Journal of Geographic Information System, 2025, 17(3), 143-165
https://www.scirp.org/journal/jgis
ISSN Online: 2151-1969
ISSN Print: 2151-1950

Spatiotemporal Dynamics of Land Use Change in Narayanganj Sadar (2002-2023) and Forecasting for 2035 Using CA-Markov Modeling

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How to cite this paper: Hossain, E., Tahia, F.J., Siemens, A.R., Islam, M.S., Rahman, Z. and Ahmad, I. (2025) Spatiotemporal Dynamics of Land Use Change in Narayanganj Sadar (2002-2023) and Forecasting for 2035 Using CA-Markov Modeling. *Journal of Geographic Information System*, **17**, 143-165.
https://doi.org/10.4236/jgis.2025.173008

Received: December 8, 2024
Accepted: June 24, 2025
Published: June 27, 2025

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Abstract

Rapid urbanization and industrial growth reshaped the landscape, making the environment and human life increasingly vulnerable. This study undergoes future land use prediction, which is necessary for future development and decision-making. Narayanganj had rapid industrial growth, and population pressure led to extensive urban expansion in the region. Using multi-temporal Landsat satellite imagery of 2002, 2014, and 2023, this research uses Cellular Automation Markov modeling to analyze Land Use Land Cover (LULC) transition dynamics for two decades and to project future trends up to 2035. The methodology for preprocessing satellite images in QGIS and ArcGIS to classify land use categories comprises built-up areas, water bodies, agricultural land, and homestead vegetation. Change detection techniques were used to track transitions in three individual periods (2002-2014, 2014-2023) and demonstrate an extreme rise of urban development from 17.64% up to 47.38% of urbanized areas, while the agricultural areas declined by 38.66% and water bodies by 4.78%. Results of the CA-Markov model, forecasting the LULC changes for 2035 through Idrisi Selva, indicate further urban growth at the expense of agricultural land and water resources. Some factors, like its proximity to the Capital City, rapid industrial development, and population pressure, led to extensive urban expansion in the region. The results suggest the need for urban planners to adopt green infrastructure, water conservation, and agricultural land protection as part of sustainable urban planning strategies to minimize the negative ecological impacts of urbanization for long-term environmental sustainability.

Keywords

Land Use and Land Cover (LULC), Cellular Automation-Markov (CA-Markov), Change Detection, LULC Prediction, Sustainable Urban Planning

1. Introduction

Land use and land cover affect ecosystem services in significant urban areas, particularly for those reliant on biodiversity [1] [2]. Sustainability necessitates altering biophysical conditions and reconfiguring constructed structures to establish land use and cover patterns [3]-[5]. Effective governance in urban planning facilitates prompt resource management within the region while maintaining urban complexity [6]. Rapid urbanization leads to the loss of ecosystem services and threats to vulnerable people [7]. On the periphery of this gradually expanding urban hub, characterized by high-rise buildings, smallholders cling to any available plots among the suburbs and newly constructed highways, uncertain of their sustainability but compelled to do so out of need [8]. Only unrestricted development may conflict with objectives if developers and planners collaborate more effectively to guarantee sustainability [9]. A balance between expansion and ecological protection necessitates innovative systemic restructuring. Unregulated growth adversely affects ecosystems and food security, and minor development displaces water bodies and agricultural land [10].

The rapid increase in population, economic advancement, and infrastructural progress have altered land use in Narayanganj Sadar, next to Dhaka [11]. Numerous rapidly expanding districts in Bangladesh have forfeited agricultural and natural landscapes to urban development due to socioeconomic transformation. Narayanganj Sadar has been a prominent district for land use and land cover changes for decades. In contrast to Dhaka, Narayanganj Sadar has received less research, and there needs to be more forecasting of future changes based on historical trends. Few studies examine the localized impacts of Dhaka's growth. Narayanganj Sadar, an emerging industrial hub beside Dhaka, requires contextually appropriate development [12]. The Land Use and Land Cover (LULC) patterns in Narayanganj Sadar to improve local and regional understanding. Dhaka, a focal point for population expansion and environmental transformation, has been the site of several studies on land use and land cover. A reduction in agricultural areas after the city jeopardized food security. Unregulated expansion adversely affects the environment. The issue is more alignment between building plans and long-term objectives. Transit networks will encroach onto Vegetation and agricultural areas as suburbanization expands [13]. The alteration of land use and land cover in Narayanganj Sadar needs monitoring for sustainable urban planning and local resource management. Two decades of land use and cover alterations indicate that urban expansion obliterates agricultural land and streams.

These modifications are essential for regional food security and water management since diminished farmlands and aquatic systems reduce ecological resilience. The cellular automata-Markov chain model is crucial in forecasting future land use. By utilizing historical data and predictive algorithms, geographical and temporal predictive accuracy can be achieved [14]. The heterogeneous land cover time series was forecasted using cellular automata and Markov chain probabilities. CA Markov land use prediction models to refine previous evaluations. The approach employs historical data and predictive algorithms to analyze spatio-temporal land changes [15].

The 2002, 2014, and 2023 photographs serve as crucial time points for understanding the evolution of land use trends in Narayanganj Sadar Upazila. These images illustrate the rapid urban development. Satellite imagery could present an ideal short-term opportunity for showing change detection [16]. The anticipated information streams are essential for sustainable land resource management, natural asset preservation, and evidence-based development planning in rapidly expanding urban areas. A CA-Markov model might assist the municipal administrations of Narayanganj Sadar Upazila in monitoring site alterations and addressing urbanization. These models assist decision-makers in forecasting future occurrences and assessing current actions' medium—to long-term impacts on ecosystems and livelihoods [17]. This research has the potential to significantly improve our understanding of urban expansion and resource distribution, leading to more sustainable and equitable urban development. It developed a sophisticated probabilistic forecast of prospective land use alterations to assist policymakers and the city in advancing sustainable urbanization [18]. Historical and anticipated land use and land cover (LULC) alterations in Narayanganj Sadar from 2002 to 2023 and projections for 2035 are essential for sustainable urban growth. This paper has two objectives: to measure the changes in land cover/land use (LULC) and urban expansion during two decades (2002-2023) at Narayanganj Sadar and to use the CA Markov land-use prediction model to project the land use/land cover (LULC) of Narayanganj Sadar for 2035.

This study examines historical land use and land cover changes in Narayanganj Sadar Upazila, employing cellular automata (CA) Markov and monitoring and prediction change modeling to analyze land use/cover change (LUCC) across three decadal scenarios and forecast future land use patterns. These models serve as a foundation for reconciling urban expansion with environmental considerations, which are essential for economic welfare while preserving the ecosystem services required by the residents of Narayanganj Sadar Upazila. This analysis uses Landsat satellite imagery. It employs QGIS, ArcGIS, and IDRISI to analyze land use and land cover dynamics comprehensively. It emphasizes many categories, including built-up areas and land cover types such as agricultural land, water bodies, and settlements with residential vegetation.

Study Area

Narayanganj Sadar is an upazila of Narayanganj District in the division of Dhaka

Division, in Bangladesh. An administrative area, Sadar Union Parishad, lies under this upazila. The Sadar Upazila is situated between 23˚33' and 23˚43' north latitudes and between 90˚26' and 90˚33' east longitudes [19]. One could see it in the country's central region as compelling. Situated on the bank of the Shitalakshya River, about 20 km southeast of Dhaka, Bangladesh's capital [20] (**Figure 1**). Narayanganj Sadar is located near Dhaka and has a remarkable relative position, constituting the major urban and industrial center in the wider Dhaka metropolitan area. There are excellent communication roads, railways, and waterways links, so trade and commuting to the upazila are also very easy (**Figure 2**). Narayanganj has quickly urbanized and industrialized due to its fast development and proximity to the capital. Because of its predominant strategic location, it is one of the best places to study urban growth, land use, and their associated environmental impacts [21].

2. Methodology

The research methodology for the above has focused on detecting Land Use Land Cover (LULC) change and predicting future LULC patterns. For the analysis, a winter season and minimal clouds were ensured, and Landsat data from 2002, 2014, and 2023 were used to obtain the results. The work approach includes supervised image classification as a method of LULC change detection and analysis of the dataset, including accuracy assessment and a probability of change matrix [22]. It has forecasted LULC changes by 2035 at the CA Markov model for visualization and proceeds to deduce the main drivers that induced observed changes. Finally, the findings are used to support sustainable development planning (**Figure 3**).

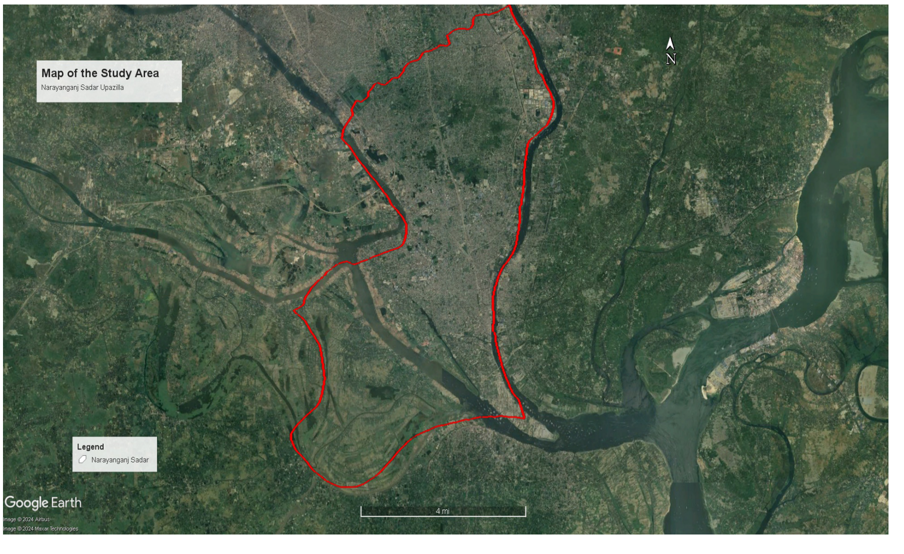

Figure 1. Showing the geographical location of the study area, which is on the southern side of Munshiganj District and the northwestern side of Dhaka South City Corporation; also, it is situated along the bank of the Shitalakshya River and the Buriganga River. (Source: Authors, 2024).

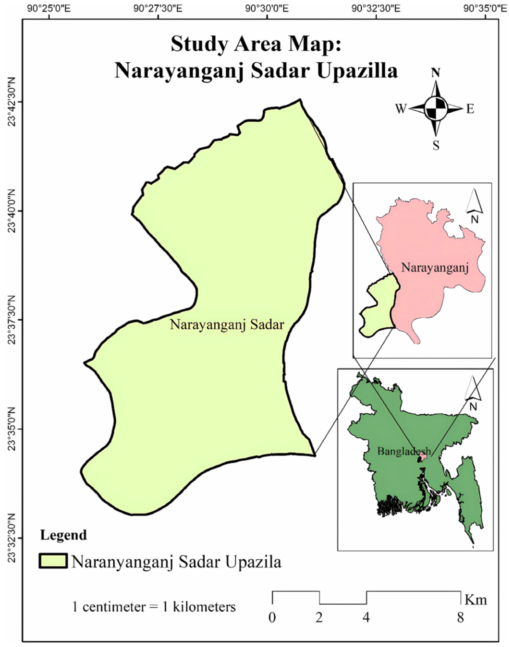

Figure 2. Displaying the location of the study area, Narayanganj Sadar Upazila, situated in the southwest of the Narayanganj district, which is located in the center of Bangladesh. (Source: Authors, 2024).

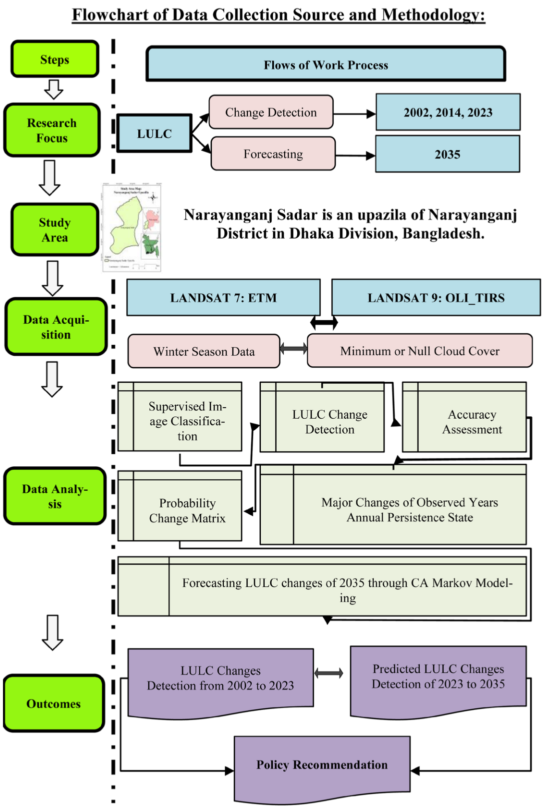

Figure 3. Methodological framework outlining data acquisition, analysis processes, outcomes, and policy recommendations. Regarding different aspects, using LANDSAT 7: ETM and LANDSAT 9: OLI_TIRS of observed years with different analyses resulted in LULC changing.

2.1. Information on Satellite Image

This insight into how changes happen in your landscape automatically emerges with at least three satellite images stitched together from the exact location over 21 years, from 2002 to 2023. Landsat-7 ETMs and (2023) Landsat-9 image data for land cover change analysis from Jan/2002-Feb/2014 at a resolution of 30 meters. Acquisitions made within seasonal windows of time that are minimally separated by one another based on the availability to reduce phenological differences between images and hence better comparability [23]. The low cloud contamination allows for a clear separation of the land cover classes at individual dates and in change analysis across the entire period with high confidence. Therefore, the three-image stack is a valuable dataset for examining changing land use, changing vegetative health during the growing season, and environmental effects by Path/Row 137/44. LULC 2002 to 2023 (**Table 1**). All satellites were taken in winter because there is no cloud cover or the least number of clouds in winter. So, because of these, we don't have to make any atmospheric corrections.

Table 1. Satellite Imagery of observed years using two types of sensors (ETM and OLI_TIRS) extracted from the winter season of the northern hemisphere with specific path/row and spatial resolution and minimal cloud cover.

Year	Landsat	Sensor	Acquisition Date	Season	Path/Row	Cloud Cover	Resolution
2002	Landsat 7	ETM	01.02.2002	Winter	137/44	0%	30 m × 30 m
2014	Landsat 7	ETM	01.01.2014	Winter	137/44	0%	30 m × 30 m
2023	Landsat 9	OLI_TIRS	10.01.2023	Winter	137/44	0.10%	30 m × 30 m

Source: https://earthexplorer.usgs.gov/.

2.2. Accuracy Assessment

The validity in which results of LULC classification are accurate and CA-Markov modeling is genuine [24]. Producer's accuracy (PA), user's accuracy (UA), overall accuracy, and Kappa statistics are computed for evaluation of the performance using LULC classification (**Table 2**) [25] [26]. Land use change is compared to reference data to assess accuracy in the CA Markov modeling of the same set of metrics. However, high accuracy values suggest that the model is robust and can be used to model future land use dynamics because they indicate strong agreement [27].

Table 2. Calculation of accuracy assessment.

Land Use	2002 PA	2002 UA	2014 PA	2014 UA	2023 PA	2023 UA
Build-up Area	83.47246	79.42857	90.01056	87.36	93.80571	91.62203
Waterbodies	88.38261	87.37143	87.94135	86.32	91.72114	88.49855
Settlement with Homestead Vegetation	76.59826	74.46429	82.76833	80.08	88.59429	86.41623
Agriculture Land	90.34667	92.33571	92.07977	94.64	90.67886	92.66319
Overall Accuracy (%)	88.18		89.16		91.82	
Overall Kappa Statistics	0.847	0.834	0.882	0.871	0.912	0.898

The formula to calculate the number of points for each LULC class is (**Table 3**) [28]:

Points for a Class = (Area of the Class (ha) Total Area (ha) × Total Points

Point for a Class = (Total Area (ha) Area of the Class (ha)) × Total Points

For example, for the **Build-up Area in 2002**:

Points (1764.8/10,000) × 300 = 53

Table 3. Calculation of Accuracy Assessment of different land covers of 2002, 2014, and 2023's selected points showing the scenario for its further evaluation.

LULC	Points of 2002	Points of 2014	Points of 2023
Build-up Area	53	108	120
Waterbodies	28	21	20
Settlement with Homestead Vegetation	17	61	75
Agriculture Land	202	109	86
Total	300	300	300

2.3. Prediction of LULC through CA Markov

A spatial continuity component with Markov chain land use forecasting to reflect the expected spatial distribution of transitions. The first fundamental land use map provides the initial reference point for the current scenario [29] [30]. Future periods of land use using a Markov chain that connects the land use of the current period to future periods, assuming that the land use of the current period will evolve without modification to achieve the forecast [31] [32]. The equation illustrates the process of estimating the expected trajectory of changing land utilization:

$$S(t, t+) = P_{ij} \times S(t) \quad (1)\ [33]$$

State transitions $(t) \leq s(t+1)$ represent the state of some system at time t or at time $(t+1)$, respectively. We determine these states using the following formula:

$$P = \left\| P_{ij} \right\| = \begin{vmatrix} P_{1,1} & P_{1,2} & \cdots & P_{1,N} \\ P_{2,1} & P_{2,2} & \cdots & P_{2,N} \\ \cdots & \cdots & \cdots & \cdots \\ P_{N,1} & P_{N,2} & \cdots & P_{N,N} \end{vmatrix}$$

$$\left(0 \leq P_{ij} \leq 1\right)$$

It denotes the probability matrix from a state of P_{ij} [33]. The model segments land use patterns, viewing each sequence from a specific historical period as originating from one of these segmented patterns. Secondly, these observations are synthesized and represented as a transition matrix. Finally, the probability of transitions to later time frames is calculated using a transition probability matrix basis [34] [35]. This study employs remote sensing techniques and IDRISI software to estimate the future land use in Dhaka. Change detection analysis, preprocessed satellite images in QGIS and ArcGIS, and classified land use classes on the imagery using spectral analyst tools. The CA Markov model shows future changes, estimating transition probabilities from the transition matrix and the same land use classes [36].

3. Results

3.1. Land Use and Land Cover Changes 2002 to 2014

A comprehensive examination of land use patterns in Narayanganj Sadar from 2002 to 2014 revealed drastic alterations in various land categories through the strategic use of geospatial tools. The persistence of LULC from 2002 to 2014 shows no change over time (**Figure 4**). Urban areas expanded markedly across the study area, increasing from 1764.81 hectares in 2002 to 3616.47 hectares in 2014, signifying a growth of approximately 1851.66 hectares (**Table 4**). The Transition Matrix of Land Use Land Cover between 2002 and 2014 shows transformation phases (**Table 5**).

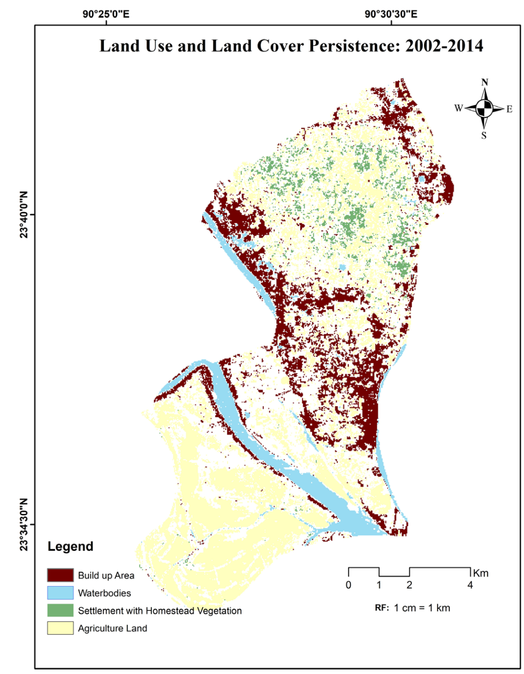

Figure 4. Showing persistence of LULC from 2002 to 2014, showing unchanged over time (Source-Authors, 2024).

Table 4. Changes in land use land cover from 2002 to 2014 shows a great leap in Build-up Areas as well as portraying a decreasing rate in Waterbodies and agricultural land, respectively.

LULC	2002 (ha)	2014 (ha)	Δ (ha)	2002 (%)	2014 (%)	Δ (%)
Build up Area	1764.81	3616.47	1851.66	17.64	36.16	18.51
Waterbodies	927.81	716.13	−211.68	9.28	7.16	−2.12
Settlement with Homestead Vegetation	575.55	2036.97	1461.42	5.75	20.37	14.61
Agriculture land	6734.07	3632.67	−3101.4	67.33	36.32	−31.01

Table 5. Transition matrix of land use land cover between 2002 and 2014, showing transformation phases among different land use and land cover classes in the study area.

LULC	Build up Area	Waterbodies	Settlement with Homestead Vegetation	Agriculture Land
Build up Area	0.795	0.015	0.0736	0.116
Waterbodies	0.136	0.662	0.029	0.173
Settlement with Homestead Vegetation	0.128	0.009	0.545	0.317
Agriculture Land	0.299	0.0103	0.237	0.458

The total area of waterbodies also declined from 927.81 to 716.13 hectares, which may be attributable to the landfill of coastal regions and their conversion to other uses, affecting regional hydrology. In contrast, the area of green-filled settlements rose from 575.55 hectares to 2036.97 hectares, an increase of 1461.42 hectares; they filled the wetlands with soil and made their settlement. In Bangladesh, there is a tradition of trees being planted in rural settlements. This result can be contradictory, but it also increases in rural settlements created by landfills of wetlands and agricultural land.

Agricultural acreage, in contrast, was dramatically reduced from 6734.07 hectares in 2002 to 3632.67 hectares in 2014. The swift transformation of farmlands into urban and residential zones resulted in an alarming loss of 3101.4 hectares. Major Changes in LULC from 2002 to 2014, and agricultural land was the most vulnerable at this time; most agricultural land was transferred into settlements with homestead vegetation or built-up areas (Figure 5). The transition matrix (derived via IDRISI's spatial modeling) indicates individual land use stability and exchange between categories. Built-up areas retained 79.5 percent, whereas agricultural land converted to urban areas climbed to 29.89 percent. Waterbodies exhibited moderate constancy at 66.23 percent but signified growing pressures on resources since the grouping covers both permanent and impermanent waterways, with 17.3 percent shifting to agriculture.

3.2. Land Use and Land Cover Changes 2014 to 2023

The developed land vigorously expanded from 3616.47 hectares to 4739.04 hectares and acted deeply in the biophysical development of 1122.57 hectares. The persistence of LULC from 2002 to 2014 shows no change over time (Figure 6). This proliferation reveals the population pressure and infrastructure dispersal that underpins urbanization in the country unit. Still, the area under water bodies was reduced from 716.13 hectares to 450.18 hectares, showing a net loss of coverage of 265.95 hectares. Such contraction is likely an outcome of continual reclamation, other use conversion, eventual desiccation or depletion of water resources, and pressures on local hydrology. Neighborhoods of residential areas surrounded by green spaces reduced slightly over the decade, from 2036.97 hectares to 1945.71 hectares, resulting

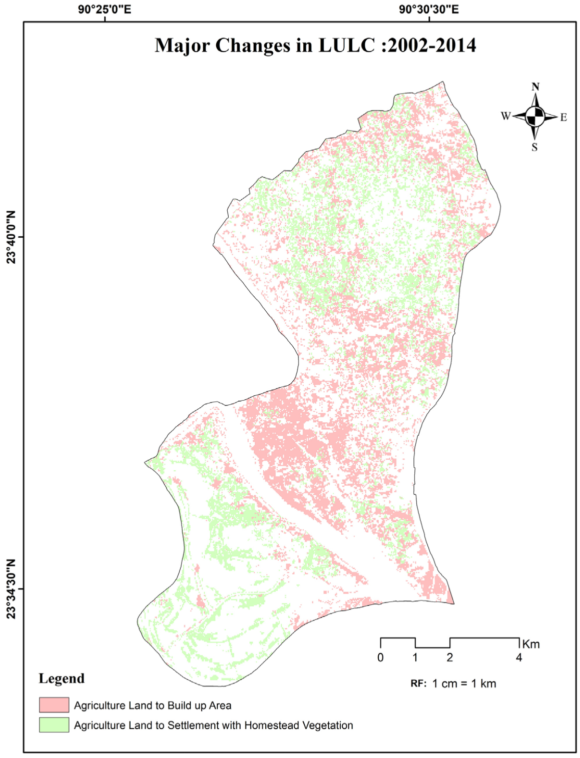

Figure 5. Displaying major changes in LULC from 2002 to 2014: agricultural land was the most vulnerable at this time; most agricultural land was transferred into settlements with homestead vegetation or built-up areas (Source-Authors, 2024).

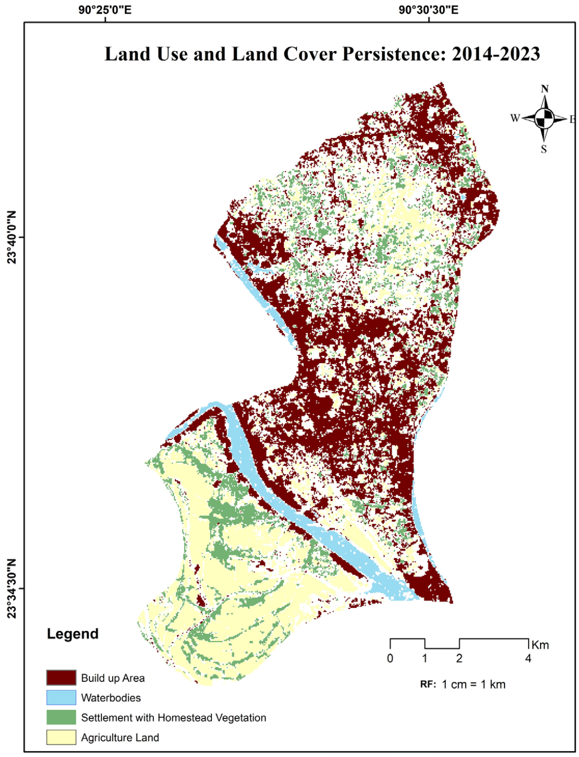

Figure 6. Showing persistence of LULC from 2014 to 2023, showing unchanged over time (Source-Authors, 2024).

in a net loss of only 91.26 hectares. Persistence of LULC from 2014 to 2023, indicating areas that remained unchanged over time (Figure 7). Architecture of home, homes wound with bush, or simply a household plot. Additionally, the range of land space area dropped from 6632.67 hectares in 2014 to 2867.31 hectares by 2023, with an absolute decrease of 765 hectares (Table 6). Transition Matrix of Land Use Land Cover between 2014 and 2023, showing transformation phases among different land use (Table 7). The constant conversion of farmland to industry and housing suggests that the place is bursting at the seams.

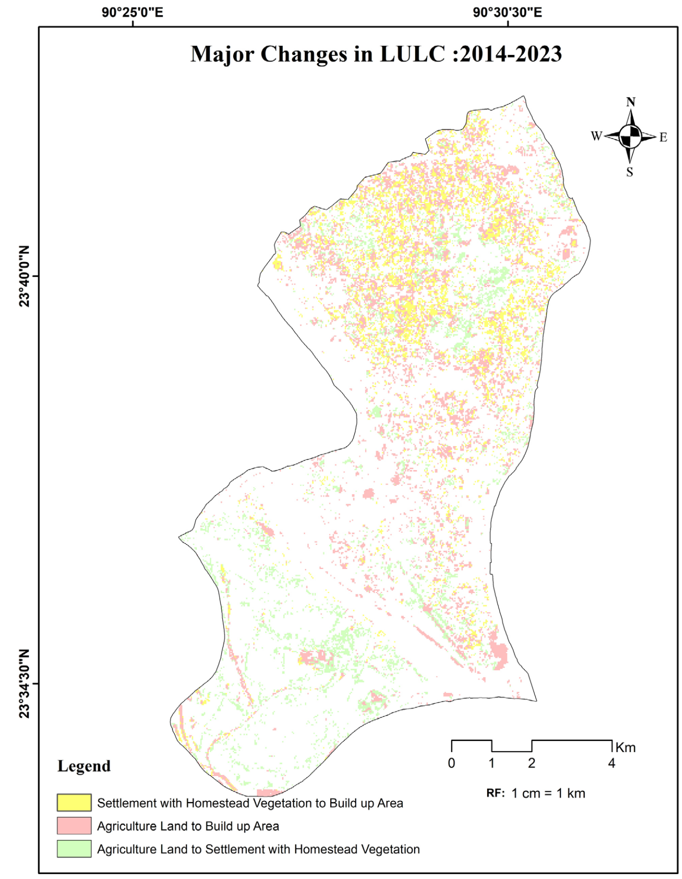

Figure 7. Showing persistence of LULC from 2014 to 2023, showing unchanged over time (Source-Authors, 2024).

Table 6. Changes in land use land cover from 2014 to 2023, showing a great leap in Build-up Areas as well as portraying a decreasing rate in Waterbodies, Homestead Vegetation settlements, and Agriculture Land, respectively.

LULC	2014 (ha)	2023 (ha)	Δ (ha)	2014 (%)	2023 (%)	Δ (%)
Build up Area	3616.47	4739.04	1122.57	36.16	47.38	11.22
Waterbodies	716.13	450.18	−265.95	7.16	4.5	−2.66
Settlement with Homestead Vegetation	2036.97	1945.71	−91.26	20.37	19.45	−0.91
Agriculture Land	3632.67	2867.31	−765.36	36.32	28.67	−7.65

Table 7. Transition matrix of land use land cover between 2014 and 2023, showing transformation phases among different land use and land cover classes in the study area.

LULC	Build up Area	Waterbodies	Settlement with homestead vegetation	Agriculture land
Build up area	0.796	0.002	0.086	0.119
Waterbodies	0.296	0.602	0.061	0.041
Settlement with homestead vegetation	0.311	8.8E−05	0.479	0.211
Agriculture land	0.282	0.003	0.170	0.546

Average levels were stable for developed regions at 79.36%, but again, 28.17% of agricultural lands transitioned to the built environment, evidence of further urban incursion into previously agricultural land. While water bodies exhibiting High/Moderate persistence (60.22%) signal anthropogenic pressures on freshwater resources, 29.63% of persistent water bodies were transformed into developed areas, and 6.05% into settlements. Residential housing zones within vegetation have a moderate degree of permanence (47.85% remain permanent) but have been somewhat unstable as the regions are being converted to agriculture and developed land from these residential housing zones. About 54.53% of agricultural land has been preserved, where changes in developed land and settlements can be seen.

3.3. Land Use and Land Cover Changes in 2002 to 2023

Significant shifts in land usage and coverage, and their mix, around Narayanganj Sadar (2002 to 2023). Land use and land cover changes in Narayanganj Sadar Upazila from 2002 to 2023 demonstrate significant shifts (**Figure 8**). The built-up area in Narayanganj Sadar increased from 1764.81 hectares in 2002 to 4739.04 hectares in 2023, a net gain of 2974.23 hectares, reflecting a major shift from natural or agricultural land to urban development. Given ongoing trends in urbanization, losing almost half of the native lakes and wetlands is certainly alarming news. This reflects massive reclamation, a drop of 477 acres, from 927.81 to just 450.18 hectares annually. Settlement expansion caused the area of homesteaded vegetation to more than double from 576 hectares in 2002, peaking at over 2037 hectares by 2014 (**Table 8**). Both involve changing cultivation from farmland to a built-up area.

3.4. Probability of Changes in Land Use and Cover 2023 to 2035

Therefore, a Trend analysis based on LULC analysis using IDRISI, QGIS, and ArcGIS spatial modeling has been provided for Narayanganj Sadar, showing land use changes anticipated during 2023-2035 (**Figure 9**) and Probable changes of land use in the land cover of the study area from 2023 to 2035 (**Table 9**).

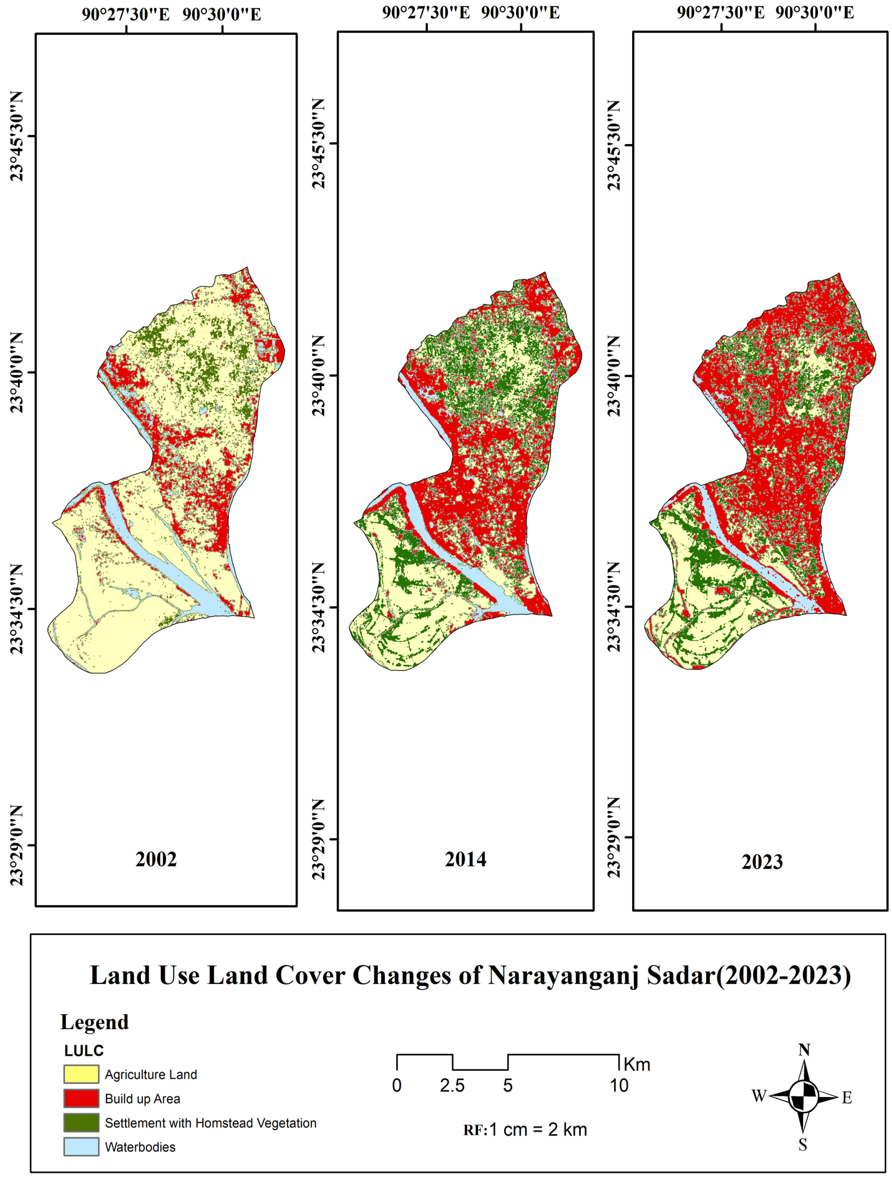

Figure 8. Land use and land cover changes in Narayanganj Sadar Upazila from 2002 to 2023 demonstrate significant shifts, with a notable decline in agricultural land and a substantial increase in built-up areas (Source-Authors, 2024).

Table 8. Overall changes in LULC between 2002 and 2023, showing significant changes in every land class in Narayanganj Sadar Upazila during the two decades of 2002 to 2023.

LULC	2002 (ha)	2014 (ha)	2023 (ha)
Build up Area	1764.81	3616.47	4739.04
Waterbodies	927.81	716.13	450.18
Settlement with Homestead Vegetation	575.55	2036.97	1945.71
Agriculture land	6734.07	3632.67	2867.31

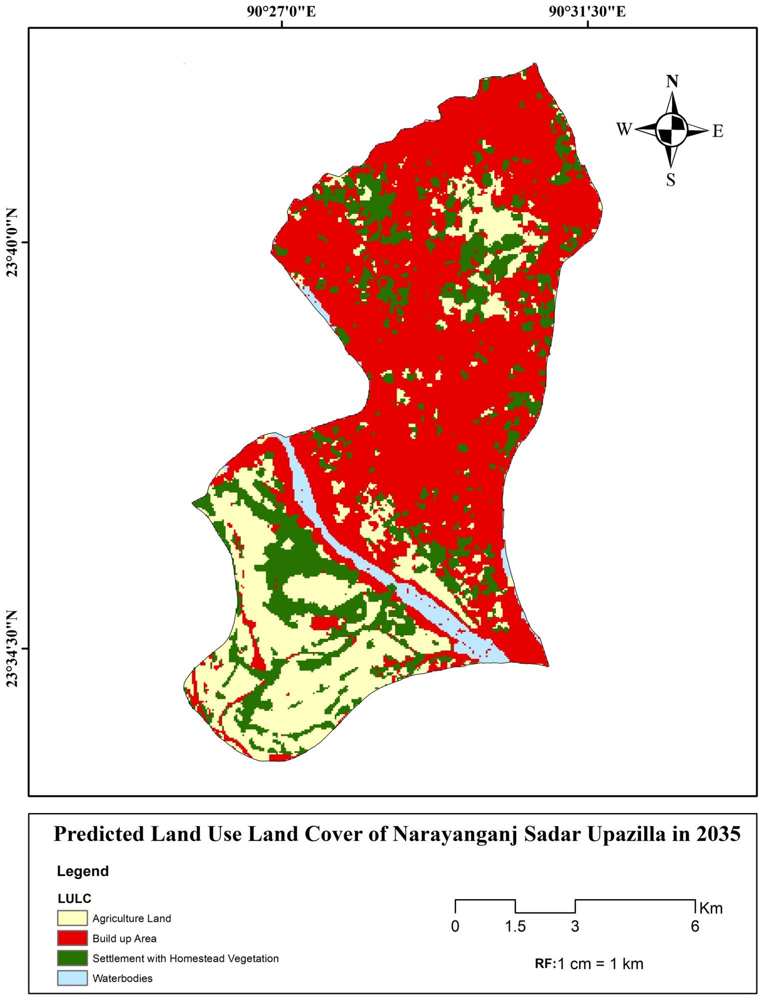

Figure 9. Predicted land use land cover changes in narayanganj sadar upazila by 2035, where the build-up area is the most commonly seen land use (Source-Authors, 2024).

Table 9. Probable changes of land use in the land cover of the study area from 2023 to 2035, showing the transformation phases between the study period.

LULC	Build up Area	Waterbodies	Settlement with Homestead vegetation	Agriculture Land
Build up Area	0.832	0.0022	0.1006	0.0652
Waterbodies	0.2652	0.6187	0.0537	0.0624
Settlement with Homestead vegetation	0.3423	0	0.4003	0.2574
Agriculture Land	0.3132	0.0006	0.225	0.4611

The built-up area would increase from 4739.04 hectares in 2023 to 5626.44 hectares by the year 2035, an increment of 887·4 hectares. Such a sustained growth trajectory posits urbanization processes that are as alive today as ever, driven by the same forces of population and economic growth that have reshaped land here at home in history and during recent memory. The total area of water bodies may be reduced by 449.18 hectares to 290 hectares. Inland farmers have used the recent project, indicating that 159 hectares have fallen by 48 hectares. Following efforts to update ecological estimates occur nationally and regionally, purely gold long-term value its environmental condition; water savings share expanded cuts from this forecast are a shifting balance across other land use degradation.

Gain of settlement caused −19.8 hectares of systematic area loss with primary homestead vegetation, which is forecast to decrease from 1945.71 hectares in 2023 to 1925.91 hectares by the time forecast year. These slight declines suggest that most sites remained stable and changed little over time. The amount of agricultural land decreased in 2035 from 2867.31 hectares to 2159.19 hectares, reducing 708.12 hectares (Table 10). This further decline adds water stress to urban expansion, presumably extending built-up lands near agricultural areas.

Table 10. Predicted changes of LULC classes showing variability in different class modifications in upcoming years forecasted by the CA-Markov Modeling technique.

LULC	2014 (ha)	2023 (ha)	Δ (ha)	2014 (%)	2023 (%)	Δ (%)
Build up Area	4739.04	5626.44	887.4	47.38	56.25	8.87
Waterbodies	450.18	290.7	−159.48	4.5	2.91	−1.59
Settlement with Homestead Vegetation	1945.71	1925.91	−19.8	19.45	19.25	−0.2
Agriculture Land	2867.31	2159.19	−708.12	28.67	21.59	−7.08

Then, the transition matrix can be used to see how persistent or spatially transient each LULC category is. The majority of this built-up area is assumed to remain unchanged. Only a tiny agricultural or vegetative land patch may be converted to urban functions. The persistence of waterbodies is 64.57%, some of which have been transformed into built-up areas, indicating sustained pressure on the water. The continued settlement area with homestead vegetation is assumed to be constant, at 81.95%, while the remainder will convert only slightly to agricultural land. Approximately 70.3% of agricultural land exhibits the same persistence, but much of it is anticipated to change into built-up areas, indicating rapid urban encroachment.

4. Discussion

This paper aims to present the dynamic LULC change of Narayanganj Sadar, Bangladesh, from 2002 to 2023 for mass-scale land-use change brought about by rapid urbanization. The area of agricultural land declined by 57.47 percent from 6734.07 hectares in 1962 to 2867.31 hectares in 2004, while built-up area increased by 168.37 percent from 1764.81 hectares in 1962 to 4739.04 hectares in 2004. But more importantly, they shrank even water bodies; 450.18 ha from as high as 927.81

ha recorded in 2002 to 2023 (**Table 8**). Year-Wise LULC Change in Narayanganj Sadar Upazila shows an uprising trend in built-up area classes and settlements with homestead vegetation (**Figure 10**).

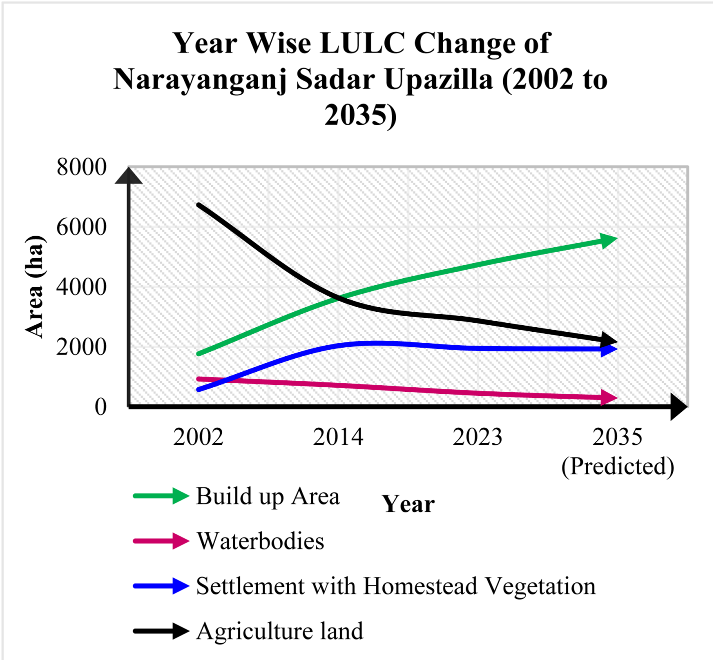

Figure 10. Year-Wise LULC Change in Narayanganj Sadar Upazila shows an uprising trend in built-up area classes and settlements with homestead vegetation, but the other two classes, like waterbodies and especially agricultural land, experience a huge downward trend.

Urban growth creeping off the agricultural and natural lands characterizes urban sprawl as a global pattern. Most farmland and freshwater resources are converted in urbanizing regions with rapid urban expansion, and exhibit this behavior [37]. Such a result echoed in past work experience research or research conducted in some areas has shown that industrialization and population growth, and changes in land use, such as peri-urban, the specific case of Narayanganj, which is close to the capital Dhaka [38]. It was found that the Narayanganj region has experienced very drastic LULC changes, and the main reasons for such drastic changes are quick urbanization and economic development. Several of these factors have been associated with this transformation.

Generally, the expansion of built-up areas of Narayanganj is used almost to increase the demand for housing and infrastructure because of the increasing population and industrialization. Due to the rising urban population, Dhaka has become an attractive residential and commercial development (**Figure 11**). The sprawl of urban areas into rural and agricultural areas is also an element of transport network improvements, such as road networks and bridges [39]. The region is urbanizing and putting tremendous pressure on the last usable land for agriculture, converting agricultural land for building use and development. It also causes agricultural land to be lost. This problem already produces food security problems in an area with many people with small amounts of arable land [40]. Also, natural resources are deposited much faster since the land is not used for planting but is converted into urban lands with infrastructure occupying wetlands and water bodies [41].

Figure 11. Major reasons behind the drastic change in Land and Land Cover (LULC) in Narayanganj Sadar Upazila illustrating several reasons like population growth, economic development, and lack of planning regarding some other valuable issues which are to be addressed by the authorities.

Our data also show that we are facing equally frightening shrinkage of water bodies of Narayanganj, which decreases the capacity of pre-existing water bodies and busy water pressure on already present water resources, causing the inability to supply water during urbanization. Wetlands and water bodies conversion to residential and commercial uses, and outland reclamation activities. It is just one small instance in the larger story of urbanization, which begets rapid urbanization of built areas and the proliferation of and consumption of natural water resources. The problem is compounded as water sources would also be necessary for local communities and agricultural activity. Furthermore, the net loss of water bodies has implications for biodiversity. Wetlands are amongst the most valuable and biodiverse ecosystems, contributing to water provisioning, habitat, water filtration, and climate regulation services [42]. Now is the best time for a sustainable land use policy in Narayanganj to maximize urban growth. Cities have been proliferating, with virtually no planning to stop the spread of built-up areas into farmland and sensitive environmental lands for the last 20 years. The use of agricultural lands should not prevent food insecurity at the expense of the employment opportunities of the local population. By putting the incentive in for green space, the park, and the water retention areas, and rewarding developers, the development will not be made at the expense of environmental sustainability [43]. This study's results reveal that urban growth policies that protect agricultural resources contribute to urban development with long-term effects on ecological and economic sectors.

5. Sustainable Development Plan

Narayanganj Sadar Upazila, being a fast-urbanizing area near Dhaka, not only brings points of juggling generating industrial growth and sustainability but also provides numerous opportunities for regeneration in different ways. Agricultural land and water bodies are converted at a high rate into urban lands, triggering socioeconomic and ecological problems; therefore, a need for purposeful and sustainable development.

The Narayanganj Sadar region faces significant challenges, including degraded natural and agricultural environments, unregulated urban sprawl, and a lack of comprehensive planning (**Figure 12**). Effective urban management is essential, beginning with transit-oriented development, comprehensive zoning rules, and mixed-use zones to optimize land use and save space [44]. Green infrastructure, such as rooftop gardens, green belts, and urban parks, can mitigate the urban heat island effect, support biological corridors, and enhance biodiversity and ecosystem stability [45] [46]. In an urban setup, temperature increases with the increase of distance from green space, and the humidity decreases, which highlights the significant role of green areas within urban environments [47]. However, there is a significant relationship between temperature and thermal comfort, and mainly the comfort areas are located near the vegetation and waterbodies [48]. Preserving wetlands is vital for maintaining biodiversity and ecosystem balance, while rainwater harvesting promotes sustainable water conservation and harmony between humans and the environment [49]. Protecting agricultural land and adopting sustainable urban farming practices like agroecology can secure food production, ecological balance, and job creation [50] [51]. Additionally, promoting a circular economy in industrial processes reduces waste, enhances resource efficiency, and supports green jobs while preserving cultural and natural heritage [52] [53]. Finally, effective governance and community involvement are indispensable for sustainable development, with local awareness campaigns and participatory conservation projects fostering stewardship and ensuring the successful management of natural resources.

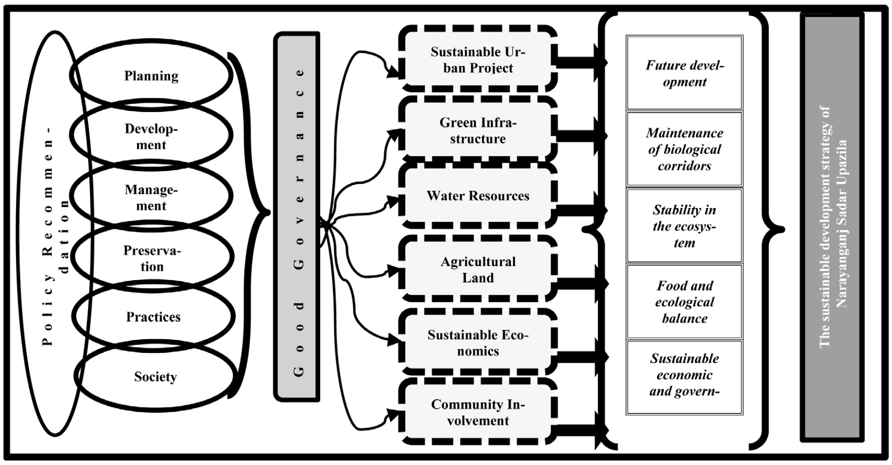

Figure 12. Policy recommendation for sustainable development plan through good governance, which sheds light on sustainable planning to community awareness with several significant variables helping to develop a socio-environmental phenomena in a strategic way.

Narayanganj Sadar Upazila's sustainable development strategy addresses the city's socioeconomic and environmental problems. One possible association may be with Sadar Narayanganj's international sustainability endeavors, which may also result in one of the paradigms in pursuing resilient urban development in Bangladesh.

6. Conclusion

The land use and land cover (LULC) change study in Narayanganj Sadar, Bangladesh, provides evidence of the substantial effects of rapid urbanization and industrial expansion on the land. Combined this multi-temporal Landsat satellite imagery and Cellular Automation Markov (CA Markov) modeling-based research for the identification of substantial transformations such as a more than 29% increase in urban areas, the dramatic decline of agricultural land and water bodies, a dramatic decline in the agriculture, wetland, etc. This one step moves the environmental cost of unchecked growth to center stage. It shows that these unchecked urban sprawls are gorging up our necessary natural resources and risking the region's long-term ecological and food security. Study findings lead this thesis to conclude that urban planning and management of natural resources in a sustainable manner is required for the Narayanganj Sadar area. Comprehensive urban planning, green infrastructural development, and the establishment of water resources are utilized to mitigate the residual effects of rapid urbanization, and agricultural lands are preserved and engage the community. In addition, sustainable economic development practices can be sustainable while leaving behind the environment and livelihoods of locals. The CA Markov model forecasts future LULC changes and informs urban planners, policymakers, and environmental managers regarding the region's sustainable growth. To establish the framework for a resilient urban environment, this study will offer insight into the policy and urban planning of rapidly developing projects such as Narayanganj Sadar and other similar projects.

Conflicts of Interest

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

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