



UDC 528.94:711.14

SPATIO-TEMPORAL ANALYSIS AND FORECASTING OF LAND USE/LAND COVER CHANGE IN EAST MEDINIPUR DISTRICT, INDIA USING CA-MARKOV MODEL

 Parag Jyoti KASHYAP , Sahana BOSE

Department of Geography, Assam University, Diphu Campus, India

Article History:

- received 5 April 2025
- accepted 5 May 2026

Abstract. Land Use/Land Cover (LU/LC) serve as essential indicators of global environmental changes. This study examined the LU/LC change in the East Medinipur district of West Bengal, India, using remote sensing data and the CA-Markov modeling approach. Through GIS tools and satellite imagery, the study maps, monitors, and analyzes LU/LC changes over a 20-year period (2001–2021), utilizing data from Landsat 4–5 and Landsat 8. Analytical tools including ArcGIS 9, IDRISI Terset, and ERDAS 2014 are employed to project LU/LC trends up to 2041. The results highlight significant transformations, notable reductions in agriculture, vegetation, barren land, and water bodies, alongside substantial increases in aquaculture and built-up areas from 2001 to 2021. Projections indicate that these trends will continue through 2041, with further declines in agriculture, vegetation, barren land, and water bodies, accompanied by continued growth in aquaculture and built-up areas.

Keywords: Land Use/Land Cover (LU/LC), remote sensing, East Medinipur, CA-Markov, aqua culture, prediction.

✉ Corresponding author. E-mail: kashyapparagjyoti@gmail.com

1. Introduction

Land Use/Land Cover (LU/LC) changes are increasingly prominent. Anthropogenic alterations in LU/LC are now widely acknowledged as crucial factors shaping global change (Lambin, 1999). They have become integral to sustainable environmental planning and management. The patterns of LU/LC cover change vary substantially from one region to another (Singh et al., 2016). These changes have direct or indirect impacts on natural resources, agricultural practices, economic growth, and the environment (Sarma et al., 2016). Analysis of LU/LC change is essential for monitoring, evaluating, protecting, and planning (Rawat et al., 2013). Human interventions have considerably reshaped the natural landscape over time (Sarma et al., 2016). Land cover denotes to the physical or artificial covering on the Earth's surface, encompassing natural features and human-made structures like buildings and roads. A comprehensive understanding of LU/LC is crucial for effective planning and management purposes (Saikia, 2014).

This research focused on analyzing past and projected future changes in LU/LC within the East Medinipur district of West Bengal. It addresses an important research gap, as few studies have been carried out on predicting future LU/LC changes in this region. The study employed supervised classification to assess historical LU/LC trends and utilized

the CA-Markov model to forecast changes from 2031 to 2041 (Nath et al., 2023). The East Medinipur district faces significant challenges due to escalating human activities, particularly the conversion of large areas of agricultural land into unsustainable aquaculture (Mondal et al., 2012).

GIS integrated with Remote Sensing provides a powerful tool for analyzing LU/LC changes at both regional and global scales. These technologies enable the analysis of natural resources such as forest cover, vegetation types, and changes in land use (Sarma et al., 2016). The combination of GIS and remote sensing is crucial for modern urban management and control by providing essential data. Geospatial technologies also play a key role in studying and monitoring natural resources for effective environmental management (Mallupattu & Sreenivasula Reddy, 2013). They facilitate the identification and analysis of growth patterns and rates, offering efficient methods for addressing LU/LC issues and supporting land use planning and modeling (Islami et al., 2022).

2. Materials and method

2.1. The study area

East Medinipur district in West Bengal, India, lies between 21°36'35"–22°57'10" N and 86°33'50"–88°12'40" E, cover-

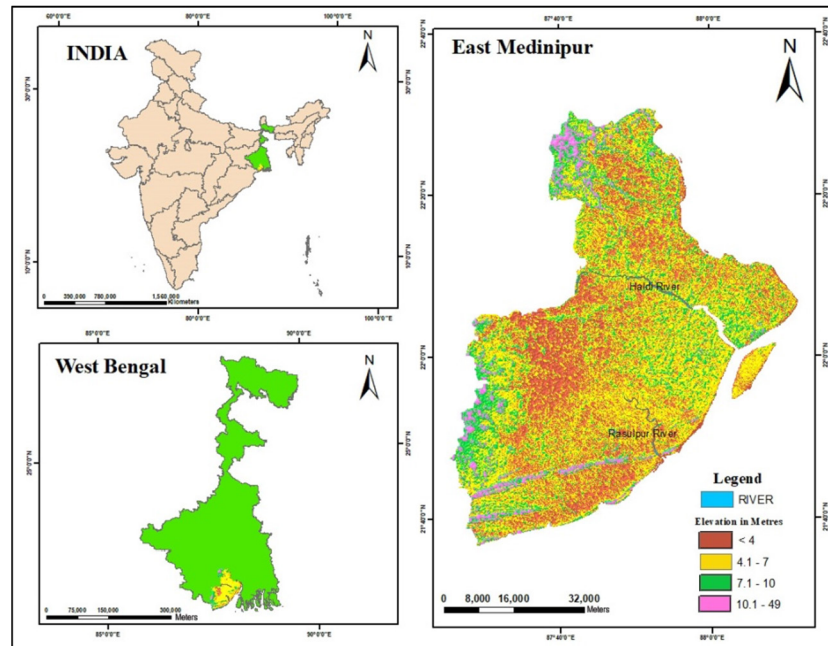


Figure 1. Location map of the East Medinipur district

ing 4736 sq. km (Figure 1). It is bordered by South 24 Paraganas (E), Paschim Medinipur (W), the Bay of Bengal and Balasore (S), and Howrah (N). Physiographically, it forms part of the Lower Ganga Plain with a coastal belt and experiences a tropical monsoon climate. Major rivers include Haldia, Rasulpur, and Kelaghai. The district had a population of 5,094,238 (Census 2011) and is divided into 4 subdivisions, 25 blocks, and 5 municipalities. Agriculture is increasingly shifting toward commercial aquaculture (Ojha & Chakrabarty, 2018; Acharyya et al., 2015).

2.2. Dataset

Landsat 4–5 and Landsat 8 imagery (30 m resolution) for 2001, 2011, and 2021 were obtained from the USGS, ensuring cloud cover below 10%, and processed in TIFF format. Additionally, SRTM DEM data from USGS were used to analyze elevation, providing essential context for interpreting LU/LC changes (Table 1).

Table 1. Details of the satellite images used in the study

Sensor	Resolution (m)	Path/Row	Acquisition date
LANDSAT 4-5	30	138/45	17/03/2001
LANDSAT 4-5	30	139/44	25/04/2001
LANDSAT 4-5	30	139/45	25/04/2001
LANDSAT 4-5	30	138/45	09/02/2011
LANDSAT 4-5	30	139/44	16/02/2011
LANDSAT 4-5	30	139/45	16/02/2011
LANDSAT 8	30	138/45	29/12/2021
LANDSAT 8	30	139/44	20/12/2021
LANDSAT 8	30	139/45	20/12/2021

2.3. Image preprocessing

Image preprocessing methods included correcting geometric distortions in raw image data. Near-infrared, red, and green bands were used to create False Color Composite (FCC) images by channeling them through the red, green, and blue channels. In FCC images, vegetation appears as red, waste/barren land as white, deep waters as black, and urban areas as cyan. All images were geo referenced to WGS84 with UTM zone 45 north projections.

2.4. Image classification

Seven LU/LC classes-vegetation, agriculture, barren land, built-up, aqua farms, ponds/tanks, and water bodies (Table 2) were mapped using pixel-based supervised classification. Training samples were collected, and classification was performed using the maximum likelihood classifier in ArcGIS. Post-classification refinement improved accuracy and removed misclassified cells.

Table 2. LU/LC classes used in the study

LU/LC Types	Description
Vegetation cover	All types of forest
Built-up	Commercial areas, urban and rural settlements, industrial areas, government secretariat areas, royal palace construction areas, traffic etc.
Water body	River, canal and other reservoirs
Agricultural land	Wet and dry croplands
Barren land	Non cultivated land and unusable land
Aqua Farm	Fish farming, shrimp farming, oyster mariculture, pisciculture, algaculture etc.
Pond/Tank	Open ponds

2.5. LU/LC change detection

A change matrix was employed in a post-classification change detection method to monitor and analyze temporal changes in LU/LC. The matrix illustrates changes in LU/LC for each time period between 2001–2021, with projected changes also considered for 2031–2041. The degree of change for each class was determined using the following equation:

$$Di = Ri - Bi, \quad (1)$$

where, Di signifies the degree of change in classes i , Bi denotes the base image, and Ri denotes the most recent image.

The following formula was applied to calculate the percentage change for each LU/LC category:

$$Pci = \frac{Ri - Bi}{Bi} \times 100, \quad (2)$$

where, Li represents the most recent image, Bi represents the base image and Pci represents the percentage of change in class i (Nath et al., 2023).

2.6. Accuracy assessment

Accuracy assessment is a critical component of image classification, used to accurately recognize, understand, and evaluate changes (Das & Sarkar, 2023). The accuracy of classified images was evaluated using the original mosaic, Google Earth images, and GPS points. A confusion matrix was created by combining the classified LU/LC map with ground reference data to determine classification accuracy. Kappa accuracy, overall accuracy, producer accuracy, and user accuracy were computed (Nath et al., 2023). The equations for producer accuracy, user accuracy, overall accuracy, and the Kappa coefficient were applied (Kashyap et al., 2025; Garg et al., 2016):

Producer accuracy:

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Column Total)}} \times 100; \quad (3)$$

User Accuracy:

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category (The Row Total)}} \times 100; \quad (4)$$

Overall Accuracy:

$$\frac{\text{Total number of correctly classified pixels}}{\text{Total number of pixels in the matrix table}} \times 100; \quad (5)$$

Kappa Coefficient:

$$\frac{N \sum_i^r 1x_{ii} - \sum_i^r 1(x_{i+} * x_{+i})}{N^2 - \sum_i^r 1(x_{i+} * x_{+i})}, \quad (6)$$

where, r is the matrix's number of rows, x_{ii} denotes the total number of pixels in row i and column i that were correctly classified, and x_{i+} and x_{+i} denote the marginal sums of row i and column i .

2.7. LU/LC change prediction using the CA-Markov chain model

Future LU/LC for 2031–2041 was predicted using the Markov chain model based on classified images (Das & Sarkar, 2019). Transition probability maps (2001–2021) and suitability maps were generated in IDRISI TerrSet using Multi-Criteria Evaluation (MCE) (Singh et al., 2016; Omar et al., 2014 ; Nath et al., 2023). Finally, the CA-Markov model integrated base maps, transition probabilities, and suitability maps to simulate future LU/LC scenarios.

The following equation shows the Cellular Automata (CA) model (Subedi et al. 2013):

$$S(t, t+1) = f(S(t), N), \quad (7)$$

where, $S(t+1)$ represents the state of the system at time $(t, t+1)$ and is calculated using the state probability at any time (N) (Hamad et al., 2018).

Future shifts in LU/LC were predicted using the following equation:

$$S(t, t+1) = P_{ij} \times S(t), \quad (8)$$

where, $S(t)$ denotes the system status at time t , $S(t+1)$ denotes the system status at time $t+1$, and P_{ij} is the transition probability matrix in a state, which is computed as follows (Hamad et al., 2018):

$$P_{ij} = \begin{matrix} & \begin{matrix} P_{1,1} & P_{1,2} & P_{1,N} \\ P_{2,1} & P_{2,2} & P_{2,N} \\ \dots\dots\dots \\ P_{N,1} & P_{N,2} & P_{N,N} \end{matrix} \end{matrix}, \quad (9)$$

$$(0 \leq P_{ij} \leq 1),$$

where, P is the transition probability, P_{ij} is the likelihood that the current state i will change to a different state j in the coming time, and PN denotes the state probability at any given time. A high transition has a probability close to 1, whereas a low transition will have one close to 0.

3. Results and discussion

3.1. Analysis the land use / land cover pattern

Land use patterns were classified to analyze LU/LC changes in East Medinipur district, West Bengal. In this study, LU/LC was categorized into seven distinct types: Agriculture, Vegetation, Barren land, Built-up areas, Aqua Farms, Ponds/Tanks, and Water Bodies. During the study period, barren land and vegetation dominated East Medinipur district in 2001, but both decreased by 2021 (Table 3).

Between 2001–2011, there was a simultaneous reduction in agriculture and vegetation. Barren land, which

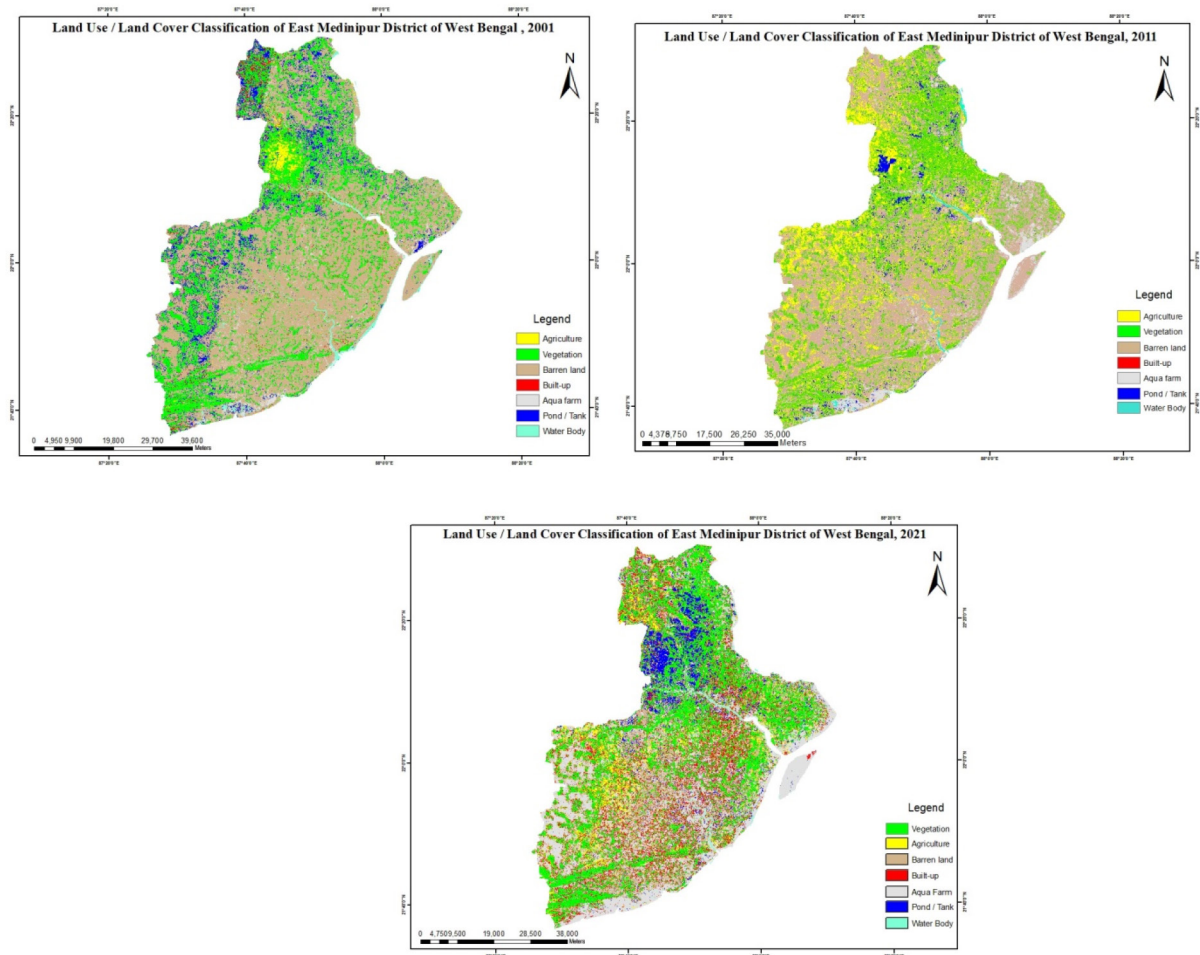


Figure 2. LU/LC distribution in: a) 2001; b) 2011; c) 2021 for Pub Medinipur district

covered a greater percentage of the landscape in 2001, decreased by 2011. In the study area, the number of water bodies and pond/tank coverage also decreased significantly over the same period. Most aqua farms increased in the southeast direction of East Medinipur district. Aqua farm coverage increased continuously from 2.97% in 2001 to 15.60% in 2011. The built-up area nearly doubled between 2001 and 2011.

In the study area, significant shifts in LU/LC occurred between 2001, 2011, and 2021. From 2011 to 2021, an upward trend was noted in aqua farms and built-up areas (Figure 2a–c). Agriculture land and vegetation cover moderately decreased from 2011 to 2021. The area covered by water bodies and ponds/tanks decreased from 2001 to 2021. In 2001, the study area was predominantly barren land, comprising 45.74% of the area. However, by 2021, this percentage had steadily decreased to 19.42%.

Table 3. LU/LC changes in East Medinipur district (2001–2021) showing area, percentage, and decadal variation

Classes	2001 Area (sq. km)	2001 (%)	2011 Area (sq. km)	2011 (%)	2021 Area (sq. km)	2021 (%)	Change 2001–2011 (sq. km)	Change (%)	Change 2011–2021 (sq. km)	Change (%)
Agriculture	207.85	5.21	200.53	5.03	195.56	4.9	–7.32	–0.18	–4.97	–0.13
Vegetation	1289.48	32.37	1213.96	30.47	1202.72	30.19	–75.52	–1.9	–11.24	–0.28
Barren land	1822.49	45.74	1047.82	26.29	773.82	19.42	–774.67	–19.45	–274.0	–6.87
Built-up	205.64	5.16	587.84	14.76	592.43	14.87	382.2	9.59	4.59	0.11
Aqua farm	118.31	2.97	621.59	15.6	952.55	23.91	503.28	12.63	330.96	8.3
Pond / Tank	279.81	7.02	266.0	6.68	234.2	5.88	–13.81	–0.35	–31.8	–0.8
Water Body	60.9	1.52	46.74	1.17	33.2	0.83	–14.16	–0.36	–13.54	–0.33

Table 4. Accuracy assessment of the classified LU/LC images

Classes	2001		2011		2021	
	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Agriculture	80%	100%	100%	100%	100%	90%
Vegetation	97%	100%	93%	93%	98%	91%
Barren land	100%	92%	100%	96%	100%	100%
Built-up	100%	100%	100%	88%	100%	100%
Aqua farm	100%	100%	84%	100%	94%	92%
Pond/Tank	83%	100%	100%	100%	100%	60%
Water Body	100%	100%	100%	85%	100%	93%
Overall Accuracy	98%		96%		95%	
Overall Kappa Statistics	0.9687		0.9545		0.9322	

Agricultural land declined from 207.85 sq. km in 2001 to 200.53 sq. km in 2011 and 195.56 sq. km in 2021. Vegetation, mainly in the western and central parts, decreased from 1289.48 sq. km (2001) to 1213.96 sq. km (2011) and further by 2021. Barren land showed a sharp decline from 1822.49 sq. km in 2001 to 1047.82 sq. km in 2011 and 773.83 sq. km in 2021. Built-up area increased significantly from 205.64 sq. km in 2001 to 587.84 sq. km in 2011, with a slight rise to 2021. Aqua farm area expanded rapidly from 118.31 sq. km (2001) to 621.59 sq. km (2011) and 952.55 sq. km (2021). In contrast, ponds/tanks decreased from 279.81 sq. km in 2001 to 234.2 sq. km in 2021. Water bodies also declined continuously over the period.

3.2. Accuracy assessment

The kappa accuracy and overall accuracy of each LU/LC categorized map remained at or above 85%, indicating their reliability for additional analysis (Table 4).

4. Future LU/LC change projections

4.1. LU/LC transition probabilities

The classified maps from 2001 and 2021 were used to generate the transition probability matrix for the LU/LC

map's 2031 prediction. Similarly, the probability matrix for projecting the LU/LC map for 2041 was also created using classified maps from 2001 and 2021. The Figure 3a–b show the simulated map. To analyze the modifications, a 6×6 LU/LC class matrix table was employed. The rows of this matrix table displayed the LU/LC classes that occurred earlier in time (t_1), and the columns showed the LU/LC classes that occurred later in time (t_2). These matrices show the LU/LC classes' prior probabilities, which were then applied to predict the LU/LC classes based on significant years.

This study presents a 20-year projection of LU/LC changes based on detailed data analysis. Table 5 outlines projected trends from 2021 to 2031. Agricultural land declined gradually from 207.85 sq. km in 2001 to 195.56 sq. km in 2021. Vegetation, mainly in the western and central parts of East Medinipur, also decreased from 1,289.48 sq. km (2001) to 1,213.96 sq. km (2011), with further decline by 2021. Barren land showed a sharp reduction from 1,822.49 sq. km in 2001 to 773.83 sq. km in 2021. In contrast, built-up area increased significantly from 205.64 sq. km in 2001 to 587.84 sq. km in 2011, with a slight rise thereafter. Aqua farms expanded rapidly from 118.31 sq. km (2001) to 952.55 sq. km (2021). Ponds/tanks declined from 279.81 sq. km in 2001 to 234.2 sq. km in 2021, while water bodies also decreased steadily over the study period.

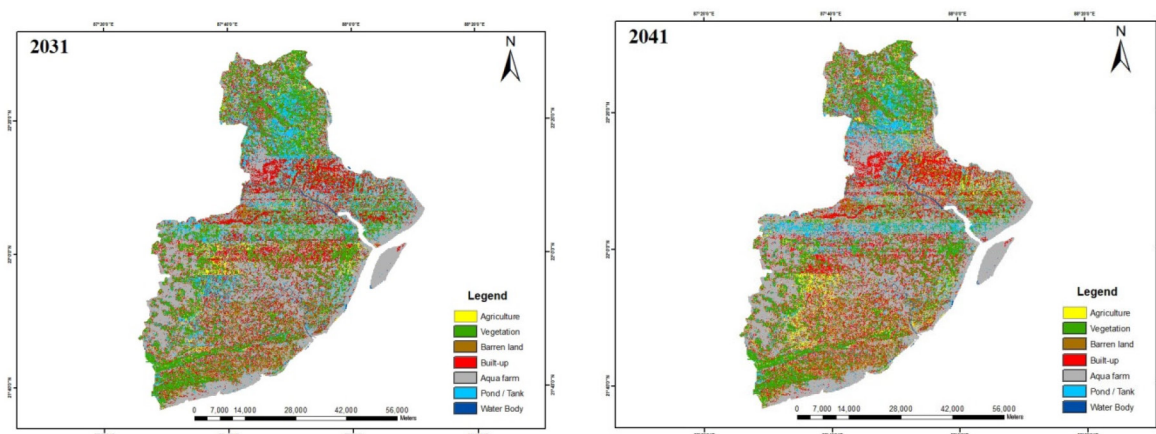


Figure 3. Predicted (LU/LC) maps of Purba Medinipur District, West Bengal: a) Predicted LU/LC for 2031; b) Predicted LU/LC for 2041

Table 5. Probability of LU/LC changes by percentage in 2031

LU/LC	Agriculture	Vegetation	Barren land	Built-up	Aqua farm	Pond/Tank	Water body
Agriculture	0.64	10.18	0.0	7.90	10.54	70.2	0.54
Vegetation	3.83	63.10	0.08	10.1	21.03	1.67	0.19
Barren land	14.72	1.28	23.90	21.82	36.08	2.52	0.0
Built-up	15.81	29.08	7.37	29.05	18.69	0.0	0.0
Aqua farm	4.54	0.0	15.53	5.71	73.02	1.18	0.05
Pond/Tank	16.36	17.39	7.76	17.79	22.5	18.2	0.0
Water body	6.62	1.04	1.03	4.32	76.45	0.0	10.54

Table 6. Probability of LU/LC changes by percentage in 2041

LU/LC	Agriculture	Vegetation	Barren land	Built-up	Aqua farm	Pond/Tank	Water body
Agriculture	5.15	18.25	3.07	11.07	18.8	43.34	0.32
Vegetation	5.65	68.30	1.50	13.69	7.43	3.42	0.03
Barren land	9.18	15.43	15.17	17.07	38.00	5.10	0.05
Built-up	12.15	31.58	7.28	22.36	22.78	3.87	0.0
Aqua farm	5.66	37.71	14.88	8.23	64.08	3.23	0.22
Pond/Tank	12.55	21.91	7.92	15.08	26.5	15.04	1.00
Water body	15.72	2.64	4.32	4.32	56.10	1.79	15.08

Table 6 shows projected LU/LC transitions from 2021 to 2041. Agricultural land has only a 5.15% chance of remaining unchanged, with major conversions to ponds/tanks (43.34%) and aqua farms (18.8%). Vegetation is relatively stable, with a 68.30% probability of persistence, though some conversion to built-up areas (13.69%) and aqua farms (7.43%) is expected. Barren land shows moderate stability (15.17%) but is likely to convert to aqua farms (38%) and built-up areas (17.07%). Built-up areas have a 22.36% chance of persistence, with notable transitions to vegetation (31.58%) and aqua farms (22.78%). Aqua farms remain largely stable (64.08%) while also converting to vegetation and barren land. Ponds/tanks show low stability (25.04%) and are likely to shift to aqua farms (26.5%), while water bodies have minimal stability (15.08%) and are mainly projected to convert to aqua farms (56.10%). Overall, the results indicate increasing dominance of aqua farms and significant transformation across LU/LC classes in East Medinipur.

4.2. Spatio-temporal analysis of the projected LU/LC

This study used LU/LC mapping and a transition probability matrix to generate future projections through the CA-Markov model. The results for 2031 and 2041 show notable landscape changes (Figure 3a, b). Agricultural land is projected to decline from 4.94% (2031) to 4.01% (2041), while vegetation will decrease slightly from 23.66% to 21.83%. Barren land is expected to reduce from 14.76% to 12.30%, whereas built-up areas will increase from 18.84% to 19.31%, indicating ongoing urbanization. Ponds/tanks may slightly decline from 5.83% to 5.39%, while water bodies remain stable at 0.59%. Aqua farms show the most

significant growth, rising from 31.38% in 2031 to 36.57% in 2041 (Table 7). Overall, the projections highlight increasing aquaculture expansion, urban growth, and gradual decline in agriculture and vegetation, providing important insights for land use planning in East Medinipur.

Table 7. Area of the predicted LU/LC classes of the district

Classes	2031 (Predicted)		2041 (Predicted)	
	Area in sq. km	Area (%)	Area in sq. km	Area (%)
Agriculture	196.82	4.94	159.95	4.01
Vegetation	942.45	23.66	869.61	21.83
Barren land	588.29	14.76	490.11	12.30
Built-up	751.03	18.84	769.53	19.31
Aqua farm	1250.53	31.38	1456.98	36.57
Pond / Tank	232.16	5.83	215.1	5.39
Water Body	23.2	0.59	23.2	0.59

5. Conclusions

This study used Landsat TM/OLI data (2001, 2011, 2021) and GIS tools to analyze LU/LC changes in East Medinipur over two decades. Results show significant transformations driven by natural and human factors. Barren land declined sharply, largely converted into aqua farms, which expanded consistently. In contrast, water bodies decreased from 60.9 sq. km (2001) to 32.2 sq. km (2021). Agricultural and vegetation areas showed slight increases, while ponds/tanks declined markedly from 279.81 sq. km to 37.64 sq. km, indicating shifting land-use priorities. Future projections using the CA-Markov model (2031 and 2041) highlight continued changes in land use. The study emphasizes

the importance of GIS and remote sensing in monitoring and predicting LU/LC dynamics, supporting informed planning and sustainable management. It recommends policy measures to conserve remaining forests and water bodies and ensure balanced development in the district.

Authors contribution

PJK and SB jointly conceptualized and designed the study. PJK collected and processed the data and drafted the manuscript, while SB reviewed and enhanced the final version.

Disclosure statement

The authors declare that they have no known competing financial, professional, or personal interests that could have influenced the work reported in this paper.

References

- Acharyya, N., Bhattacharya, M., Das, P., Patra, B. C., & Bandyopadhyay, J. (2015). Changing phenomenon of aquaculture land through space and time using geoinformatics techniques: A case study of Moyna and Nandakumar Block, Purba Medinipur, West Bengal, India. *American Research Thoughts*, 1, 1337–1348.
- Das, S., & Sarkar, R. (2019). Predicting the land use/land cover change using Markov model: A catchment level analysis of the Bhagirathi-Hugli River. *Spatial Information Research*, 27, 439–452. <https://doi.org/10.1007/s41324-019-00251-7>
- Garg, R., Kumar, A., Prateek, M., Pandey, K., & Kumar, S. (2022). Land cover classification of spaceborne multifrequency SAR and optical multispectral data using machine learning. *Advances in Space Research*, 69(4), 1726–1742. <https://doi.org/10.1016/j.asr.2021.06.028>
- Hamad, R., Balzter, H., & Kolo, K. (2018). Predicting land use/land cover changes using a CA-Markov model under two different scenarios. *Sustainability*, 10(10), Article 3421. <https://doi.org/10.3390/su10103421>
- Islami, F. A., Tarigan, S. D., Wahjunie, E. D., & Dasanto, B. D. (2022). Accuracy assessment of land use change analysis using Google Earth in Sadar Watershed Mojokerto Regency. *IOP Conference Series: Earth and Environmental Science*, 950, Article 012091. IOP Publishing. <https://doi.org/10.1088/1755-1315/950/1/012091>
- Kashyap, P. J., Sarmah, K., Bose, S., & Sarma, P. K. (2025). Assessing land use and land cover changes in the buffer zone of Nambor Wildlife Sanctuary (WLS), Assam. *Discover Geoscience*, 3, Article 104. <https://doi.org/10.1007/s44288-025-00217-3>
- Lambin, E. F. (1999). Monitoring forest degradation in tropical regions by remote sensing: Some methodological issues. *Global Ecology and Biogeography*, 8(3–4), 191–198. <https://doi.org/10.1046/j.1365-2699.1999.00123.x>
- Mallupattu, P. K., & Sreenivasula Reddy, J. R. (2013). Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. *The Scientific World Journal*, Article 268623. <https://doi.org/10.1155/2013/268623>
- Mondal, A., Kundu, S., Chandniha, S. K., Shukla, R., & Mishra, P. K. (2012). Comparison of support vector machine and maximum likelihood classification technique using satellite imagery. *International Journal of Remote Sensing and GIS*, 1(2), 116–123.
- Nath, N., Sahariah, D., Meraj, G., Debnath, J., Kumar, P., Lahon, D., Chand, K., Farooq, M., Chandan, P., Singh, S. K., & Kanga, S. (2023). Land use/land cover change monitoring and prediction of a UNESCO world heritage site: Kaziranga eco-sensitive zone using cellular automata-Markov model. *Land*, 12(1), Article 151. <https://doi.org/10.3390/land12010151>
- Ojha, A., & Chakrabarty, A. (2018). Brackish water aquaculture development and its impacts on agriculture land: A case study on coastal blocks of Purba Medinipur district, West Bengal, India using multi-temporal Satellite data and GIS Techniques. *International Journal of Applied Engineering Research*, 13(11), 10115–10123.
- Omar, N. Q., Ahamad, M. S. S., Hussin, W. M. A. W., & Samat, N. (2014). Modelling land-use and land-cover changes using Markov-CA, and multiple decision making in Kirkuk city. *International Journal of Scientific Research in Environmental Sciences*, 2(1), 29–42.
- Rawat, M. S., Zhimo, V. V., & Imchen, N. Deforestation in Nagaland, North-East India: Causes, effects and subsequent environmental degradation – a preliminary review. *Global Journal of Current Research*, 6(3), 61–70.
- Saikia, A. (2014). *Over-exploitation of forests: A case study from North East India*. Springer. <https://doi.org/10.1007/978-3-319-01408-1>
- Sarma, P. K., Sarma, K., Sarma, K., Nath, K. K., Talukdar, B. K., Huda, M. E., & Baruah, B. (2016). Analysis of land use/land cover changes and its future implications in Garo Hill region of Meghalaya: A geo-spatial approach. *International Journal of Innovative Research in Engineering & Management (IJIREM)*, 3(1), 38–44.
- Singh, A. M., & Devi, K. R. (2016). Landuse and landcover change detection of fringe areas Of Imphal City, Manipur, India. *IOSR Journal of Humanities and Social Science*, 21(2), 9–16.
- Subedi, P., Subedi, K., & Thapa, B. (2013). Application of a hybrid cellular automaton – Markov (CA-Markov) model in land-use change prediction: A case study of Saddle Creek Drainage Basin, Florida. *Applied Ecology and Environmental Sciences*, 1(6), 126–132. <https://doi.org/10.12691/aees-1-6-5>