention induced land use land cover changes in the study area are shown below Table 1.

Table 1: Demographic Characteristics of the Surveyed Respondents

Factors	**Classes**	**Percentage**
Gender	Male	52
	Female	48
	18-24	6
	25-34	32
	35-44	35
	45-54	20
	55-64	5
Age group	65+	2
Level of education	Illiterate	11
	Primary	58
	Secondary	20
	Technical/vocational	2
	College	6
	University	3
Occupation	Farming	58
	Fishing	10
	Business	9
	Day labor	12
	Services	4
	Housekeeping	5
	Others	2
House type	Pucca	33
	Semi-pucca	87
	Pucca	1

Source: Field Survey, 2023

Changing Trends of ChalanBeel Area in Last 20 Years

ChalanBeel has experienced a huge change in the last 20 years as a result of human interventions. The environmental and socio-economic conditions of the residents of the Beelarea transformed significantly due to construction of new roads, changes in settlement patterns, changing agricultural practices, the use of chemical fertilizers, changes in vegetation coverage, and land use land cover changes etc. However, recently developed road networks caused a huge change in the livelihoods and the socio-economic condition of the local residents. Due to human interferences in the study area, settlement and road networks were developed than the past and brought huge changes in the areas over the period of time. The respondents indicated a significant increase in the tourism sector, with 95% noting growth over the last 20 years (Table 2). In contrast, 43% reported a decline in natural vegetation.

Table 2: Respondents' Perceived Changes in ChalanBeel Area in Last 20 Years

Issues	Increased (%)	Unchanged (%)	Decreased (%)
Settlement	70	22	8
Road networks	91	7	1
Natural vegetation	21	36	43
Manmade vegetation	63	33	3
Agricultural land	62	13	25
Uses of chemical fertilizers	93	1	6
Pollution	30	68	2
Tourism	95	5	0

Source: Field Survey, 2023

Major Changes in Chalan Beel Area

In last 20 years, Chalan Beel area went under huge changes due to human interventions. Among them, some major changes were land ues change, permenent water bodies decrease, polpulation change, change in agricultural practices, blocking of natural water flows, increase of road networks, etc. Here assigned weight(w) were strongly disagree, disagree, neutral, agree and strongly agree which represented the value 0, 0.25, 0.50, 0.75 and 1, respectively. In a Weighted Average Index (WAI), each data point value (x) was multiplied by the assigned weight(w), which was then summed and divided by the number of data points (N). The formula is as folllows:

$$WAI=(\sum wx)/N$$

A significant portion of the respondents focused more on land use land cover change and population dynamics, and the WAI value were 0.82 and 0.87, correspondingly (Table 3). Most of the respondents highlighted the increase of population for the change in landuse and that also change croping pattern in the area.Changes in agricultural practice was noticable in the study area and the WAI value was 0.69. Traditional crops like Amon, Kaun, Wheat, Jute etc. were shifted by High Yield Variety (HYV) crops like Boro rice, corn, mustrad, onion, vegetables etc.

A large part of permenent wetlands were transformed into low-lying area, agricultural land and human settlement. People focused more on population increase as a major factor that caused the depletion of natural water bodies, and the WAI value was 0.68. Natural water flows also reduced significantly in last few years due toconstruction of various infrastructures obstructing the water flowsin the area.

Table 3: Respondents' Percieved Changes in Chalan Beel Area

Type	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N = 150 WAI
Land use change	0	2	13	59	76	0.82
Reduction of the water bodies	1	23	37	42	47	0.68
Population changes	0	0	0	62	88	0.87
Changes in agricultural practices	7	16	26	54	47	0.69
Blocking the natural water flows	13	17	67	40	13	0.76

Source: Field Survey, 2023

Majority of the respondents highlighted that population increase and landuse land cover change were noticable in the study area (Figure 3). Changes in agricultural practices, blocking the natural water flows and reduction of natural water bodies became major concerns of the surveyed area also.

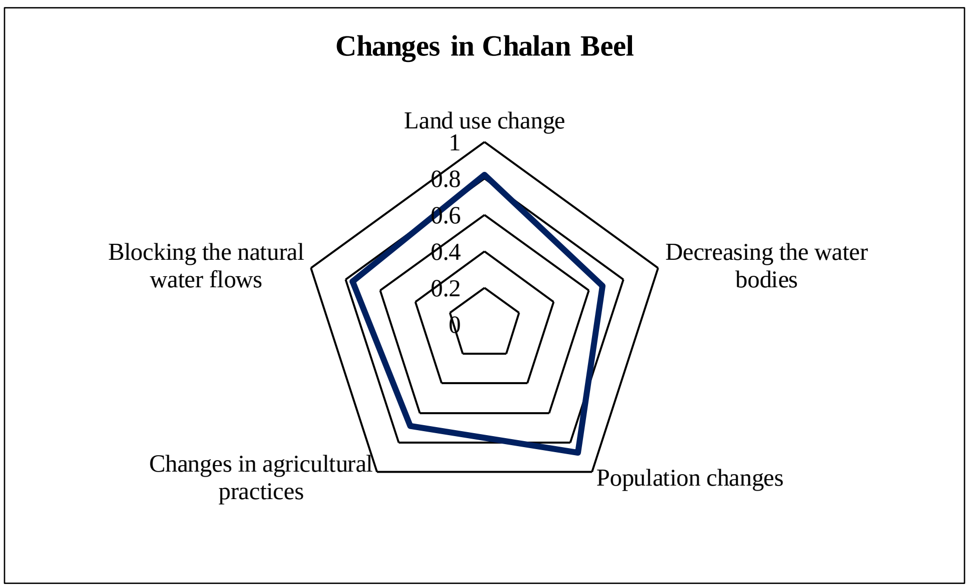

Figure 3: Respondents' Percieved Changes in Chalan Beel Area

Land Use Land Cover (LULC) Changes in ChalanBeel from 2003 to 2023

LULC is a dynamic process influenced by various factors, including infrastructural development, urbanization, and agricultural growth. Land use patterns are transformed by human intervention largely to accommodate the changing needs and requirements of locals. The land use pattern in the study area has been dramatically changed by human activities in last 20 years.

LULC Changes between 2003 and 2013

ChalanBeel was largely covered by permanent water bodies and low-lying floodplains in 2003, with the remaining tiny area being made up of communities and agricultural land. Due to human encroachment, 1.66 sq. kms. of permanent wetlands were converted to built-up areas. More space for accommodation was, therefore, required for the growing population. In the study area, 52.19 square kilometers of low-lying seasonal wetland have been developed; exhibiting a rapid growth rate. A significant conversion took place of permanent water bodies to low lying areas, and the areas were 125.13 sq.km. between 2003 and 2013, water bodies converted into low-lying area, and the area accounted 125.13 sq. km. This showed that permanent water bodies were accumulating water due to both human activities and natural siltation. At the same time, water bodies were being transformed into built-up areas. Furthermore, the number of low-lying areas declined on the regular basis due to filling up by locals.

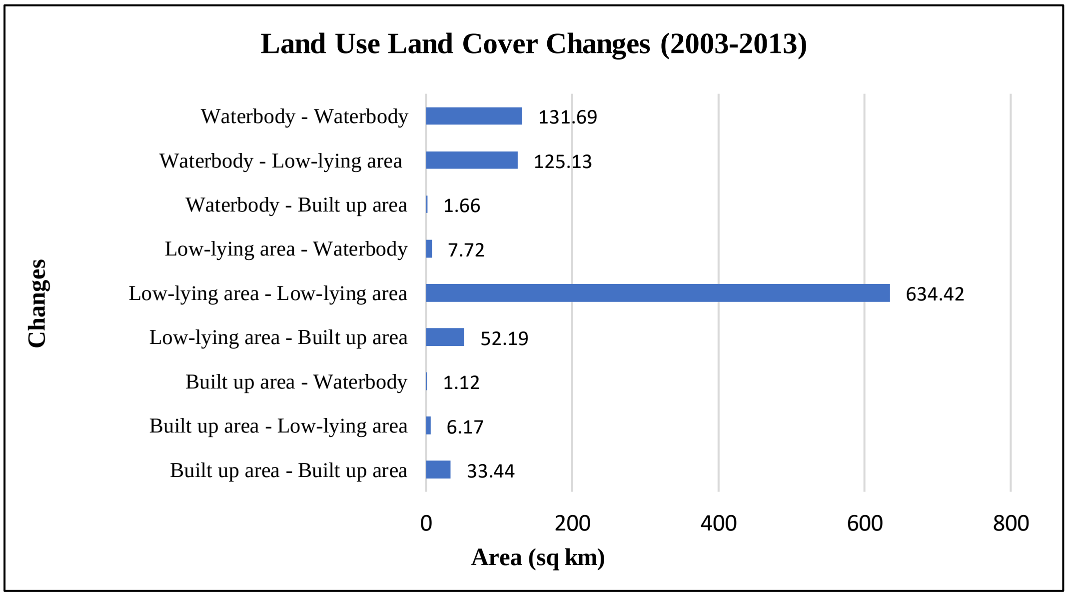

Figure 4: Land Use Land Cover Changes from 2003 to 2013

The study region's various land use types—33.44 sq. km. of built-up area, 634.42 sq. km. of low-lying area, and 131.69 sq. km. of permanent water bodies—did not change between 2003 and 2013 (Figure 4).

Major transformations of LULC in between 2003 and 2013 were depicted in Figure 5. A significant portion (125.13 sq.km.) of permanent water bodies were transformed into low-lying seasonal wetland. The next significant conversion was the development of low-lying land (52.19 sq.km.) into built-up areas. Less than 10 sq.km. areas made up the other modifications, which were regarded as minor ones. The rise of agriculture and the expansion of agricultural lands, as well as population changes, land fragmentation, rising settlement, development of communication networks and other factors, were the main reasons of the shift in water bodies and low-lying seasonal water bodies.

Permanent water bodies became dried up as a result of the installation of barriers in the natural water flows, which caused siltation and the conversion of permanent water bodies into agricultural lands. Moreover, during the dry season, the majority of low-lying seasonal water bodies are used for agriculture. Due to the growing need for housing, food, and other necessities brought on by human development, water bodies decreased.

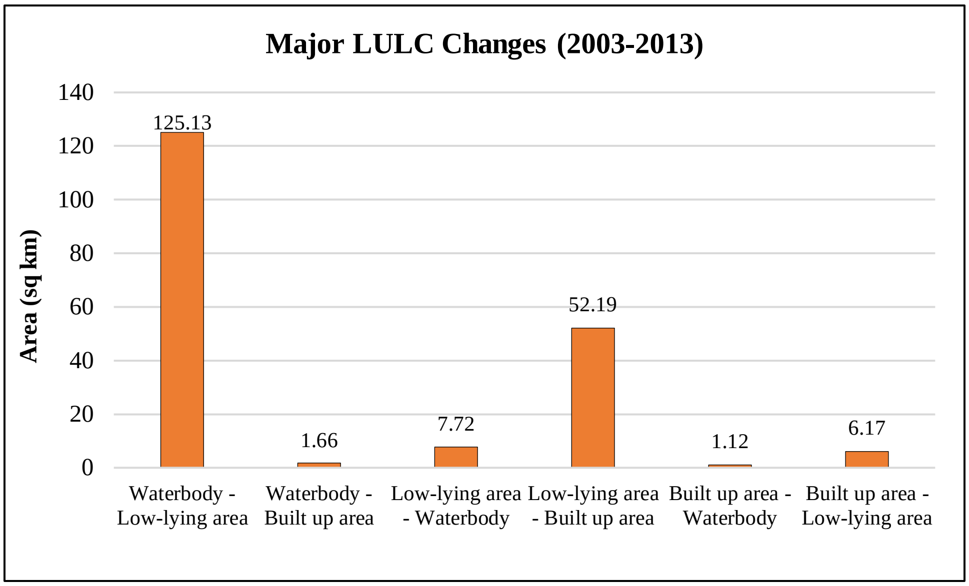

Figure 5: LULC Changes in between 2003 and 2013.

According to the change detection map (Figure 6), permanent water bodies were reduced and converted into seasonal low-lying wetlands. Majority of seasonal wetlands were transformed into built-up areas and rest of the portion of land converted into agricultural land and settlements. Throughout time, permanent wetlands were also transformed into built-up areas.

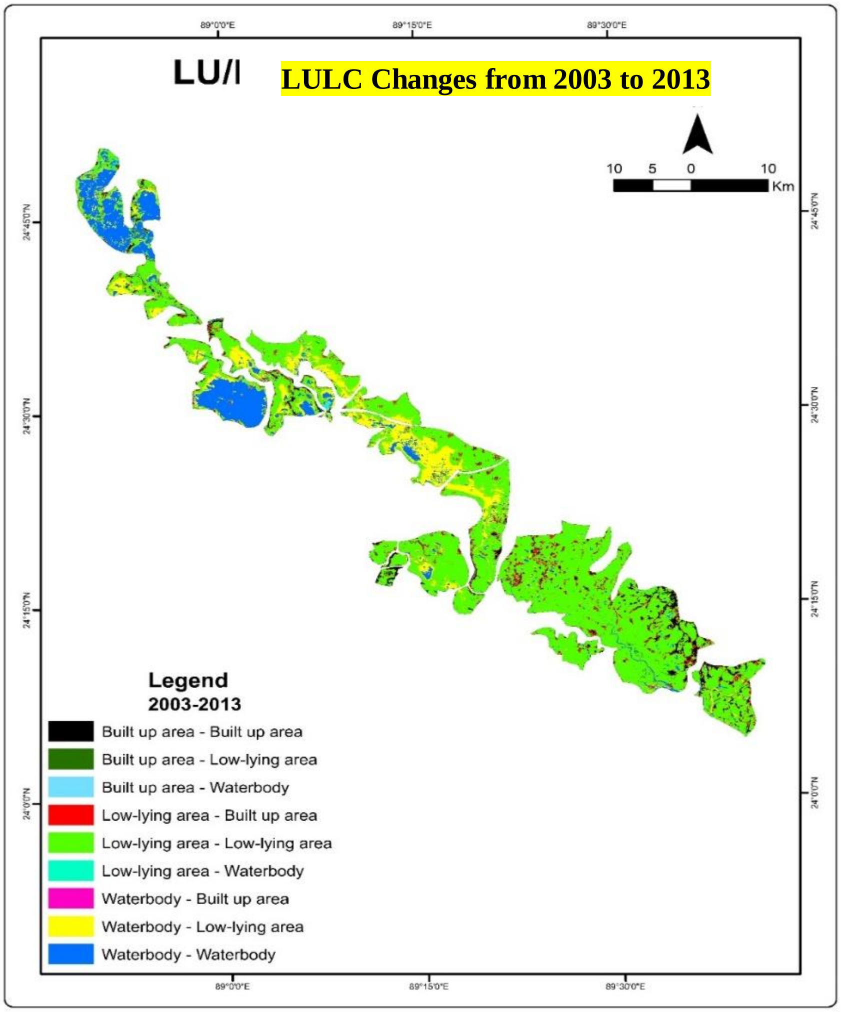

Figure 6: LULC Changes from 2003 to 2013

LULC Changes between 2013 and 2023

From 2013 to 2023, the most notable changes occurred, and 55.58 sq. km. permanent wetlands were converted to low-lying seasonal wetlands and about 18 sq.km. permanent wetland converted into built-up areas, and 60.69sq. km. low-lying areas were converted into built-up area. Over this period, nearly 13 sq. km. low-lying areas converted into permanent wetlands, and 11.66 sq. km. built-up areas converted into low-lying areas (Table 4).

Table 4: Land use land cover changes between 2013 and 2023

LULC Changes	**Area (sq. km.)**
Water body-Water body	76.97
Water body - Low-lying area	55.58
Water body – Built-up area	7.93
Low-lying area - Water body	12.92
Low-lying area - Low-lying area	692.08
Low-lying area – Built-up area	60.69
Built-up area - Water body	0.69
Built-up area - Low-lying area	11.66
Built-up area – Built-up area	75.03

However, the Figure 7 showed some unchanged land areas, which were not transformed in between 2013 and 2023. These were 75.03 sq.km. built-up areas, 692.08 sq. km. areas of low-lying seasonal water bodies and 76.97 sq.km. areas of permanent water bodies which remained unchanged. Low-lying seasonal wetland areas were the largest among all unchanged land areas.

A significant shift of land use and land cover with low-lying areas becoming built-up areas. Around 60.69 sq.km. of low-lying lands were developed over the period (Figure 7). The major factor associated with the shift was the requirement for greater room to accommodate the growing human population. Therefore, these low-lying areas were used for human settlement development.

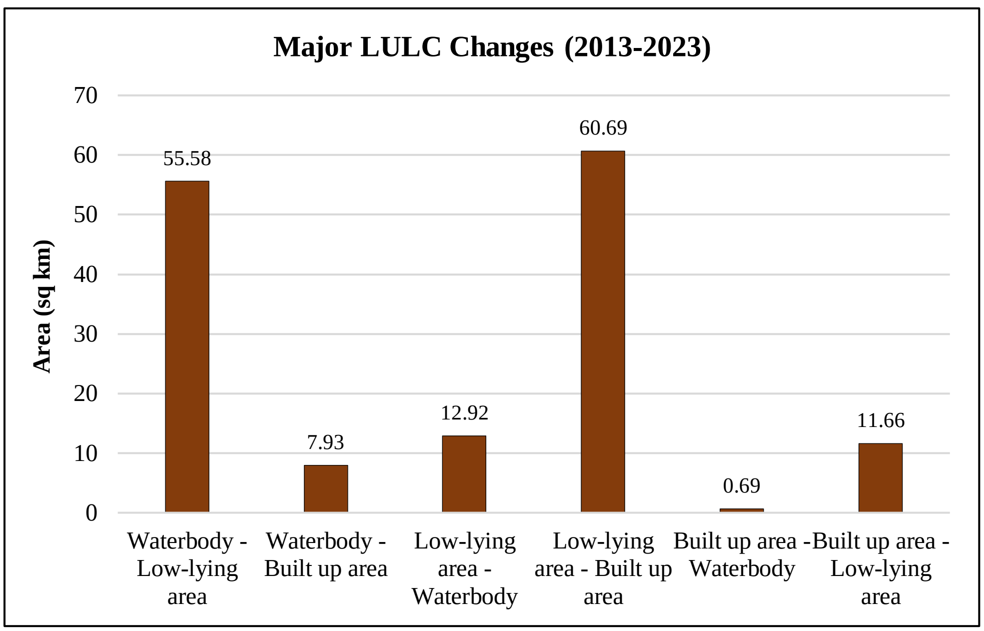

Figure 7: LULC Changes from 2013 to 2023.

Another major change was noticed that was permanent water bodies were converted into low-lying area (Figure 8). Almost 55.58 sq.km. areas which were previously uses as wetland were converted into low lying areas. The main reason of these changes was natural siltation in the Beel area, human interventions such as land filling, infrastructure development, expansion of agricultural lands etc. In addition to this, permanent water bodies have been created on around 12.92 sq. km of low land (Figure 8). This was mostly caused by soil erosion and land degradation. The low-lying region was permanently transformed into a wetland by erosional activity. Another reason was soil excavation. Human influences on land use changes were partly to blame. Almost 11.66 sq.km. built-up areas were converted into low lying areas, 7.93 sq.km. water bodies converted into built-up areas and 0.69 sq.km. built-up areas were converted into water bodies due to some natural and manmade causes. So, LULC changes were noticeable from 2013 to 2023 (Figure 8).

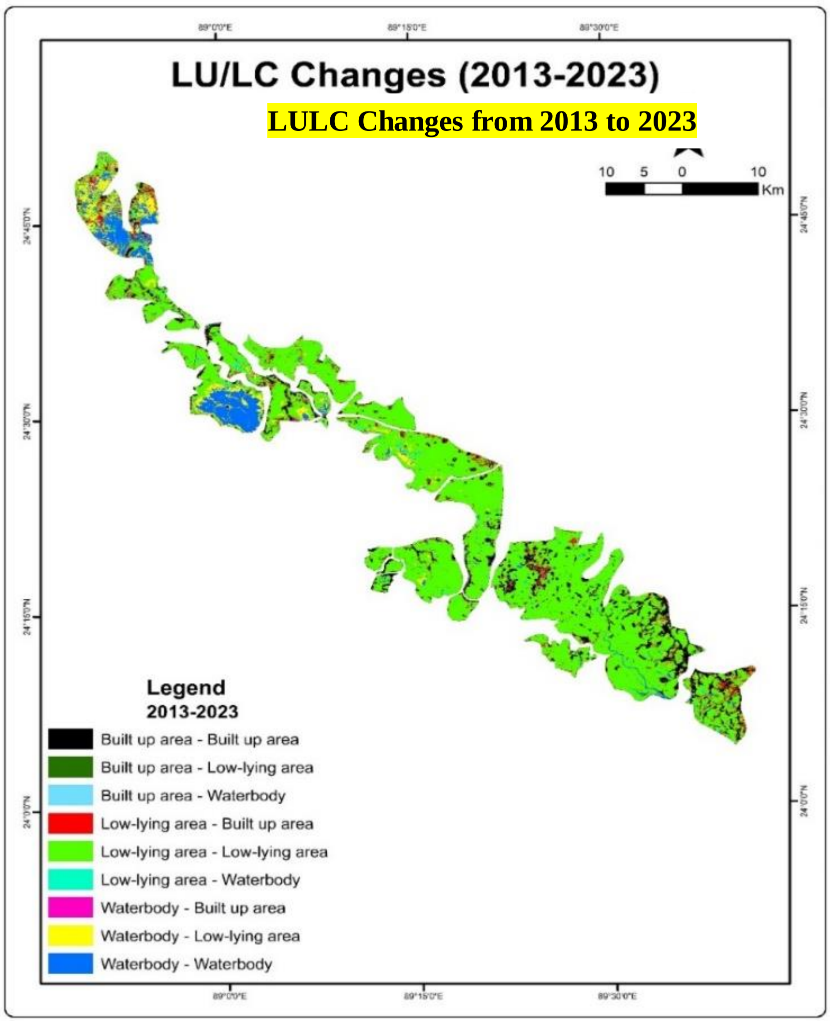

Figure 8: LULC Changes between 2013 and 2023

LULC Changes between 2003 and 2023

The significant changes of wetlands have been calculated using visual interpretation of satellite images. The study was conducted by comparing the distribution of each type of area for a certain year comparing with the previous year's distributions. However, the minor changes were not considered in this investigation due to the difficulties of visual image interpretation.

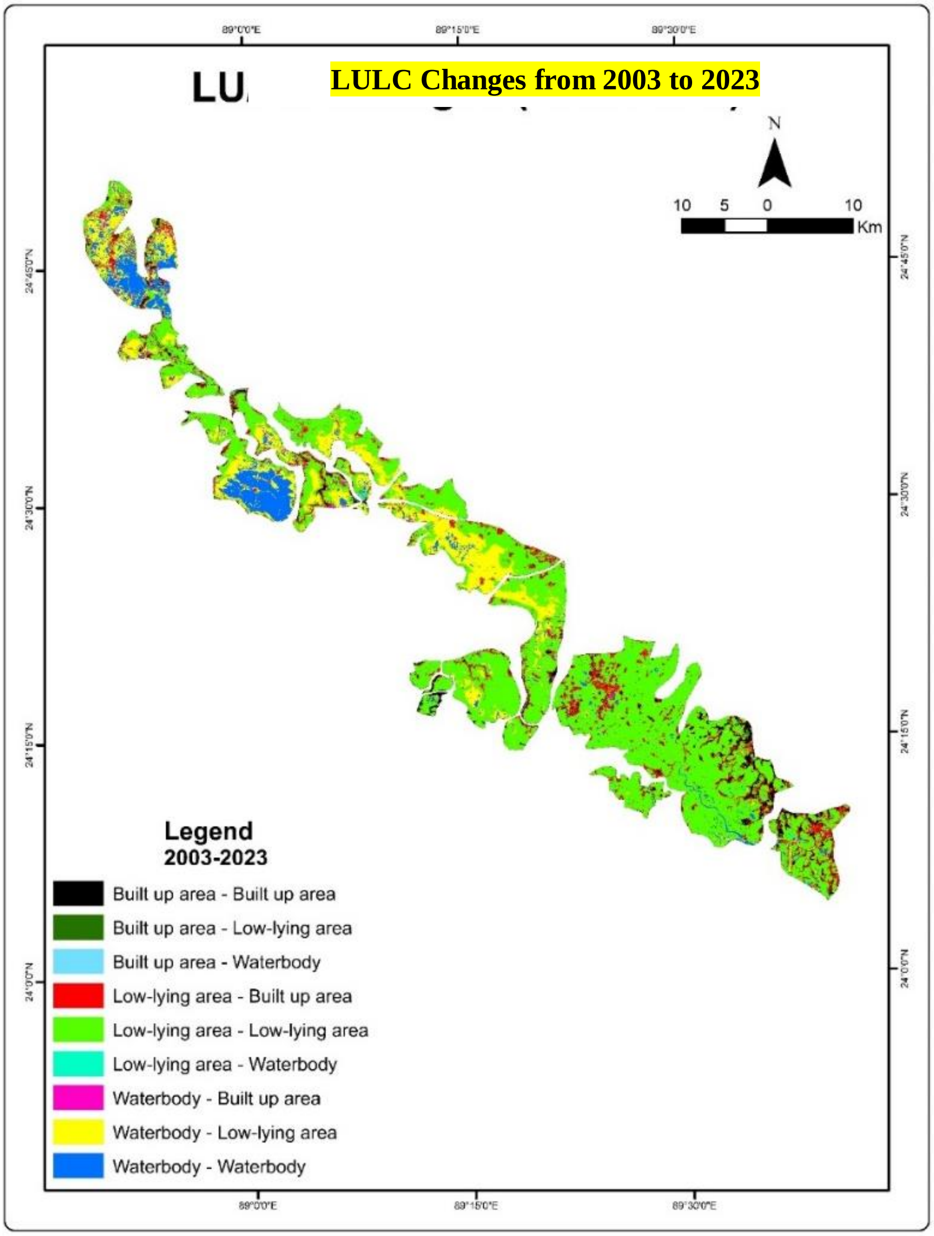

Figure 9: LULC Changes from 2003 to 2023

The wetland of ChalanBeel area has seen significant transformation in the last 20 years. A lot of changes were driven by human activities. Numerous permanent water reservoirs were transformed into low-lying seasonal water bodies and built-up areas, accounting nearly 76 sq. km. In 2023, a significant portion of the permanent water bodies in the ChalanBeel area were converted into built-up area and agricultural land to meet the requirements of the people (Table 5).

Table 5: Land use land cover changes between 2003 and 2023

Changes	Area (sq. km.) Changes (2003-2023)
Water body - Water body	82.20
Water body - Low-lying area	162.77
Water body – Built-up area	13.46
Low-lying area - Water body	7.42
Low-lying area - Low-lying area	591.05
Low-lying area – Built-up area	95.70
Built-up area - Water body	0.95
Built-up area - Low-lying area	5.35
Built-up area – Built-up area	34.42

The noticeable changes were the conversion of permanent water bodies into low-lying land, which is normally known as seasonal wetland. Around 162.77 sq. km. of permanent water bodies were converted into low-lying areas (Figure 10). However, low-lying areas were converted into built-up areas in large quantities, about 95.7 sq.km. of land areas from 2003 to 2023. Almost 13.46 sq.km. of wetland areas were converted into built-up areas due to human intervention like settlement, agriculture, roads, and other infrastructural development. Low-lying areas encompasses 7.42 sq. km. were converted into permanent water bodies and 5.35 sq. km. of built-up areas were converted into low-lying areas.

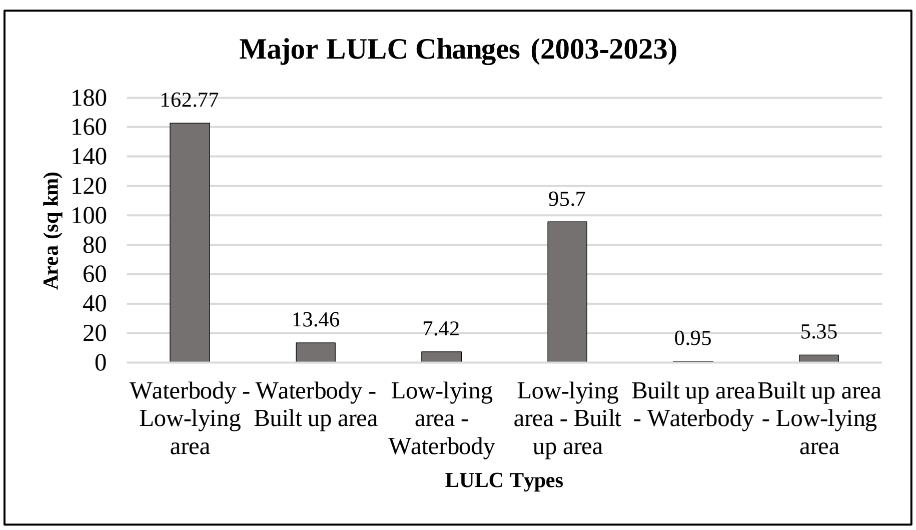

Figure 10: Major Land Use Land Cover Changes from 2003 to 2023

The built-up area has increased significantly during the last 20 years. In 2003, there were 40.87 sq. km. of built-up land but in 2023 the amount increased to 144.06 sq. km., and built-up area grew from 4.11% to 14.48% over the period of time. Rapid reduction of permanent water bodies occurred and it declined from 258.65 sq. km. to 90.63 sq. km.in the same period (Table 6).

Table 6: Over all LULC changes from 2003 to 2023

Year	Built-up area (sq. km.)	Low-lying area (sq. km.)	Water body (sq. km.)
2003	40.87	695.12	258.65
2013	87.62	766.41	140.6
2023	144.06	759.89	90.63

The three categories in the table are built-up areas, wetlands (which include permanent water bodies), and low-lying areas (which contain seasonal water bodies). Built-up areas varied steadily from 2003 and 2023, increasing by 4.11%, 8.81%, and 14.48%, with a peak in 2023. Permanent water bodies decreased from 26% to 9.11%, whereas low-lying areas increased from 69.89% to 76.40%. Permanent water bodies were disappearing at an alarming rate due to the construction of various infrastructures by the local people. The overall rate of land use change in ChalanBeel from 2003 to 2023 was shown in Table 7.

Table 7: Rate of LULC change from 2003 to 2023

Class	Area insq.km. (2023)	Percentage	Area in sq.km. (2013)	Percentage	Area in sq.km. (2003)	Percentage
Water body	90.63	9.11	140.60	14.14	258.65	26.00
Built-up area	144.06	14.48	87.62	8.81	40.87	4.11
Low-lying area	759.88	76.4	766.41	77.06	695.12	69.89
Total	994.58	100.00	994.63	100.00	994.65	100.00

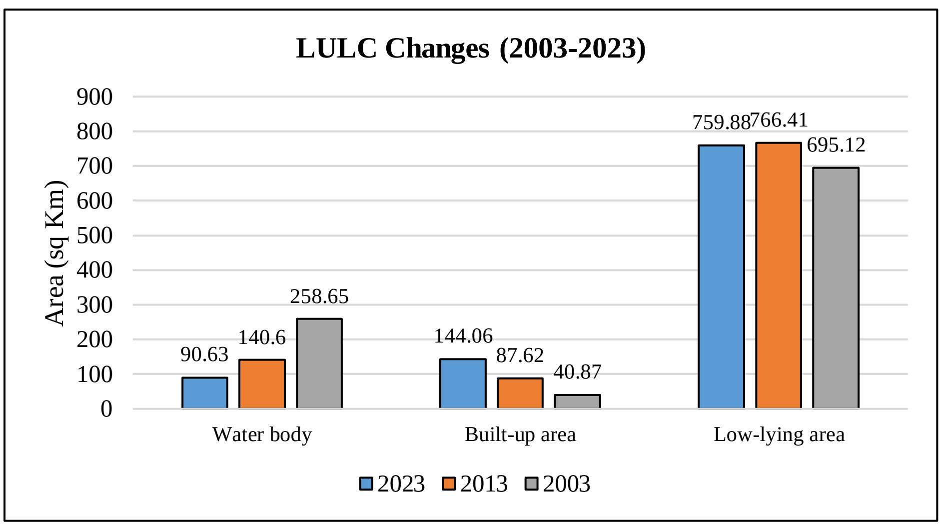

Figure 11: LULC Changes in ChalanBeel Area

However, the built-up area increased significantly in 2023 and it accounted 144.06 sq. km. The built-up area gradually increased during this period (2003–2023). There was a little change observed in the low-lying areas. Moreover, the permanent water bodies gradually declined in between 2003 and 2023. Built-up areas increased from 4.11% to 14.48% during the last 20 years (2003–2023). Low-lying areas increased from 69.89% to 76.40% (Table 7). On the other hand, permanent water bodies decreased from 26% to 9.11% during the 20-years period, which is a matter of concern for the surveyed areas. The overall land use changes occurred in the ChalanBeel area during the time period of 2003, 2013 and 2023 are shown in Figure 11 and Figure 12.

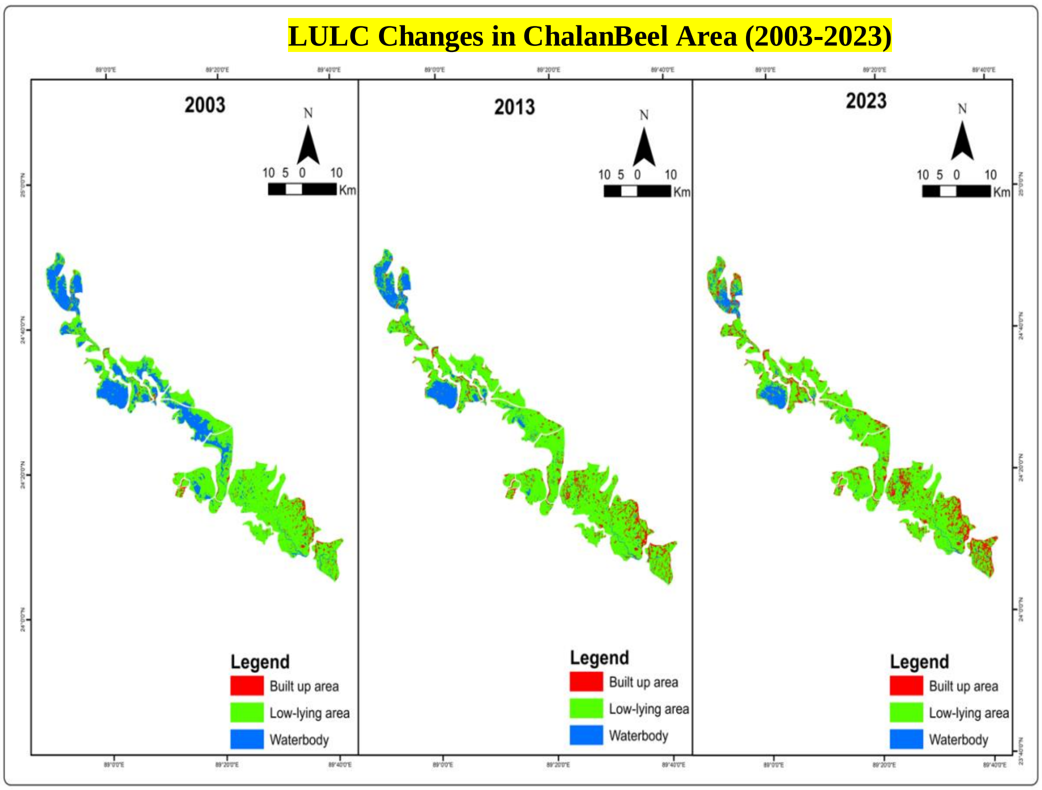

Figure 12: LULC Changes in ChalanBeel Area from 2003 to 2023

Conclusion

ChalanBeel, the largest wetland of Bangladesh, is in vulnerable condition due to various human interventions. Human interferences have drastically impacted the land use and land cover in this area, particularly in the last 20 years, resulting in environmental changes and socio-economic transformations. The study results demonstrated that the built-up areas increased from 40.87 sq.km. to 144.06 sq. km. between 2003 and 2023, whereas the water bodies decreased from 258.65 sq. km. to 90.63 sq. km. in the same period. The increasing trend of built-up area and decreasing trend of water bodies are also key indicators of a major environmental shift in this area.Rapid population growth, agricultural expansion, infrastructure development, and unplanned and unregulated human activities have created the substantial reduction of wetlands. This change has contributed to the degradation of local biodiversity and ecosystems. Moreover, traditional livelihoods, economy and cultures are negatively affected by these changes. To address these challenges, sustainable land management strategies are essential, along with the effective implementation of government policies to protect this wetland. Local communities need to be made aware of the adverse effects of human interventions and encouraged to follow the sensible use principles for the conservation of these well considered wetlands. Balanced ecological restoration with considering ongoing human interventions is essential to protect the ChalanBeel and keep it beneficial for the ecosystem and local community, which will eventually contribute to the country's ecosystem and environment.

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