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Application of GIS and Remote Sensing for Analyzing Agricultural Land Dynamics of Munshiganj Sadar, Bangladesh

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Abstract: *Agricultural land in Munshiganj Sadar has faced continuous pressure from urbanization, infrastructural growth, and population increase over the past two decades, resulting in notable transformations of the landscape. This study employs GIS and Remote Sensing technologies to analyze land use and land cover (LULC) changes from 2004 to 2024 and predict future dynamics up to 2034. Findings reveal a substantial increase in cropland, with a 37.8% rise between 2014 and 2024, alongside a severe decline in waterbodies and minor forest loss. Probability matrix analyses indicate continued expansion of agriculture and urban areas, while river courses and aquatic zones show signs of environmental stress. Despite projected stability in agricultural land through 2034, the results highlight the urgent need for sustainable land management strategies. The integration of GIS and RS proves critical for monitoring spatial patterns and supporting informed decision-making for agricultural planning and ecological preservation in the region.*

Keywords: Agriculture, Land dynamics, CA-Markov model, GIS, RS, Bangladesh.

Introduction

Agricultural land in Munshiganj *Sadar* has experienced continuous decline due to rapid urbanization, infrastructural expansion, and population pressure over the past two decades. According to the *District Statistics 2011: Munshiganj*, significant portions of cultivable land have been gradually transformed into built-up areas, reducing the region's agricultural capacity (Bangladesh Bureau of Statistics, 2011). This transformation is exacerbated by seasonal river erosion and changing water flow

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dynamics in the surrounding river systems, which threaten the stability of farmlands (Rahman, 2015). Moreover, the lack of strong land-use policy enforcement has further accelerated unplanned land conversion (Williamson and Ting, 2001; Dale and McLaughlin, 2000). Employing advanced geospatial tools helps to visualize and quantify these dynamics, supporting better planning decisions (Bennett et al., 2020; Joseph, 2005). If current trends continue, agricultural sustainability in Munshiganj *Sadar* will face serious risks, calling for immediate strategic interventions to safeguard food security and ecological balance (Enemark et al., 2005; Henssen, 2010). Remote sensing and GIS technologies have revealed a marked shift in land cover from agricultural fields to urban settlements (Tagore et al., 2012). For processing the data, RS provides 30 m resolution data assigning different colors indicating specific land covers which helps us to classify land data and GIS can update, process, monitor, manipulate and demarcate the land area over the time frame (Kirby, 1988; Thapa and Murayama, 2009).

The significance of the study lies in its ability to harness the advanced capabilities of Geographic Information Systems (GIS) and Remote Sensing to analyze the evolving agricultural land dynamics of Munshiganj *Sadar*, Bangladesh, a region where fertile land is increasingly threatened by rapid urbanization, population growth, and environmental pressures (Dale and McLaughlin, 2000; Bennett et al., 2020). By integrating spatial and temporal data, this research offers a powerful tool for detecting, mapping, and understanding patterns of land use and land cover change with high precision (Joseph, 2005 and Tagore et al., 2012). Such insights are critical for informed policy-making, strategic land-use planning, and the development of sustainable agricultural practices (Enemark et al., 2005 and Henssen, 2010). Moreover, the study contributes to a broader understanding of how modern geospatial technologies can support data-driven decision-making, helping local authorities and stakeholders mitigate the adverse effects of land degradation while promoting agricultural resilience and long-term food security (Choudhary K. B et al, 2018; Bennett et al., 2017; Hendriks et al., 2019; Stocker, et al., 2019 and Williamson, 2001)

The aim of the research is to apply GIS and Remote Sensing (RS) technology to analyze agricultural land probabilities matrix in Munshiganj *Sadar Upazila* from 2004 to 2034. The objectives are: (i) to prepare LULC (Land Use Land Cover) map of study area; (ii) to analyze LULC dynamics of the study area focusing on agricultural land dynamics from 2004 to 2024; and finally, (iii) to create an agricultural land probability matrix spans from 2024 to 2034.

Methodology

Selection of the study area

The study site includes Munshiganj *Sadar Upazila* under Munshiganj District in the Division of Dhaka, Bangladesh that covers an area of approximately 160.79 km², characterized by fertile agricultural land and a dense network of rivers and canals that support its agrarian economy (BBS, 2022).

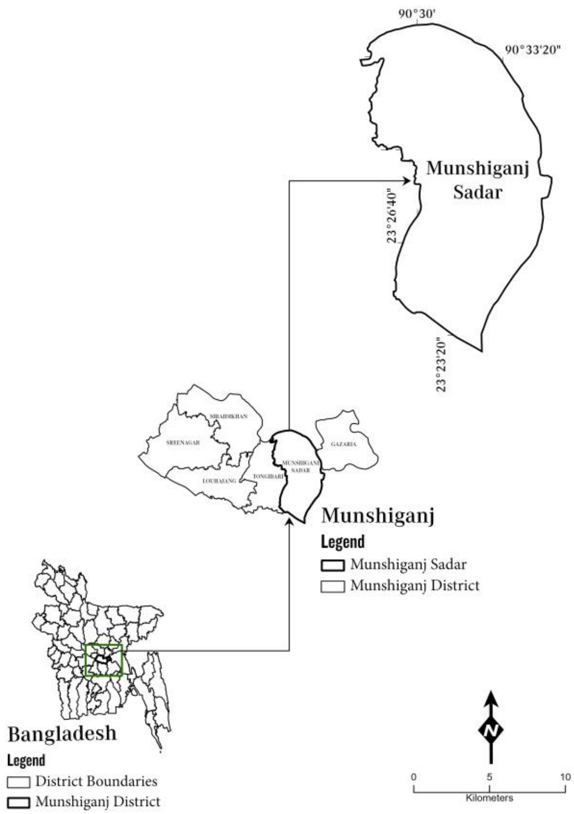

Figure 1: Study Area Map Showing Munshiganj *Sadar Upazila* within its District and National Administrative Boundaries, Highlighting its Geographical Location in Bangladesh

Source: Compiled by authors, 2024

Data Sources

This study used satellite imagery as one of the most effective and powerful tools for mapping, monitoring, and assessing the landscape environment. Landsat TM (Thematic Mapper), Landsat 8 Operational Land Imager (OLI), WorldView, and Sentinel-2 were included in this study. Landsat TM (Thematic Mapper) images consist of eight spectral bands, each with a spatial resolution of 30 meters. Band 8 (panchromatic) has a resolution of 15 meters. On the contrary, the images from the Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) have nine spectral bands, each with a spatial resolution of 30 meters for Bands 1 to 7 and 9. Thermal bands 10 and 11 are collected at 100 meters and are useful for having more accurate surface temperatures.

Table 1: Detail Information of Satellite Images used in this Research.

Satellite Imagery	Resolution (m)
Landsat 5 Thematic Mapper (TM)	30m
Landsat 5 Thematic Mapper (TM)	30m
Landsat 5 Thematic Mapper (TM)	30m
Landsat 8 Operational Land Imager (OLI)	30m
Landsat 8 Operational Land Imager (OLI)	30m

Source: Compiled by Authors, 2024

Ground Control Points (GCPs) are identified locations on the earth's surface that are used to geo-reference imagery and related maps for greater accuracy. Ground Control Points (GCP) were collected through GPS survey method to edge correction of the satellite images. Besides that, this paper allocates pixels or physical objects by supervised image classification (maximum likelihood) to the given class using training samples. A training sample (x 9 pixels) and Ground Control Points (GCP) were collected through pixel values and a GPS survey. Each training sample contains a minimum nine pixels for individual features. The training sample and the Ground Control Points (GCP) examples are shown below:

Table 2**:** Based on LULC Each Satellite Images were Following Categories-

Class	**Subclass**	**Training sample x 9 pixels**	**Ground Control Points (GCP)**
Forest cover	Highly dense Moderate dense Low dense	30	12
Bare land	Bare land	15	9
Rivers	Tributaries Distributaries	28	10
Homestead vegetation	Homestead vegetation Plantations	25	10
Built up area	Homestead Constructed area	35	15
Agricultural land	Fallow land Crop land	30	10
Water bodies	Pond *Haor* *Baor* *Beel*	60	10

Source: Compiled by authors using ERDAS IMAGINE® Tour Guides™. (2006), Norcross and Georgia: Leica Geosystems Geospatial Imaging, 2024

Methods

This study used spatial modelling (Markov Chain and Cellular Automata) for predicting land use changes using LANDSAT TM for the future planning. This spatio-temporal analysis using CA Markov chain model facilitated to predict spatial pattern of future LULC changes for the study area. Hereafter, *kappa* statistic and confusion matrix were used to calculate the overall supervised LULC classification accuracy for assessing the quality of the classified Landsat TM images from 2004 to 2024.

GIS and Remote Sensing (RS) approaches were utilized in this research to conduct detailed analysis and support future planning purposes. ArcGIS 10.5 and IDRISI Selva were used for geospatial attributes along with current, potential and future land management planning. Global Positioning System (GPS) was also used for primary data collection such as GCPs, features identification and mete data development.

Results

Probability Matrix for Land Cover Change from 2004 to 2014

The provided change matrix illustrates the alterations in land cover from 2004 to 2014 within Munshiganj *Sadar.* Between 2004 and 2014, notable transformations in land cover occurred. The data reveals that while the majority of land cover types remained stable or experienced minor changes, some exhibited significant alterations. *Char* land, for instance, saw a reduction of 5.71%, indicating potential transformations in the landscape. Crop land expanded, with a gain of 24.45%, indicating an increase in agricultural activities over the decade. Forest cover remained relatively stable, with a slight decrease of 1.75%, reflecting potential deforestation or reclassification of forested areas. Waterbodies witnessed significant changes, with a decrease of 77.58%, suggesting potential impacts on aquatic ecosystems. Notably, rivers also experienced alterations, with a combined gain and loss of 6.87%, indicating potential shifts in river courses or human interventions affecting water resources. Urban and industrial areas exhibited a minor increase of 0.24%, suggesting gradual urbanization processes. These measured changes underscore the dynamic nature of land cover within Munshiganj *Sadar* over the ten-year period, highlighting the importance of continued monitoring and sustainable land management practices to address and adapt to these transformations.

Table 3**:** Probability matrix for land cover change from 2004 to 2014 in Munshiganj *Sadar*, Bangladesh

Probability of change by 2014										
Changing from 2004	**Char Land**	**Crop Land**	**Forest**	**Lake**	**River**	**Rural Settlement**	**Urban and Industrial Area**	**Waterbodies**	**Subtotal**	
									Total	**Loss**
Char Land	0.9429	0	0	0	0	0	0	0.0571	1.00	0.0571
Crop Land	0	0.9754	0.0001	0	0.0037	0.0012	0	0.0195	1.00	0.0245
Forest	0	0.0175	0.9825	0	0	0	0	0	1.00	0.0175
Lake	0	0	0	1	0	0	0	0	1.00	0
River	0	0.0504	0.0001	0	0.9312	0.0004	0.0001	0.0177	1.00	0.0687
Rural Settlement	0	0.004	0	0	0.0001	0.9959	0	0	1.00	0.0041
Urban and Industrial Area	0	0	0	0	0.0008	0.0016	0.9976	0	1.00	0.0024
Waterbodies	0	0.1724	0	0	0.5172	0.0862	0	0.2241	1.00	0.7758
Total	0.9429	1.2197	0.9827	1	1.453	1.0853	0.9977	0.3184		
Gain	0	0.2443	0.0002	0	0.5218	0.0894	0.0001	0.0943		

Source: Compiled by authors, 2024

Probability Matrix for Land Cover Change from 2014 to 2024

The provided change matrix offers insights into the alterations in land cover between 2014 and 2024 within Munshiganj *Sadar*. From 2014 to 2024, Munshiganj *Sadar* witnessed various changes in land cover. The data indicates that while some land cover types remained relatively stable, others experienced significant transformations. *Char* land, for example, underwent a decrease of 6.9%, suggesting potential changes in land use or environmental factors affecting these areas. Crop land, on the other hand, saw a substantial increase of 37.8%, indicating significant agricultural expansion over the decade. Forest cover remained relatively consistent, with a minor decrease of 3.5%, potentially due to deforestation or land conversion. Waterbodies experienced a notable decrease of 99.81%, indicating significant impacts on aquatic ecosystems. Rivers also underwent changes, with a combined gain and loss of 6.08%, indicating potential alterations in river courses or human interventions affecting water resources. Urban and industrial areas witnessed moderate growth, with an increase of 2% over the period. These measured changes underscore the dynamic nature of land cover within Munshiganj *Sadar* over the ten-year period, highlighting the importance of continued monitoring and sustainable land management practices to address and adapt to these transformations.

Table 3: Probability matrix for land cover change from 2014 to 2024 in Munshiganj Sadar, Bangladesh

Probability of change by 2024										
Changing from 2014	Char Land	Crop Land	Forest	Lake	River	Rural Settle ment	Urban and Industrial Area	Water bodies	Subtotal	
									Total	Loss
Char Land	0.931	0.069	0	0	0	0	0	0	1	0.069
Crop Land	0.0001	0.9622	0.0003	0	0.0072	0.0253	0.0049	0	1	0.0378
Forest	0	0.0284	0.965	0	0.0022	0.0022	0.0022	0	1	0.035
Lake	0	0.2	0	0.8	0	0	0	0	1	0.2
River	0	0.0552	0.0003	0	0.9393	0.0044	0.0009	0	1	0.0608
Rural Settlement	0	0.044	0	0	0.0027	0.9513	0.002	0	1	0.0487
Urban and Industrial Area	0	0.0032	0.0016	0	0.004	0.0112	0.98	0	1	0.02
Waterbodies	0.0018	0.9286	0	0	0.0677	0	0	0.0018	1	0.9981
Total	0.9329	2.2906	0.9672	0.8	1.0231	0.9944	0.99	0.0018		
Gain	0.0019	1.3284	0.0022	0	0.0838	0.0431	0.01	0		

Source: Compiled by authors, 2024

Probability Matrix of Land Cover Change from 2024 to 2034

The probability matrix for land cover changes by 2034, compared to the data from 2024, offers insights into the potential dynamics of various land cover types in Munshiganj *Sadar*. According to the probabilities, there is a high likelihood of stability in most land cover categories. *Char* land, forest, lake, rural settlement, urban and industrial areas, and waterbodies all show a 100% probability of maintaining their respective areas as observed in 2024. However, for crop land and rivers, there are slight probabilities of change. Crop land has a 99.87% probability of remaining constant, with a small chance (0.13%) of a slight increase. Similarly, while rivers have a high probability (98.03%) of maintaining their area, there's a small chance (1.97%) of a decrease. These probabilities collectively suggest a predominantly stable landscape in Munshiganj *Sadar*, with minimal alterations expected by 2034. However, continued monitoring and adaptive management practices are essential to address potential changes and ensure sustainable land use in the region.

Table 5**:** Probability matrix for land cover change from 2024 to 2034 in Munshiganj *Sadar*,Bangladesh

Probability of change by 2034										
Changing from 2024	**Char Land**	**Crop Land**	**Forest**	**Lake**	**River**	**Rural Settlement**	**Urban and Industrial Area**	**Water bodies**	**Subtotal**	
									Total	**Loss**
Char Land	1	0	0	0	0	0	0	0	1	0
Crop Land	0	0.9987	0	0	0	0.0013	0	0	1	0.0013
Forest	0	0	1	0	0	0	0	0	1	
Lake	0	0	0	1	0	0	0	0	1	0
River	0	0.0197	0	0	0.9803	0	0	0	1	0.0197
Rural Settlement	0	0	0	0	0	1	0	0	1	0
Urban and Industrial Area	0	0	0	0	0	0	1	0	1	0
Waterbodies	0	0	0	0	0	0	0	1	1	0
Total	1	1.0184	1	1	0.9803	1.0013	1	1		
Gain	0	0.0197	0	0	0	0.0013	0	0		

Source: Compiled by authors, 2024

Predicting the Decadal Changes of LULCC from 2004 to 2034

The data from 2004 to 2024 for land use and land cover in Munshiganj *Sadar* reveals several notable trends. Over this period, there is a consistent increase in crop land area, rising from 10,109.31 hactor in 2004 to 10,163.81 hactor in 2024, suggesting sustained agricultural expansion. The area occupied by rivers shows a slight decrease, declining from 2,186.805 hactor in 2004 to 2,027.984011 hactor in 2024, indicating potential alterations in river courses or human interventions affecting water resources. Urban and industrial areas experienced moderate growth, with the area increasing from 279.6799 hactor in 2004 to 332.100651 hactor in 2024, reflecting ongoing urbanization processes. However, there are also some concerning trends, such as the significant decrease in waterbodies area from 26.30538 hactor in 2004 to just 0.9 hactor in 2024, indicating potential environmental degradation or human interventions affecting aquatic ecosystems.

Table 4**:** Land use land cover change of Munshiganj *Sadar* from 2004 to 2034, Bangladesh

Land Use Land Cover of Munshiganj *Sadar*				
	2004	**2014**	**2024**	**2034**
	Area (Ha)	**Area (Ha)**	**Area (Ha)**	**Area (Ha)**
Char land	6.401595	6.87831	6.873285	6.386827
Crop land	9998.151	10109.31	10163.80906	10249.65
Forest	101.9464	101.951	101.93905	99.51867
Lake	1.371187	1.371187	1.371187	0.615506
River	2103.173	2186.805	2027.984011	1970.448
Rural Settlement	3738.427	3736.223	3796.633951	3764.087
Urban and Industrial	279.6799	279.6799	332.100651	330.0497
Waterbodies	240.63	26.30538	0.9	0.60323
Total	16469.78	16448.53	16431.6112	16421.36

Source: Compiled by authors, 2024

Looking ahead to the predicted data for 2034, based on the trends observed up to 2024, it's projected that agricultural expansion will likely continue, urban and industrial areas may further expand, and the area of waterbodies could potentially continue to decrease. Nonetheless, recognizing the inherent uncertainties in long-term predictions and the potential for changes in socio-economic, environmental, and policy factors that could alter these projections. Continued monitoring and assessment of land use dynamics are essential to refine predictions and inform sustainable land management strategies.

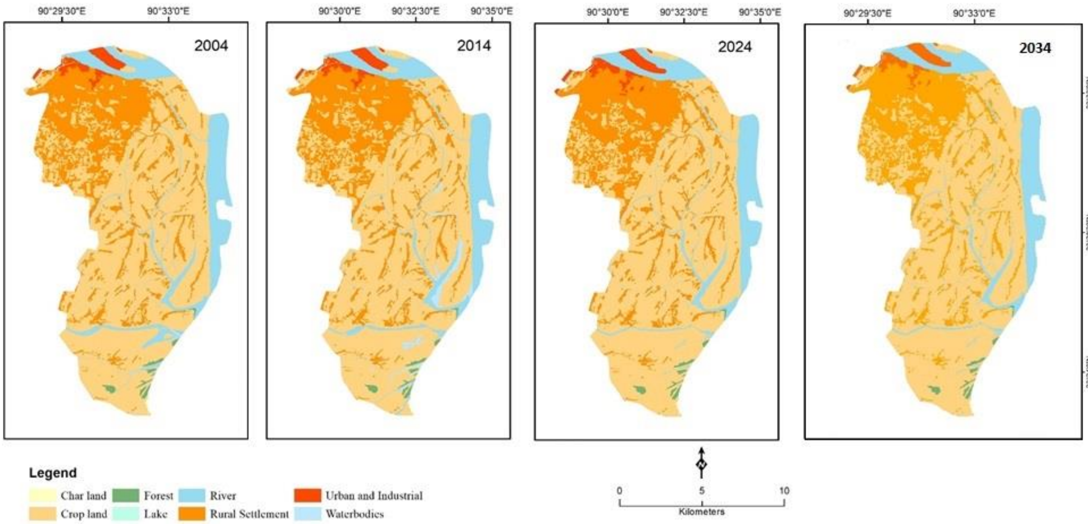

Figure 2: Land use Land Cover Map of Munshiganj Sadar from 2004 to 2024 and Predicted Land use Land Cover Map of Munshiganj Sadar for the year of 2034
Source: Compiled by Authors, 2024

Accuracy assessment of LULC classification

In 2004, the overall accuracy across all land cover classes was measured at 80.3%, with a kappa statistic of 0.82. This indicates a high level of agreement between the classified land cover and the reference data for that year. Notable user's and producer's accuracy values were observed across various land cover classes, ranging from 77.5% to 83.2%. These metrics suggest that the classification process effectively captured the characteristics of each land cover class.

In 2014, the overall accuracy remained consistent at 82.1%, with a *kappa* statistic of 0.83. This indicates that the classification process continued to perform well in accurately classifying land cover classes compared to the reference data for that year. User's and producer's accuracy values ranged from 78.4% to 83.1%, indicating consistent performance across various land cover classes. The high overall accuracy and *kappa* statistic suggest that the classification process effectively captured the spatial distribution and characteristics of different land cover types in Munshiganj *Sadar* during this period. By 2024, the overall accuracy decreased slightly to 79.7%, with a corresponding *kappa* statistic of 0.81. Despite this slight decrease, the classification process maintained relatively high accuracy in accurately classifying land cover classes compared to the reference data for that year. User's and producer's accuracy values ranged from 78.9% to 83.0%, indicating consistent performance across various land cover classes similar to previous years. The decrease in overall accuracy may reflect changes in land cover dynamics or classification uncertainties, emphasizing the importance of continued monitoring and refinement of classification techniques to maintain accurate land cover assessments over time.

Over the span of three different years 2004, 2014, and 2024, land cover classification in Munshiganj *Sadar* demonstrated overall consistency in accuracy assessment, with overall accuracy ranging from 79.7% to 82.1% and *kappa* statistic between 0.81 and 0.83. This suggests that the classification process effectively captured the spatial distribution and characteristics of various land cover types over time. While there were slight fluctuations in overall accuracy, user's and producer's accuracy values remained relatively stable across different land cover classes. These results underscore the reliability of the classification process in monitoring land cover dynamics within Munshiganj *Sadar* over the examined period.

Table 5**:** Accuracy assessment of land cover classification in Munshiganj *Sadar* for 2004, 2014, and 2024

Year	2004		2014		2024	
Class	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)
Char land	81.2	78.4	79.5	81.2	78.9	80.6
Crop land	77.5	82.1	83.1	78.9	82.4	79.2
Forest	79.8	80.3	80.7	82.5	80.2	81.5
Lake	80.4	79.9	78.4	80.2	79.1	81.2
River	83.2	81.5	82.3	79.8	81.8	83
Rural Settlement	82.5	80.7	79.8	81.3	80.5	79.9
Urban and Industrial	81.6	79.3	81.5	83.1	83	81.8
Waterbodies	78.9	84.2	82.1	80.5	79.8	82.3
Overall Accuracy	80.3		82.1		80.5	
Kappa Statistics	0.82		0.83		0.81	

Source: Compiled by authors, 2024

Discussion

Between 2014 and 2024, Munshiganj *Sadar* experienced notable agricultural land expansion, with crop lands increasing by approximately 37.8%, as identified through GIS and Remote Sensing analysis. This growth reflects intensified agricultural activity, possibly at the expense of natural ecosystems, including waterbodies and forested areas, which have concurrently declined. The probability matrix predicts that by 2034, agricultural land will remain highly stable, with a 99.87% chance of persistence and only a 0.13% likelihood of further expansion. While this stability suggests effective current land use management, it also calls for careful planning to prevent environmental degradation and ensure balanced growth. Moving forward, enhanced use of GIS and Remote Sensing technologies will be crucial for sustainable land management. Predictive models like Cellular Automata and Markov Chain analysis should be complemented with high-resolution satellite imagery and real-time monitoring to detect subtle changes and guide adaptive policies. Future strategies must prioritize sustainable farming practices, protect remaining natural habitats, and build resilient agricultural systems to support Munshiganj *Sadar's* long-term environmental and food security goals.

Conclusion

The application of GIS and Remote Sensing (RS) technologies in this study has provided valuable insights into the evolving land use and land cover (LULC) dynamics in Munshiganj *Sadar*, Bangladesh. Over the past two decades (2004-2024), rapid urbanization and population growth have led to the conversion of agricultural and natural lands into built-up areas. Notably, cropland has increased by nearly 38%, driven by intensified agricultural activities. However, this growth has come at a cost, there has been a drastic reduction in waterbodies (down by nearly 99.81%) and gradual forest degradation. The spatiotemporal analysis using CA-Markov models predicts relative stability in agricultural land through 2034, but it also reveals vulnerabilities in aquatic and ecological zones. Without sustainable management and enforcement of policy, Munshiganj *Sadar* may face environmental degradation, water scarcity, and declining biodiversity, potentially compromising food security and long-term resilience.

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