

Monitoring Urban Growth and Its Impact on Arable Land Consumption in the Lower Turag Basin of Dhaka: A Google Earth Engine Based Study

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Abstract

As population increases, urban expansion occurs leading to the need for more food production. However, expanding urban areas at the cost of agricultural land is common worldwide, especially in developing countries like Bangladesh. This study examines the impact of urban growth on agricultural land in the Lower Turag Basin, Dhaka, Bangladesh, from 2000 to 2020, using Google Earth Engine (GEE) for satellite-based analysis. Rapid urban expansion has dramatically reduced agricultural areas, prompting concerns about food security and sustainable land use. Land use and land cover (LULC) were mapped and quantified across three-time points—2000, 2010, and 2020—highlighting significant declines in arable land, particularly in Dhaka North City Corporation and Savar Upazila. Results align with SDG Indicator 11.3.1, as the ratio of agricultural land consumption to population growth reveals a faster rate of land loss compared to population increase, with agricultural land per capita dropping by 76% over the last two decades. This study suggests the urgency for policies promoting sustainable urban development to preserve essential arable spaces. Thus, it emphasizes the importance of integrating satellite data for urban planning and supports data-driven decisions to balance urbanization and agricultural preservation.

Keywords

Urban Expansion, Land Use Land Cover, River Basin, Arable Land, Google Earth Engine

1. Introduction

Land use land cover change (LULCC) have emerged as important concerns in the context of environmental and resource conservation, especially where the pace of development is fast as in the Lower Turag River Basin in Bangladesh. The expansion of urban areas typically results in drastic changes in vegetation cover, thereby having a profound impact on local ecosystems, agriculture and water resources. It is worth mentioning the changes in the extent and pattern of urbanization and the quantity and quality of the agricultural land that is consumed as the population expands. Land is needed to fulfill this need by converting agricultural lands into urban forms. In addition, problems of water source disruption and bio-diversity loss are not an exception to this issue; thus, general food insecurity endangers ecological balance [1]. From 1989 to 2009, agricultural land use in areas close to Dhaka decreased significantly due to urban encroachment and improved transportation networks [2]. Rural-urban migration, especially, caused the growth of the Dhaka Metropolitan Development Planning area at an average annual rate of 3.84% between 1981 and 2011 [3].

The Lower Turag River Basin primarily occurs in the highly productive agricultural zone and has experienced significant urbanization within the past twenty years. Various factors may lead to the transformation of rural areas, such as population, economic, and infrastructural development. Such dynamics of land use/land cover changes (LUCC) have implications for other hydrologic, nutrient, and general ecosystem status in the region [4] [5]. Research has revealed that urbanization has characteristic effects on runoff, sediment transportation, and water quality deterioration if the ratio of urban land extends beyond some benchmarks [6] [7]. To mitigate the challenges of unplanned urbanization, effective monitoring and management of land use changes is necessary [8]. The lack of adequate development planning has led to vulnerabilities in peri-urban areas [9]. Measuring the agricultural land consumption and population growth rates is important to determine the spatial pattern of land conversion [10]. A study reveals the decadal change of LULC, showing a 22.1% increase in built-up areas where agricultural land and green space have reduced significantly by utilizing remote sensing data [11]. Moreover, the use of remote sensing devices and Geographic Information System (GIS) have made it easier for the researchers to assess these changes.

It is appreciable that using Google Earth Engine (GEE) tools, temporal land cover dynamics can be determined and consequences of urbanization on agricultural land and water quality can be analyzed [5] [12]. Again, SDG Indicator 11.3.1 evaluates the balance between urban land consumption and population growth, providing a framework to assess sustainable urbanization. A ratio greater than 1 indicates disproportionate land consumption relative to population growth, often linked to inefficient land use practices. Integrating Land Consumption Rate (LCR) and Population Growth Rate (PGR) can be helpful to analyze the land use efficiency which provides a framework that can be applied to Dhaka to assess urban growth sustainability [13]. This study intends to identify and measure land cover conversion by Urban Expansion in the Lower Turag River Basin between the years

2000 and 2020, with particular emphasis on arable land consumption per head of the growing population, which will be conducted up to 2030 based on the next census. Identifying these dynamics will better inform sustainable land management practices and policy decisions that balance urban development with agricultural needs and environmental conservation.

2. Study Area

Turag River of Bangladesh is a tide-influenced River passing through west-north and north of Dhaka City [14]. The Turag River originates from the Bangshi River [15] which originates from the foot of the madhupur tract. Turag is also the upper tributary of the Buriganga River [15]. Buriganga merges with the Shitlakyia River near Narayanganj district. The Turag flows through Gazipur district and joins the Buriganga at Mirpur in Dhaka district. The Tongi Khal links the Turag with the Balu River [16]. The entire regime of the Turag is almost a semi-funnel-shaped basin, and its catchment is located on the central and southern parts of the Madhupur tract, which flows from north to south within the basin [17]. The lower Turag River Basin area includes 11 Unions with 88 Mauzas and 42 Wards having 199 Mauzas from 2 districts (Dhaka and Gazipur).

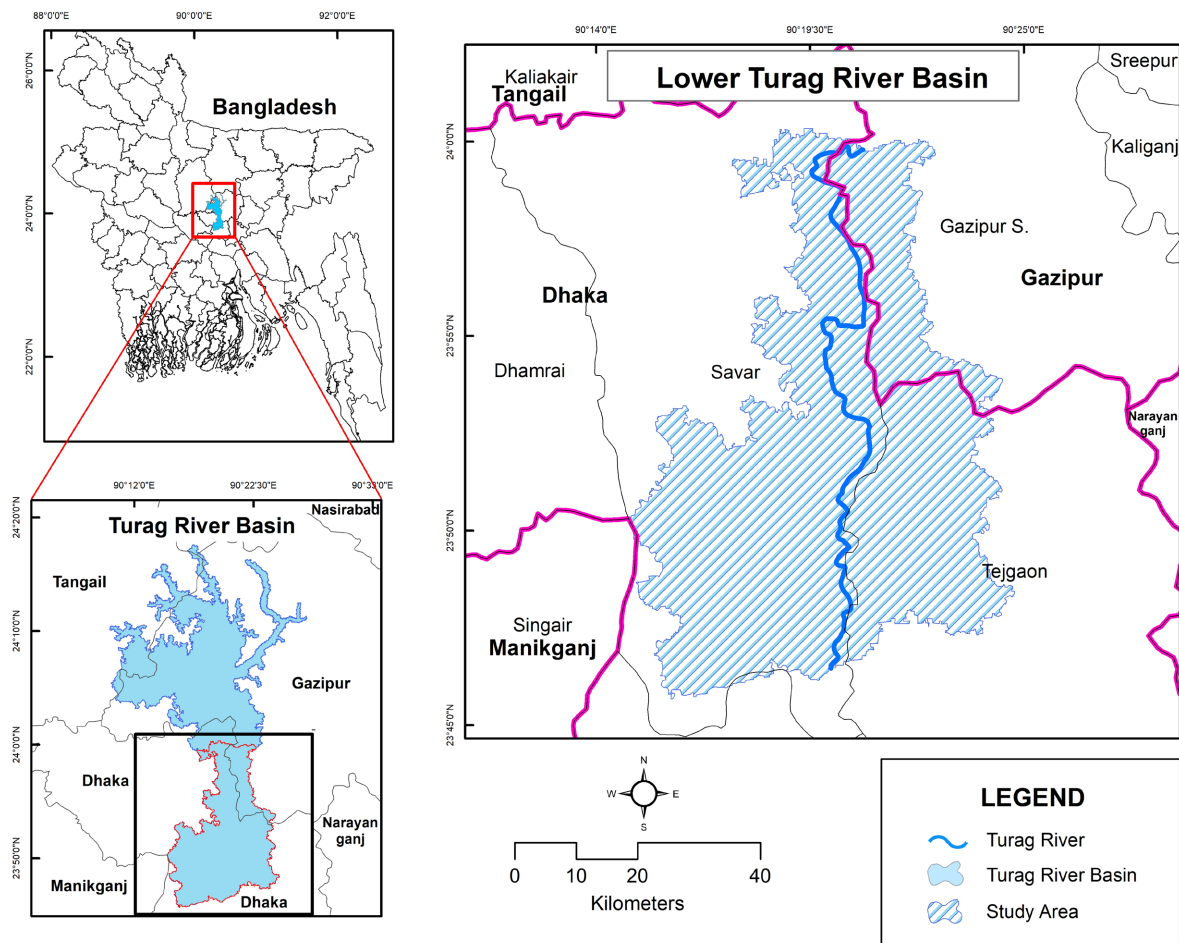


Figure 1. The lower Turag River Basin (Source: Compiled by author, 2024).

The Digital Elevation Model (DEM) of the Lower Turag River Basin shows that the basin's highest elevation is 55 meters and is located primarily in the south-western and northern parts. The lowest elevation, which is -16, is concentrated in the central region, which has the main course of the river, according to SRTM DEM data.

The total area of the Turag River is about 631 km². The Lower Turag River basin is considered southward from the Kodda Bridge, Tangail, and ends at the point where Turag meets the Buriganga River, covering a total area of approximately 252 square kilometers (Figure 1).

3. Data Collection and Research Methods

SRTM DEM data was used to produce the map of the Lower Turag Basin area. By using satellite imageries from Landsat 5 and Landsat 8 on the GEE platform, LULC maps in JavaScript have been produced. Google Earth Engine (GEE) is a cloud-based geospatial analysis platform that enables efficient processing of large-scale satellite data. It is particularly effective for tracking land cover changes over time due to its integration of multi-temporal and multi-resolution datasets. To assess the statistical significance of those produced maps, Kappa Accuracy and Overall Accuracy, taking 70% for training samples and 30% for testing samples, were calculated (Figure 2).

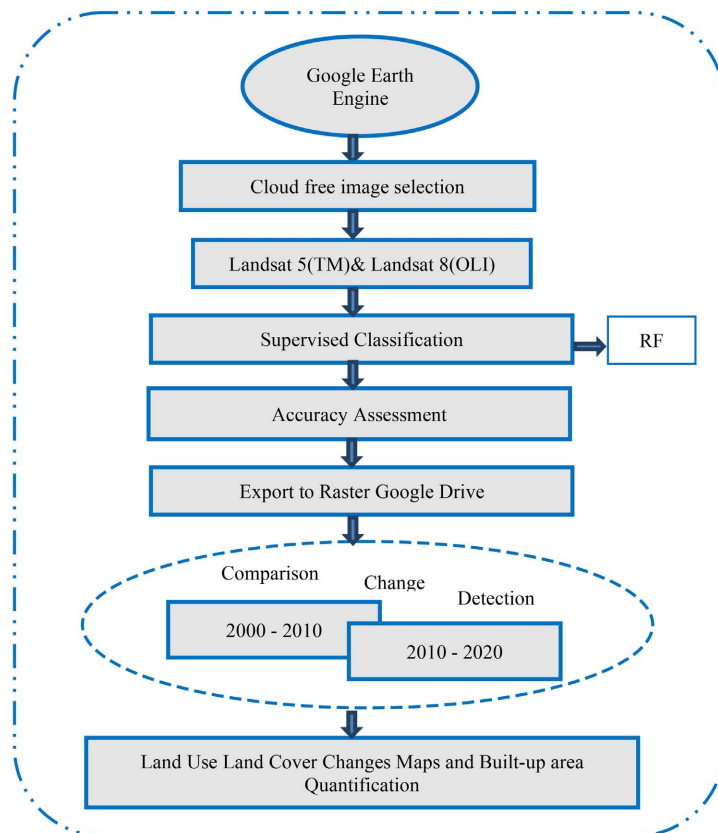


Figure 2. Methodology to produce LULC maps.

Following the formula provided by UN Habitat to calculate SDG Indicator 11.3.1, Agricultural Land Consumption Rate to Population Growth Rate (ALCRPGR) across Turag River Basin has been calculated for the period of 2000-2010 and 2010-2020 (Figure 3) and agricultural land transforming pattern has been observed at 1 km² gridded map for the respective years in ArcMap 10.8.

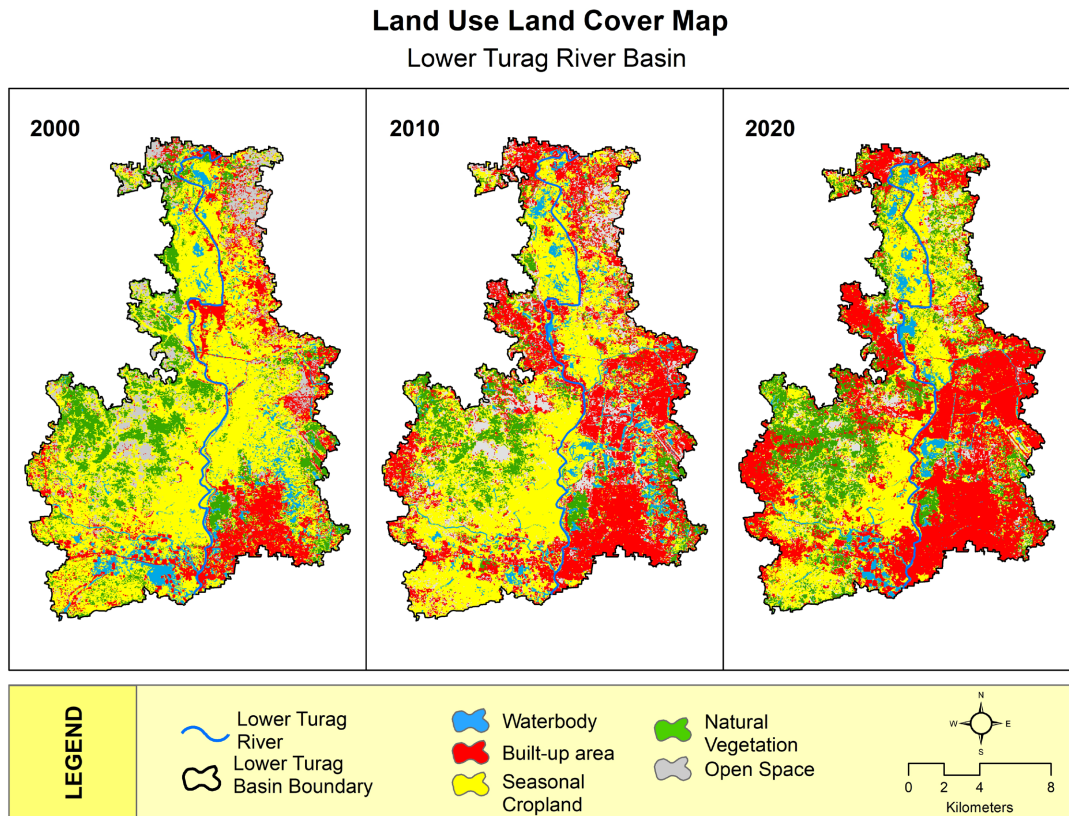


Figure 3. Spatio-temporal changes of LULC map from 2000 to 2020 (Source: Compiled by author, 2024).

Equation (1) is Land Consumption Rate, *i.e.*

$$LCR = \frac{V_{\text{present}} - V_{\text{past}}}{V_{\text{past}}} * \frac{1}{(t)} \tag{1}$$

where:

V_{present} is total built-up area in the current year;

V_{past} is total built-up area in the past year;

t is the number of years between V_{present} and V_{past} (or length in years of the period considered).

Equation (2) is Population Growth rate, *i.e.*

$$PGR = \frac{\text{LN}(\text{Pop}_{t+n} / \text{Pop}_t)}{(y)} \tag{2}$$

where:

LN is the natural logarithm value;

Pop_t is the total population within the urban area/city in the past/initial year;

Pop_{t+n} is the total population within the urban area/city in the current/final year; y is the number of years between the two measurement periods.

Equation (3) is

$$LCRPGR/LUE = \left(\frac{\text{Land Consumption rate}}{\text{Population growth rate}} \right) \quad (3)$$

The overall formula can be summarized as:

$$LCRPGR = \left(\frac{V_{\text{present}} - V_{\text{past}}}{V_{\text{past}}} * \frac{1}{T} \right) / \left(\frac{\text{LN} \left(\frac{\text{Pop}_{t+n}}{\text{Pop}_t} \right)}{y} \right) \quad [18]$$

4. Results and Discussion

4.1. Land Cover Dynamics over 2 Decades

A total of five land class types are considered to produce LULC maps. These are waterbody, built-up area, seasonal cropland, natural vegetation and open space. Through Kappa accuracy and overall accuracy, the statistical significance of those produced maps has been assessed in GEE (**Table 1**).

Table 1. Accuracy assessment for each map.

Maps	Accuracy Assessment	
	Kappa Coefficients	Overall Accuracy
LULC Map 2000	0.95	0.96
LULC Map 2010	0.89	0.91
LULC Map 2020	0.87	0.90

4.2. LULC Conversion from 2000 to 2010

In **Table 2**, it is clearly visible that in 2000, agricultural land covered the largest area, comprising 52% of the total study area, while the built-up area was 16% only. Waterbody covered a very small area, only 7% of the entire study area. Open space and natural vegetation covered a larger area than waterbody which was about 25 km² and 38 km² respectively comprising 10% and 15% of the study area.

After 10 years, in 2010, a noticeable overall decrease in agricultural land and an increase in built-up area was observed. 39% of the area was covered by agricultural land losing 31.49 km² or 19% of agricultural area to other land use while built-up area has increased to 33%. An increasing pattern is observed in the water body and open space. Vegetation has decreased to 22 km² in 2010.

However, in terms of land transformation 32 km² of agricultural land in 2000 was converted to a built-up area in 2010 which indicates a critical scenario for cultivated areas. A total of 8.88 km² of Open space has also been converted into Built-up area. This transformation has caused a remarkable loss of agricultural land, though a total of 15.78 km² of land has been converted to agricultural land from wetland and natural vegetation during the decade. Thus, this increase in built-up area is contributing to urban growth at an alarming rate (**Figure 4**).

Table 2. LULC Transformation 2000-2010.

Land Category		Land Use and Land Cover 2010					
		Waterbody	Built-up Area	Seasonal Cropland	Natural Vegetation	Open Area	Area (sq-km)
Waterbody	Area (sq-km)	7.34	3.12	5.30	0.43	0.66	16.85
	Percentage	43.56	18.52	31.45	2.55	3.92	100
Built-up Area	Area (sq-km)	0.66	28.48	6.54	0.36	5.96	41.99
	Percentage	1.57	67.83	15.58	0.86	14.19	100
Seasonal Cropland	Area (sq-km)	9.00	32.20	71.32	5.60	12.00	130.80
	Percentage	6.88	24.62	54.53	4.28	9.17	100
Natural Vegetation	Area (sq-km)	1.09	9.77	10.48	15.10	1.60	38.01
	Percentage	2.87	25.70	27.57	39.73	4.21	100
Open Area	Area (sq-km)	0.10	8.88	5.68	0.85	9.26	24.80
	Percentage	0.40	35.81	22.90	3.43	37.33	100
Total Area (sq-km)		18.45	82.45	99.31	22.30	29.95	252.45

Source: Computed by author, 2024.

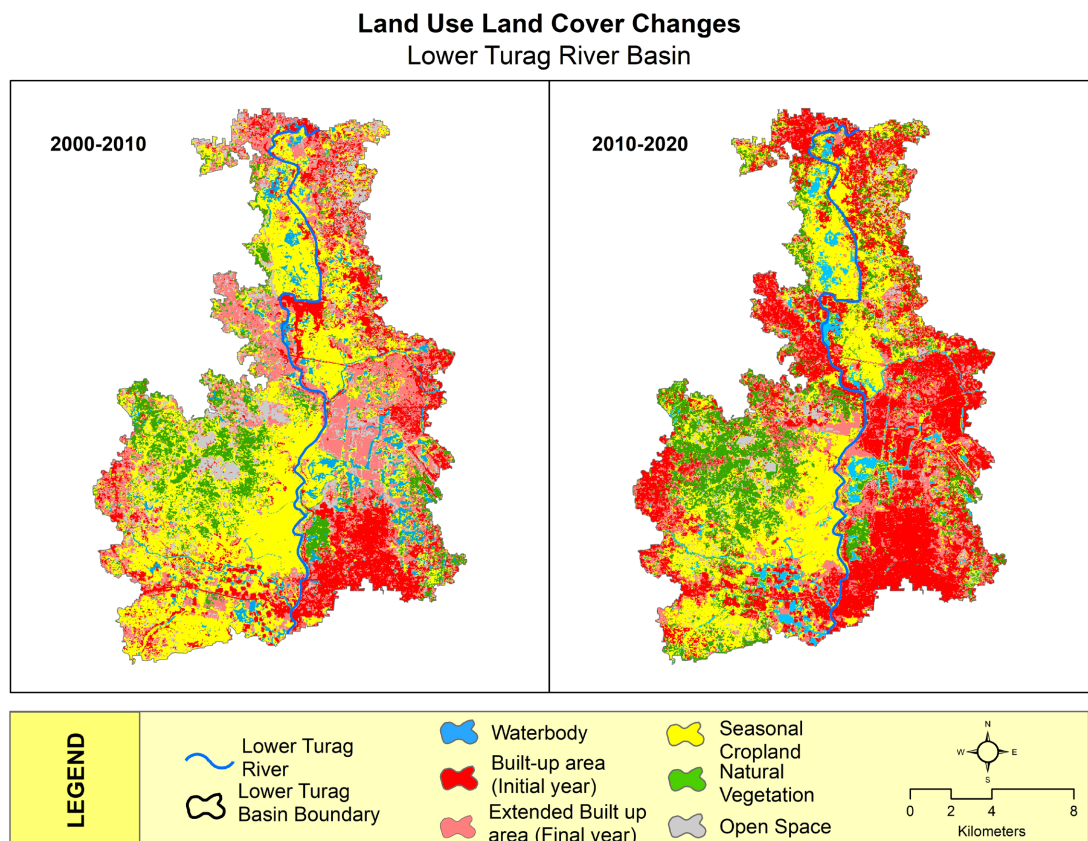


Figure 4. Built-up area extension over time (Source: Compiled by author, 2024).

4.3. LULC Conversion from 2010 to 2020

Built-up area has continued to increase the cost of agricultural areas at an alarming rate, as shown in **Table 3**. In 2020, built-up area increased to 40%, comprising an area of 100 km² and the trend showcases a consistent upward trajectory. On the contrary, agricultural area has decreased to 82 km². With time, the body of water and open spaces have also decreased while vegetation area has increased. About 19% of agricultural land as well as 41% of open space was converted to built-up area during the period. 55% of the agricultural land in 2010 has remained the same; however, the remaining 45% has been transformed into other land use. During this time period, a major portion of agricultural land was converted into natural space also, alongside converting into impervious area which suggested a direct correlation between urban expansion and agricultural land reduction.

Table 3. LULC Transformation 2010-2020.

Land Category		Land Use and Land Cover 2020						
		Waterbody	Built-up Area	Seasonal Cropland	Natural Vegetation	Open Area	Area (sq·km)	
Land Use and Land Cover 2010	Waterbody	Area (sq·km)	8.12	3.70	4.63	1.66	0.34	18.45
		Percentage	44.02	20.06	25.10	9.00	1.82	100
	Built-up Area	Area (sq·km)	0.77	61.92	10.48	5.75	3.53	82.44
		Percentage	0.93	75.10	12.71	6.97	4.29	100
	Seasonal Cropland	Area (sq·km)	5.00	18.87	54.22	17.10	4.00	99.31
		Percentage	5.04	18.99	54.60	17.23	4.02	100
	Natural Vegetation	Area (sq·km)	0.18	3.83	2.96	14.70	0.62	22.30
		Percentage	0.81	17.18	13.28	66.00	2.79	100
	Open Space	Area (sq·km)	0.20	12.22	9.35	2.38	5.82	29.95
		Percentage	0.67	40.82	31.22	7.95	19.43	100
	Total Area (sq·km)		14.07	100.54	81.63	41.61	14.60	252.45

Source: Computed by author, 2024.

The analysis clearly illustrates the pervasive impact of urban expansion on the LULC in the Lower Turag River Basin over the last two decades. Here, a large portion of cropland has been converted into impervious areas, revealing direct loss of agricultural land due to various factors. As the area includes three urban centers including a large portion of the megacity of Dhaka which is DNCC along with Savar City and Gazipur City Corporation, rural-to-urban migration played a crucial role in rapid urbanization. Furthermore, the transformation of seasonal cropland into natural vegetation depicts the loss of land quality due to urban encroachment. Degraded land and soil disrupt productivity, and they have become

fallow land. Most of the land along the river is now used for brick kilns.

The significant increase in built-up areas due to rapid urbanization leads to potential concerns regarding food security, environmental sustainability, and ecosystem services. The decrease in waterbodies and open space is less pronounced in comparison to agricultural loss; however, it indicates the stress on ecological buffers, which leads to further stress on the local environment. However, the overall trend suggests that urban expansion is likely to continue exerting pressure on the region's natural resources unless sustainable land use planning and conservation strategies are implemented.

4.4. Agricultural Land Transformation Pattern over Time

Figure 5 illustrates the transformation of land in the study area from 2000 to 2020. The area has been divided into grids, and each grid shows the percentage of land used for agriculture over three time periods: 2000, 2010, and 2020.

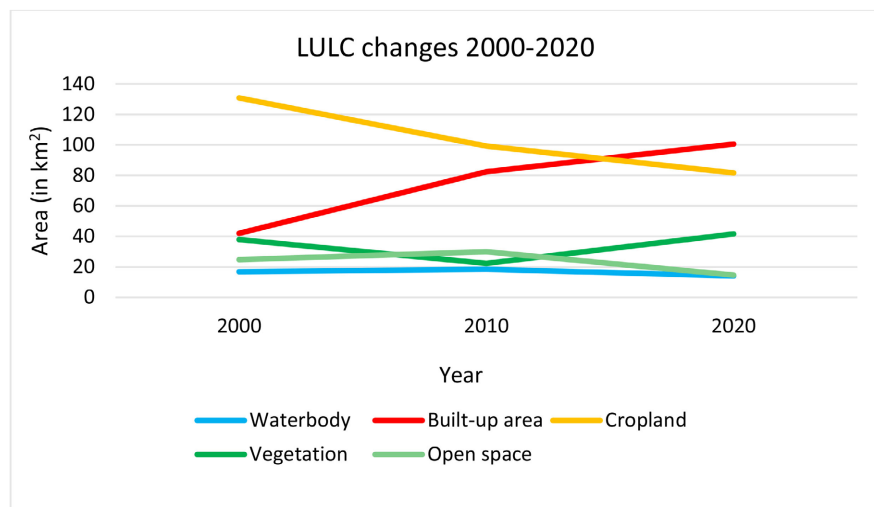


Figure 5. LULCC pattern over time (2000-2020).

Figure 6 clearly illustrates the cultivated land transformation pattern. In 2000, a significant portion of the study area along the banks of the Turag River was covered by agricultural land. In the central and southwestern regions along the bank line, most of the area was used only for agricultural activities. However, a noticeable decrease in the density and coverage of agricultural land has been depicted in 2010.

A major reduction of agricultural land has occurred in the Dhaka North City Corporation area (DNCC). Almost all the areas in DNCC have been converted to non-agricultural uses due to rapid urban development. A decreasing trend is also visible in Savar Upazila. The reduction of agricultural land appears more dominant in Savar Upazila in 2020, where most of the 1 km² grid had an agricultural area of a proportion of 60% or more. In 2020, there are a small number of grids with agricultural areas between 200 meters and 400 meters, and all of the remaining grids have agricultural areas below 200 meters.

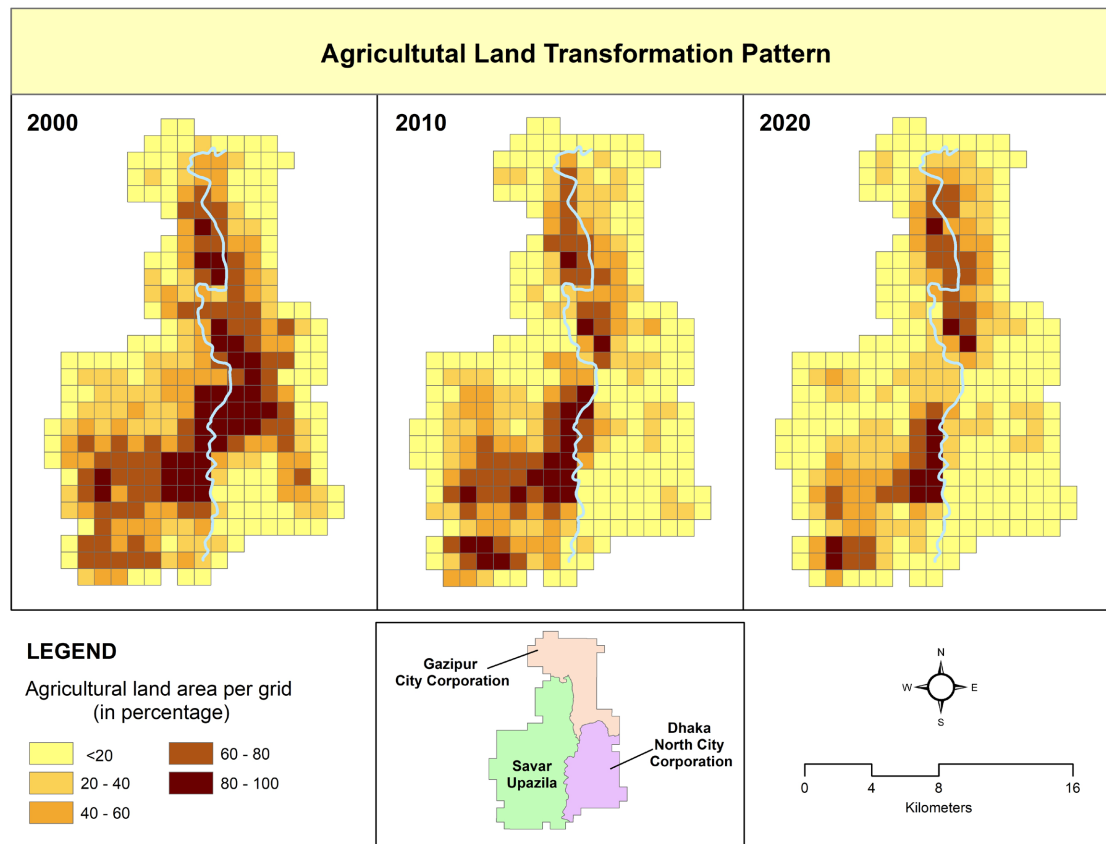


Figure 6. Map of the Agricultural Land Transformation Pattern (Source: Compiled by author, 2024).

The most drastic reduction in these two decades is visible in the central areas along the Turag River. This reduction in agricultural land is mainly driven by the expansion of built-up areas as the population grows and urban areas spread, causing the degradation of land and water quality that support optimum productivity.

The growing populations and expanding cities encroach upon traditionally agricultural regions highlight the need for careful land use planning to balance urban growth with agricultural preservation.

4.5. Ratio of Agricultural Land Consumption Rate to Population Growth Rate

ALCRPGR in **Table 4** focuses on how the availability of agricultural land per capita has changed as the population has increased and how the amount of agricultural land consumption rate (ALCR) corresponds to the population growth rate (PGR).

Over time, per capita agricultural land has decreased from 68.55 meter² to 16.23 meter² only. Negative ALCRPGR indicates that the cropland is being lost at a pace that outstrips population growth, particularly between 2010 and 2020. Between 2000 and 2010, for every 1% increase in population, there was a 0.44% decrease in agricultural land, indicating that the land is being consumed faster than the population is growing. Similarly, from 2010 to 2020, the ratio worsened slightly,

meaning that for every 1% increase in population, there was a 0.46% decrease in agricultural land. This suggests that the rate of agricultural land loss has become even more pronounced relative to population growth.

Table 4. Agricultural Land Consumption Rate to Population Growth Rate (ALCRPGR).

Agricultural Land Consumption Rate to Population Growth Rate								
Year	Population	Agricultural Land (in km ²)	Agricultural Land (in sq meters)	Agricultural land area per capita (in m ²)	Total change in agricultural land area (%)	ALCR	PGR	ALCRPGR
2001	19,08,148	130.803	130,803,000	68.55				
2011	32,82,034	99.311	99,311,000	30.26	-0.24	-0.024	0.054	-0.44
2022	50,31,092	81.636	81,636,000	16.23	-0.18	-0.017	0.038	-0.46

Source: Computed by author, 2024.

The data underscores the growing pressure on agricultural land from urbanization. As the population continues to rise, more agricultural land is likely to be consumed unless significant changes in land-use planning are made. This trend not only threatens food security but also exacerbates pressure on ecological vulnerabilities. Unplanned construction of built-up also causes fragmented landscapes and disrupted biodiversity. Furthermore, the loss of vegetation also diminishes the basin's ability to mitigate the seasonal flooding and heat island effects in the highly populated area of Lower Turag Basin in Dhaka. To ensure sustainable development, strategies must be implemented that protect the remaining agricultural lands and balance urban expansion. Sustainable land use policies, such as compact city planning and integrated urban-rural development approaches, can be implemented to mitigate the observed adverse effects of uncontrolled urban expansion.

5. Conclusion

This study shows the land use and land cover dynamics over two decades, which will continue up to 2030, based on the next census. By leveraging Google Earth Engine and SDG metrics, it is evident that the study indicates a clear decline in agricultural land as urban expansion continues to consume cultivated areas in the Lower Turag River Basin. The agricultural land consumption rate demonstrates that cropland is being lost at a significant rate relative to population growth. The spatial analysis further reveals that the areas closest to urban centers and along the riverbanks have been the most affected by this conversion. The findings highlight the need for strategic planning and policy interventions to protect the remaining agricultural land from further encroachment. Without such measures, the region risks losing vital farmland, which could have serious consequences for local food security and environmental sustainability. This study emphasizes the urgent need to balance urban development with agricultural preservation to ensure a sustainable future for the Lower Turag River Basin.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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