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Assessment of Development Plans for Small Urban Areas of Bangladesh: Remote Sensing and GIS-based Approach

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Abstract

Assessment of development plans particularly in terms of land use and land cover can strategically support conventional land use planning practices. This paper attempts to assess the land cover related proposals mentioned in the development plans of two small urban areas, namely Madaripur and Rajoir of Bangladesh, which are rapidly growing and facing shrinkage of agricultural lands and water bodies by such growth. Land cover data for the study have been extracted from Landsat satellite images of 1995, 2005 and 2015. The classified satellite data have been employed in a Multi-Layer Perceptron Markov model to predict the land cover scenario of the study areas for 2035, the terminal year for the development plans. The proposed development plan and the modelpredicted land cover maps of 2035 are both quantitatively and spatially compared. The study also determines the degree of conformance and identifies the affected sites within respective protected areas. The analysis reveals significant mismatches between the development plans and the model predictions for the unconstrained simulation of the model, whereas fewer differences are observed in the case of guided simulation. The results imply that lack of implementation of the development plans may result in undesired land cover transformations. It recommends employing remote sensing and GIS-based models to support the land-use plan-making process in the development authorities.

Keywords Development planning · Urban growth modelling · Assessment · Remote sensing

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Introduction

Bangladesh, predominantly a rural country, is undergoing a remarkable transformation toward urbanization. According to Islam et al. (2013), about 50% of the total population will be living in the urban areas of the country by the year 2047. However, the process of urbanization in Bangladesh has been rapid and uneven (The World Bank, 2007). This unplanned trend of growth has prompted undesired spatial transformations in small urban areas. The small urban areas are vital elements of the country's urban hierarchy and act as growth and service centers for the surrounding rural hinterland (Rouf & Jahan, 2000). The uncontrolled growth of these settlements creates irregularities in urban–rural balance. Urban Development Directorate (2014) estimates, 1% of Bangladesh's agricultural land is being compromised due to uncontrolled anthropogenic growth every year.

In order to control undesired land cover transformation, the Urban Development Directorate (UDD) of the Government of Bangladesh has taken an initiative for comprehensive development for selected small urban areas and their respective rural hinterlands (UDD, 2015). Comprehensive development planning has been devised for two of the small urban areas of the country: Madaripur and Rajoir. However, previous examples of development planning in Bangladesh have been found deficient in controlling the haphazard trend of land cover change in various cities of Bangladesh (BIP, 2008; Hussain, 2018; Lima, 2003; Mahmud, 2007; Zannat & Islam, 2015). These findings have made room for debate to discuss the development policies' compliance with the present growth trend of Bangladesh (Shubho, 2016).

To find out how much the development planning initiatives in Bangladesh are fulfilling their respective goals, a quantitative evaluation is required. Monitoring the land covers and accordingly anticipating their changes can strategically support conventional land use planning processes (Sylla et al., 2012; Yin et al., 2007). Although assessment of the development plans is regarded as just as important as the formulation of the plan (Tilaki & Marzbali, 2014), it is neglected in almost all developing countries (UN-Habitat, 2009). Through quantitative assessment of development plans, more suitable guidelines can be derived for the target regions. With the current advancement of Geographic Information Science (GIS) and Remote Sensing (RS) technologies, abundant possibilities have been made available to monitor and quantify Land Use Land Cover (LULC) changes in spatial and temporal dimensions. A combination of urban modelling and GIS-RS data can be very useful for predicting future changes of the spatial dimension of fast transforming urban areas.

The present study intends to assess development plans of selected small urban areas of Bangladesh based on land cover change. This research involves GIS and RS technologies for the assessment of development plans. Both unconstrained and guided development have been considered for simulating the future land cover scenario of the study areas. The research demonstrates the temporal and spatial changes of selected land cover categories and reveals the spontaneous nature of growth within the selected region. The outcome of this research intends to support development authorities by facilitating their decision-making procedure.

Quantitative Assessment of Development Plans

The subjects of development plan assessment are broad, and the variables are often multidisciplinary, making the process an arduous effort. Although non-quantitative methods are more commonly used, quantitative methods are better capable of explaining the aspects of assessment (Tian & Shen, 2011). Assessment of a development plan can be perceived as a review of the planning policies and practices from the historic perspective (Armstrong, 1986). Many researchers have emphasized on application of a context-specific evaluation framework to increase the efficiency of the development process (Rossiter, 1996; Tilaki & Marzbali, 2014; Neamțu, 2011; Stevens, 2013).

Advancement in research and technology has helped to access reliable data source, which contributed to the uprising of quantitative methods for assessment of development plan assessment. Oliviera and Pinho (2005) discussed popular master plan evaluation methods such as Cost–Benefit Analysis (CBA), Planning Balance Sheet (PBS), Goals Achievement Matrix (GAM), Multi-criteria Analysis and Environmental Impact Assessment (EIA). Determining the degree of conformance of actual land use to planned land use is one quantitative approach that has been adopted in many types of research. Numerous researchers have regarded this approach as a feasible measure for the quantitative assessment of development plans (Berke et al., 2006; Mabaso et al., 2015; Tian & Shen, 2011). Nyiransabimana et al. (2019) have prepared guidelines for the studied master plans by measuring the degree of conformity using GIS overlay analysis.

One of the prerequisites to master planning is to determine the scale of urban development in the future. Integration of mathematical modelling and remotely sensed data have supported tremendously to simulate future scenarios of areas of interest. Reliable future prediction methods of land use land cover can address various issues such as urban expansion and land use structure, urban transportation system, planning for water and green conservation, special protection plan preparation, environmental planning etc. (Kadhim et al., 2016; Xiao & Zhan, 2009). Land cover change forecast can estimate the urban area and the type of land cover that would be affected by the proposed development (Meaille & Wald, 1990). Rahman (2007) regarded remote sensing as an effective and powerful tool for the management and potential solution to various urban and regional spatial problems in Delhi city, such as urban hydrology, solid and hazardous waste, effective traffic management, urban heat island mapping etc. Seto et al. (2007) provided a quantitative assessment of the spatial and temporal dynamics of urban development in five large urban areas.

Land Use Land Cover Modelling

Since the late 1980's, integration of GIS and RS technologies with urban studies have facilitated urban growth modelling with platforms for data management, spatial analysis, and visualization techniques (Allen, 1995; Batty & Longley, 1994;

Kashem, 2008). Urban growth patterns maintain close ties with spatial and temporal dimensions of respective land cover transformation, as the physical aspects of urban growth are inherently connected to land cover (Cheng, 2003). In order to explore the trends and processes of land cover transitions, land cover change models have been into practice as a provider of quantitative evidence of the changing landscapes of urban systems. Quantitative models such as Fractal-based models, Markov Chain analysis, Multiple Regression models, Logistic Regression etc. have been applied commonly by urban researchers (Cheng, 2003). Cellular Automata (CA) is one of the widely accepted models for spatial modelling (Liu & Andersson, 2004; Wu & Webster, 1998). In recent years, ANN-based models are considered to be robust for urban growth modelling due to their ability to learn nonlinear, organic and complex patterns (Mas & Flores, 2008). Artificial Neural Network based models have been promisingly used in remote sensing fields since the beginning of the 1990s (Atkinson & Tatnall, 1997; Bishop, 1995; Simpson, 1990).

Multi-Layer Perceptron Markov (MLP_Markov) model is one such example of hybrid spatial model that combines neural networks' algorithm with statistical decisions of Markov Chain. Application of Multi-Layer Perceptron Markov (MLP_Markov) models can be traced from the early 90 s, as Markov's probability grid data were integrated into MLP algorithm. Acceptance of MLPs have increased among remote sensing communities, leading to a growing number of literatures reported in recent years due to availability of powerful and flexible software (Ahmed, 2011; Chan et al., 2001; Dadhich & Hanaoka, 2010; Li & Yeh, 2002; Mas & Flores, 2008; Mirici et al., 2017; Pijanowski et al., 2002). In his study, Ahmed (2011) identified MLP_Markov as the best fit for Bangladesh context among the selected models by model validation. To apply MLP_Markov model in remotely sensed images more efficiently, Land Change Modeler (LCM) application has been used in numerous studies (Dereli, 2018; Jain et al., 2017).

Methodology of the Study

Study Area Selection and Data Acquisition

For this study, two small urban areas of Bangladesh, Madaripur upazila[1] and Rajoir upazila are selected. Urban Development Directorate (UDD) of the Bangladesh government had prepared a development plan for Madaripur paurashava (1989) under National Physical Plan which expired in 2009. On the other hand, the development plan for Rajoir Upazila Shahar (1990) also expired in 2010. Development plans of both these areas have been formulated in 2014 for the period of 2015–2035 by the UDD. This was the first concerted effort for comprehensive development of small urban areas of Bangladesh, aimed at balancing the urban–rural continuum (UDD, 2015).

[1] an administrative region in Bangladesh, functioning as a sub-unit of a district, equivalent to a county or a borough of Western countries.

It is noteworthy that Madaripur municipality is designated as an "A class" municipality whereas Rajoir municipality is designated as a "C class" municipality (LGED, 2019). The class difference[2] between the study areas contributes to the fact that studying both adds value to the study and is suitable for a comprehensive understanding of the region's transformation. Satellite images of 30 m resolution of Madaripur and Rajoir from United States Geological Survey (USGS) database are the main data for the study (Table 1). The acquired satellite images are shown in Fig. 13 (Appendix 1).

Image Classification

For this study, satellite images of 1995, 2005 and 2015 are classified into five land cover classes: i) Built-up area, ii) Fallow land, iii) Vegetation, iv) Agricultural land and v) Water body (Appendix 1: Table 6). The classification procedure is undertaken through a supervised Multi-Layer Perceptron (MLP) neural network classifier using the back propagation algorithm. To determine the separability of the classes, Transformed Divergence measures have been calculated. Resultant maps of the image classification phase are illustrated in Fig. 1.

Accuracy Assessment

As suggested by Lillesand et al. (2004), this research have assigned 250 stratified random sample points per study area to assess accuracy of the classified raster data. The contingency tables of kappa calculation are listed in Tables 7 and 8 (Appendix 1).

For the classified land cover maps of Madaripur upazila, producer's accuracy is found ranging from 71.43% to 91.30%, while user's accuracy is found ranging from 74.07% to 91.17%. The overall accuracy for 1995, 2005 and 2015 are calculated as 87.35%, 86.72% and 85.66%, with kappa values of 0.8018, 0.8088 and 0.7893. For the classified land cover maps of Rajoir upazila, producer's accuracy ranges from 71.43% to 95.24%, while user's accuracy ranges from 74.07% to 95.30%. The overall accuracy for 1995, 2005 and 2015 are calculated as 88.80%, 86.40% and 91.60%, with kappa values of 0.8072, 0.8065 and 0.8576. As suggested by Viera & Garrett (2005), Kappa value of 0.61 to 0.80 indicates substantial agreement and Kappa value of 0.81 to 0.99 indicates almost perfect agreement. Accuracy assessment measures of the classified land cover maps of Madaripur upazila and Rajoir upazila show that the corresponding kappa values have remained within the acceptable values of substantial agreement and almost perfect agreement. These values of the accuracy measures imply that accuracy of the classified maps is well within satisfactory level and are acceptable for further analysis.

[2] the 328 municipalities of Bangladesh are classified into A, B and C categories based on the annual revenue generation capacity of the incumbent local authority, where "A class" is the largest and "C class" is the smallest of the municipalities.

Table 1 Properties of acquired satellite images

Study area	Year	Satellite sensors	Number of bands	Acquisition date & time (dd/mm/yyyy) (hh:mm:ss)	Cloud cover
Madaripur and Rajoir	1995	Landsat 5 Thematic Mapper (TM)	6	21/11/1995 03:24:28 AM	0%
	2005	Landsat 5: Thematic Mapper (TM)	6	16/11/2005 04:13:15 AM	1%
	2015	Landsat 8: Operational Land Imager (OLI)	8	12/11/2015 04:24:55 AM	0.09%

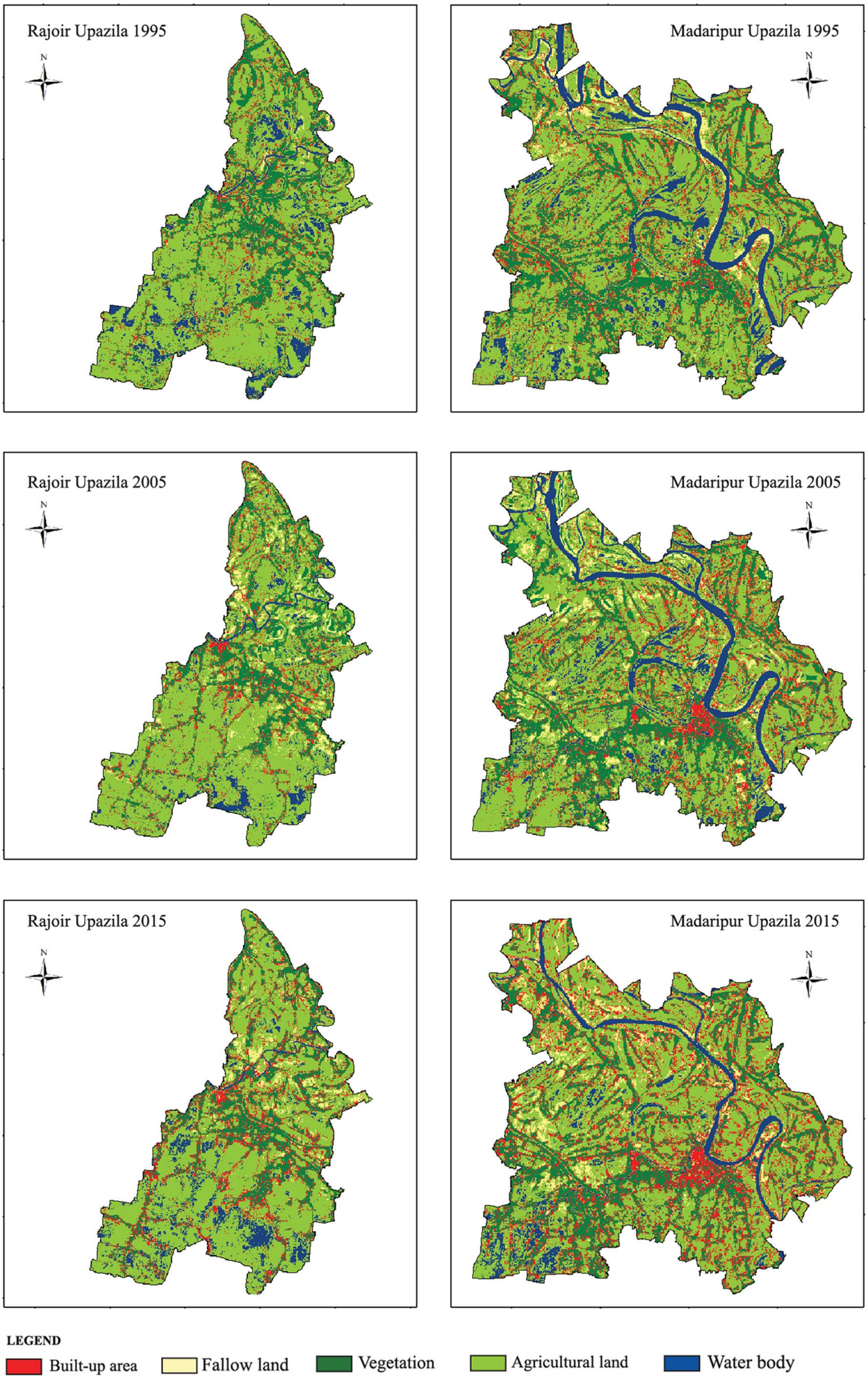


Fig. 1 Classified land cover maps of Madaripur upazila and Rajoir upazila

Model Validation

To validate the MLP_Markov model, land cover maps of the year 2015 has been simulated by using land cover data of the year 1995 and 2005 (Appendix 2). The resultant maps have been validated by the classified land cover data of the year 2015 (Appendix 2: Table 9). For Madaripur, kappa value, $K_{location}$ and K_{histo} have been calculated as 0.77, 0.85 and 0.91 respectively. And for Rajoir, kappa value, $K_{location}$ and K_{histo} have been calculated as 0.72, 0.73 and 0.97 respectively. These values indicate that the MLP_Markov models results are acceptable for predicting future land cover maps of the study areas.

Model Calibration

The MLP_Markov model is composed of three consecutive tasks: analyzing past land cover change data, modeling the potentials of land transitions, and predicting the course of change into the future (Eastman, 2016). The model employed in this study, considers urban growth as the driving force of land cover changes occurred during the study period. Expansion of built-up area is regarded as the primary contributor to the transformation of land covers in the study areas. Therefore, "Fallow land to Built-up area", "Vegetation to Built-up area", "Agricultural land to Built-up area" and "Water body to Built-up area" are identified as sub-models to create transition potentials for the neural network.

Creating Driver Variables

At the first stage of MLP-Markov's algorithm, few driver variables have been created. Distance maps of the areas that have transformed into built-up area during 2005–2015 period is first of the several driver variables. Distance maps of other land covers of 2015 are additional parameters that influence future growth. Another driver variable is the empirical likelihood transformation map of the study areas based on land cover data of 2005. The empirical likelihood transformation map is a means of involving categorical variables into the analysis. The last variable is the distance map of the road network within the study areas. Aforementioned variable maps are illustrated in Figs. 2 and 3 for Madaripur and Rajoir respectively.

Generating Transition Potentials

Driver variables are used for generating transition potential maps for the four transitions. In the transition potential creation stage, per class sample size is set as 902 and 500 respectively for the two study areas. These sample sizes are set equal as or larger than to the minimum number of cells that have experienced change during 2005 and 2015. From the specified sample size, the MLP neural network uses 50% of them for testing and remaining 50% for training. The simulation has reported high levels of accuracy: 98.16% and 86.68% for Madaripur upazila and Rajoir upazila respectively. The accuracy measure depends upon the sampling specifications for

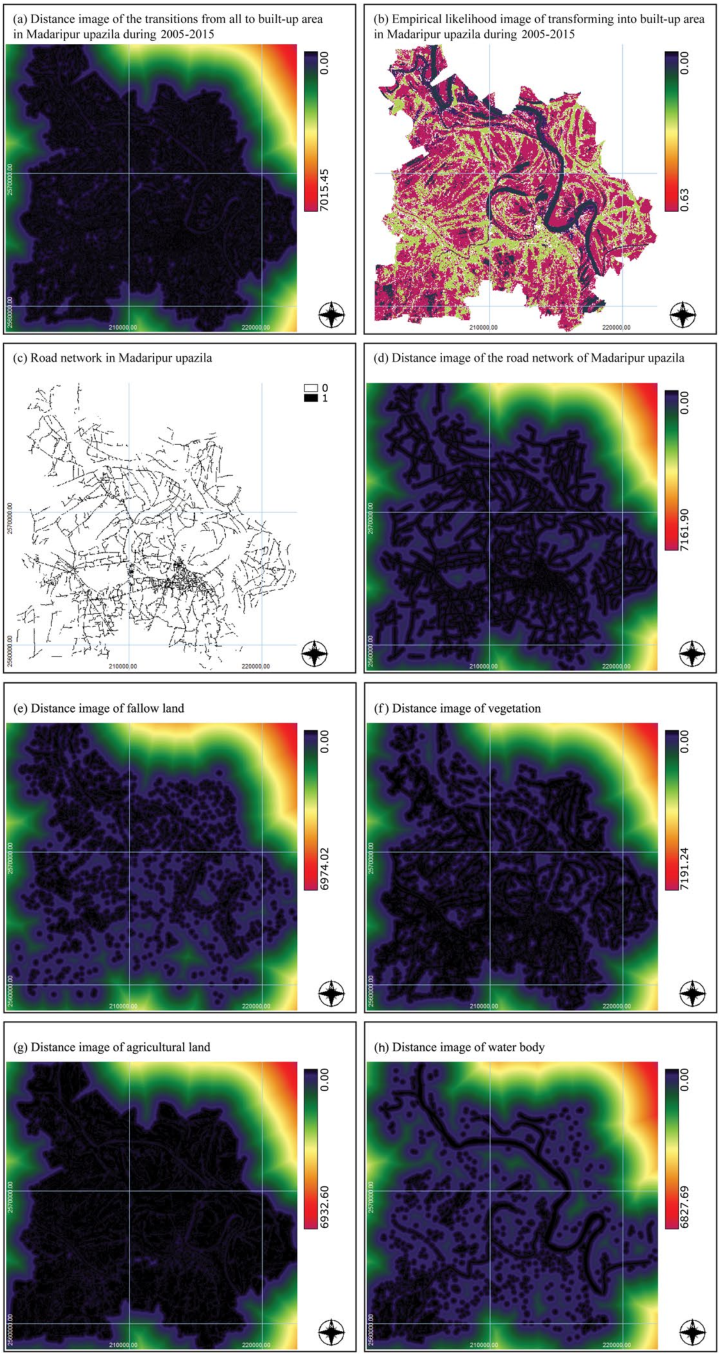


Fig. 2 Driver variables for MLP_Markov simulation of Madaripur

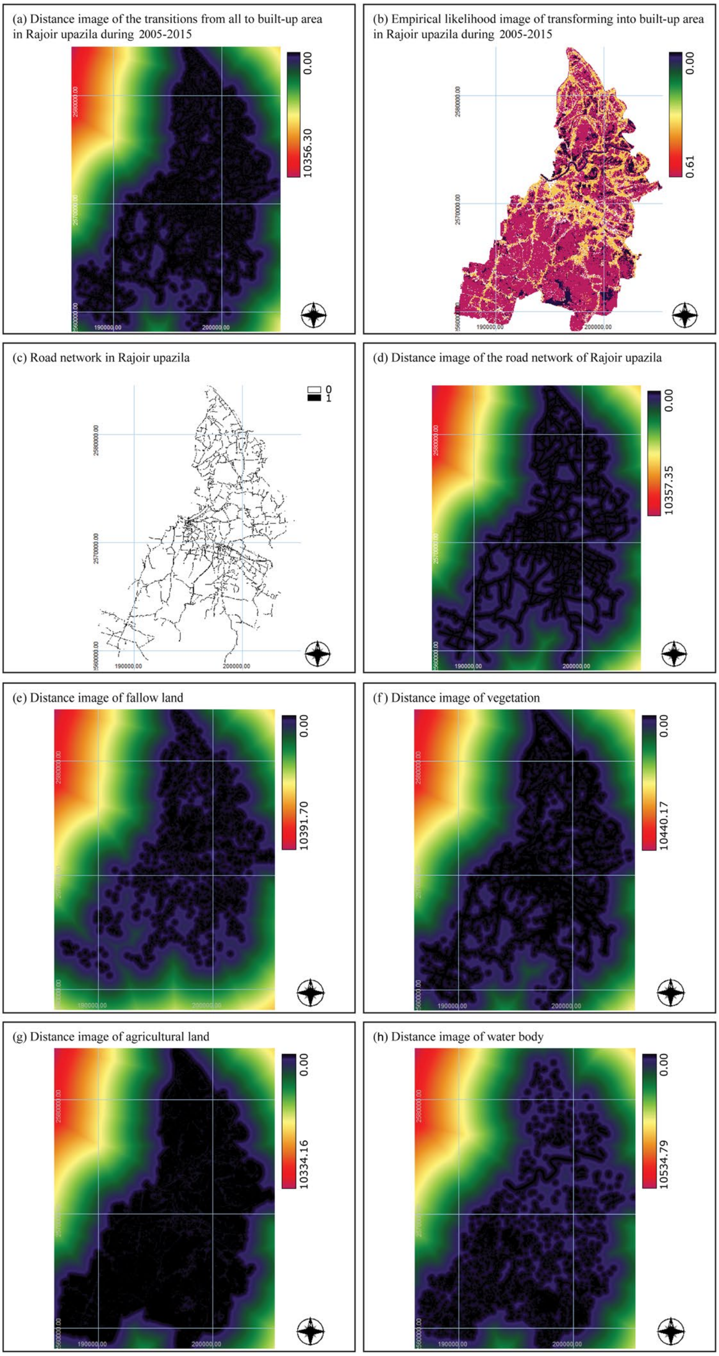


Fig. 3 Driver variables for MLP_Markov simulation of Rajoir

training and testing pixels per category. Final output from the neural network iterations is a set of transition potential maps. In the final phase, these raster datasets are utilized for generating final prediction maps of the study areas.

Resultant Maps of MLP_Markov Simulation

At the final stage of the MLP_Markov model, the transition potential maps are inserted into the change prediction modelling. Change allocation is simulated under two separate circumstances: unconstrained change prediction and guided change prediction. The unconstrained change prediction does not impose any restriction on the land cover parcels for them to change or persist during the model's iterations.

In contrast, the guided change prediction follows the development plan and restrict any changes to occur in the protected areas i.e., the Urban Promotion Control Area (UPCA). The end date for the iterations of the simulation has been specified as 2035. This prediction modelling calculates the future changes based on a Markov Chain probability grid. Therefore, the final simulated maps of 2035 are generated based on the transition potential maps, previous land cover data and Markov Chain probability matrix. The unconstrained model simulation and guided model simulation results are shown in Figs. 4 and 5 respectively.

Assessment of the Development Plans

Assessment procedure performed in this study is a comparative analysis between the development plans and the model simulated maps. This strategy can be further explained under four separate sections:i) Quantitative comparison, ii) Spatial comparison, iii) determination of degree of conformity, andiv) effects on the protected areas.

Generalization of the LULC Categories

It is important to generalize the categories of the land cover maps by converting them into common sets of categories before assessment. For the purpose of the comparative analysis, the development plans and the model simulated maps are reclassified into three land cover categories: i) Built-up area, ii) Agricultural land and iii) Water body. Reclassification of the maps is conducted in reference to the definition of the land covers mentioned in the development plan document (UDD, 2015). After reclassification, the simulated land cover maps and the development plans have three land cover categories and are thus prepared for comparative analysis. The generalized development plans of the study areas are illustrated in Fig. 6. Also, the generalized-unconstrained predicted land cover maps and generalized-guided land cover maps of the study areas are shown in Figs. 7 and 8 respectively.

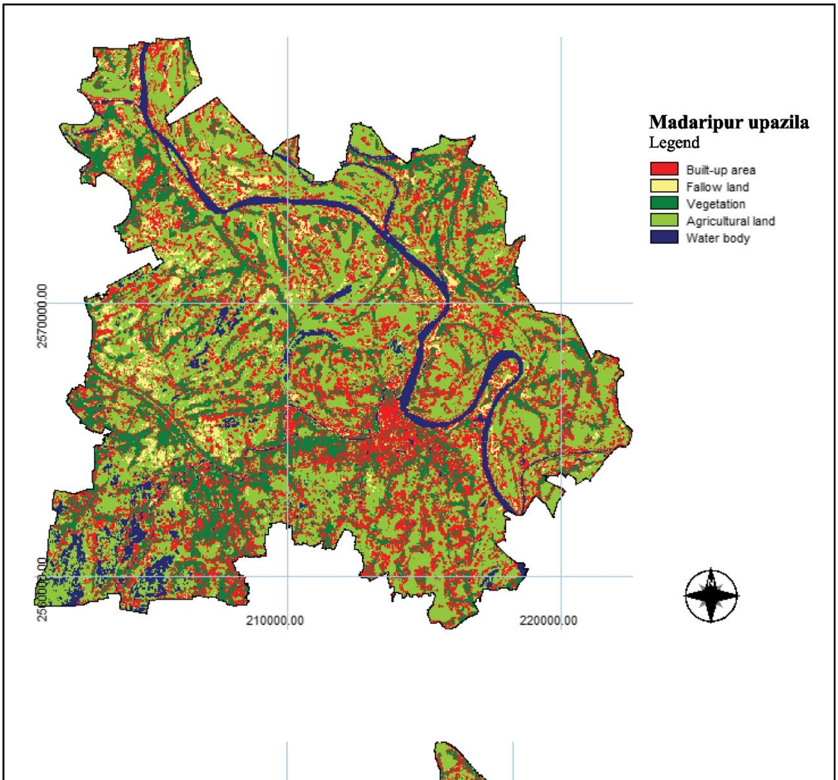


Fig. 4 Final unconstrained MLP_Markov simulated maps of 2035

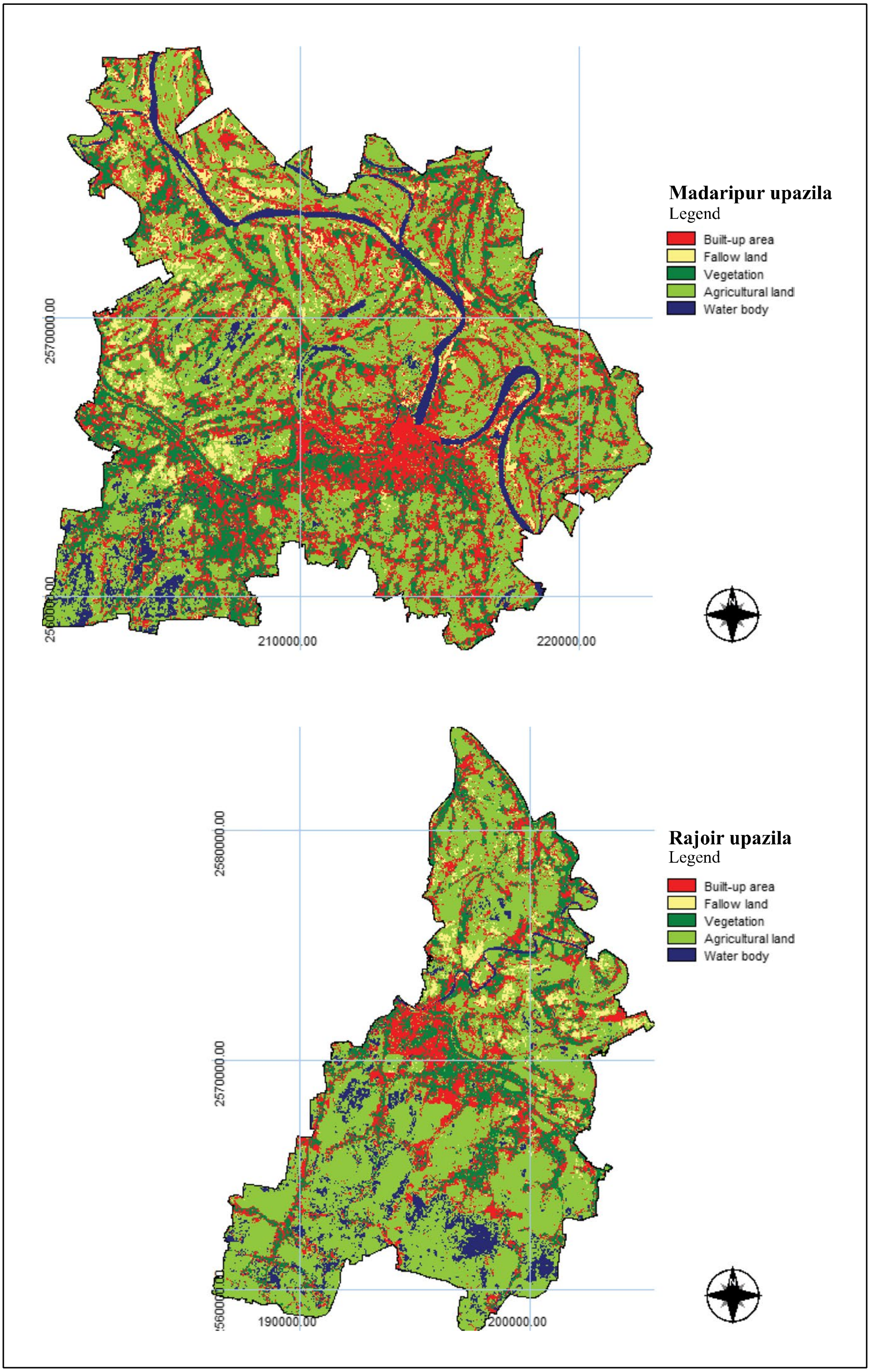


Fig. 5 Final guided MLP_Markov simulated maps of 2035

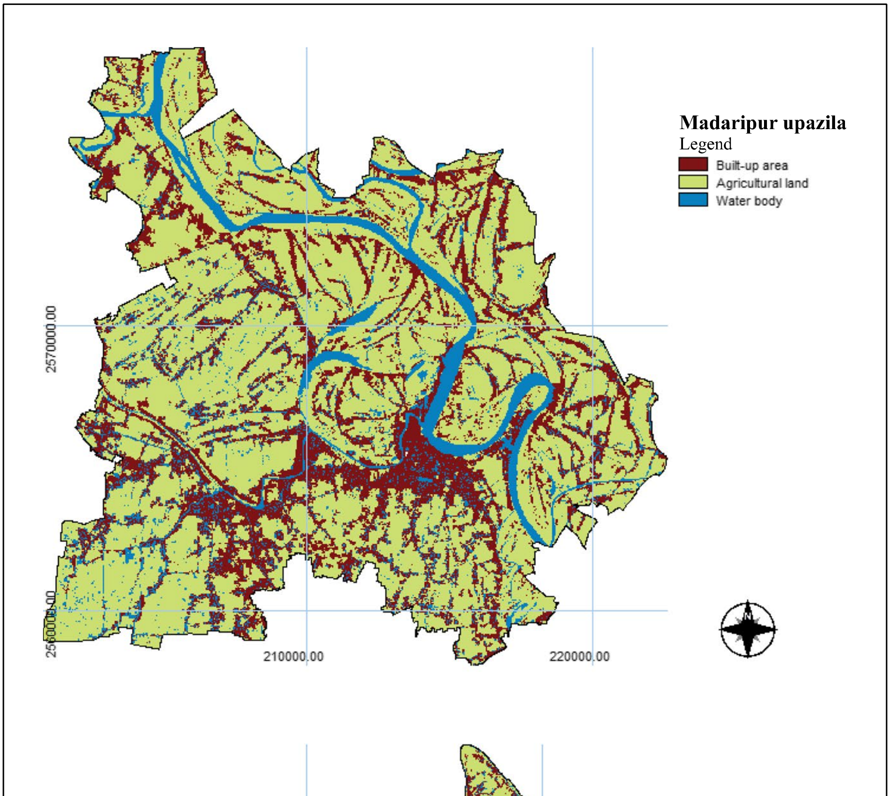


Fig. 6 Generalized development plans (2015–2035)

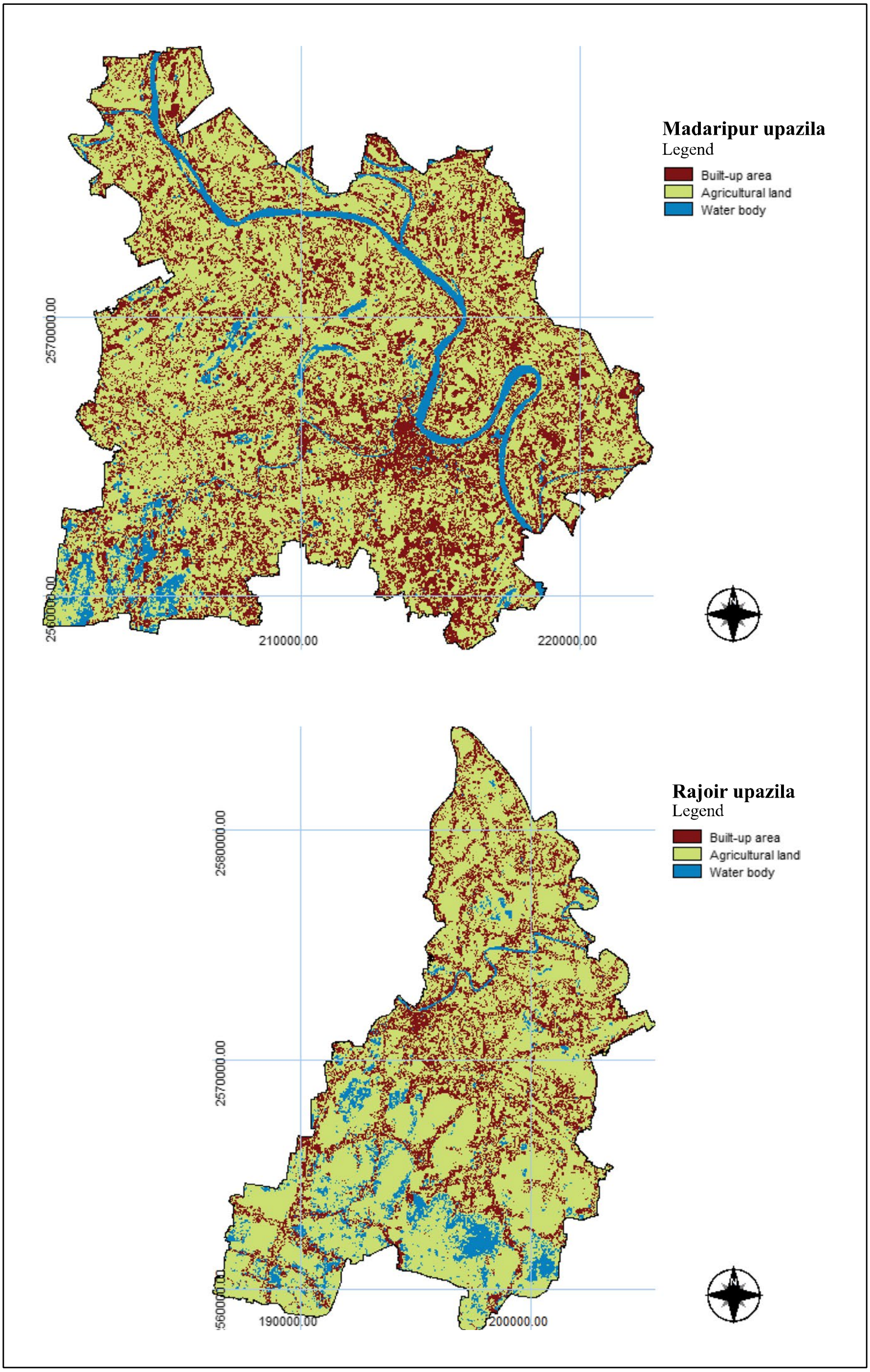


Fig. 7 Generalized-unconstrained model simulated land cover maps (2035)

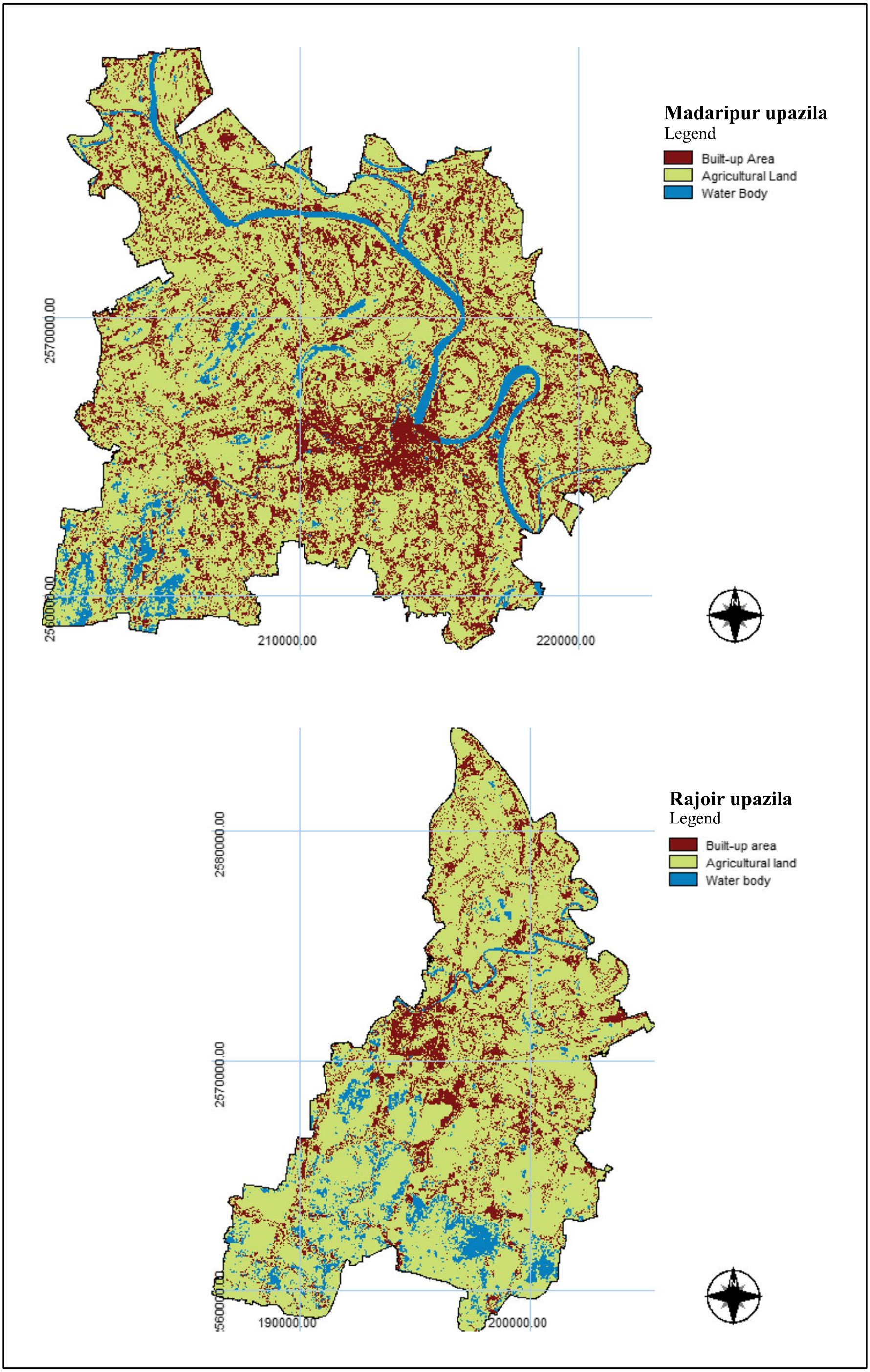


Fig. 8 Generalized-guided model simulated land cover maps (2035)

Table 2 Quantitative comparison between the development plan and relevant maps of Madaripur

Land cover class	In Development Plan (km^2)	In Unconstrained Predicted Map (km^2)	Difference (in reference to development plan)	In Guided Predicted Map (km^2)	Difference (in reference to development plan)
Built-up area	68.35	89.77	(+) 31.33%	74.36	(+) 08.79%
Agricultural area	181.77	176.46	(-) 02.92%	179.62	(-) 01.18%
Water body	35.50	19.40	(-) 45.35%	31.66	(-) 10.82%

Table 3 Quantitative comparison between the development plan and relevant maps of Rajoir

Land cover class	In Development Plan (km^2)	In Unconstrained Predicted Map (km^2)	Difference (in reference to development plan)	In Guided Predicted Map (km^2)	Difference (in reference to development plan)
Built-up area	35.73	52.81	(+) 47.80%	39.59	(+) 10.80%
Agricultural area	171.52	159.47	(-) 06.08%	170.25	(-) 0.74%
Water body	22.50	17.72	(-) 21.42%	19.95	(-) 11.33%

Assessment of Madaripur and Rajoir Development Plan

Quantitative Comparison

Differences between the development plan and both model simulated maps of Madaripur upazila are calculated by quantitative comparison. Table 2 shows that, the unconstrained growth of built-up area will cover 89.77 km^2 of land in 2035, which is 31.33% greater than the amount of land provided in the development plan. While the predicted map has allocated 176.46 km^2 for agricultural lands and 19.40 km^2 for water bodies, the development plan of Madaripur upazila has allocated 181.77 km^2 and 35.50 km^2 of land for the respective land covers. According to the model prediction, this land cover change trend will result in a decline of agricultural land and water body, estimated as 2.92% and 45.35% less than the allotted area in the development plan respectively. However, between the guided predicted map and the development plan, the difference is much narrow. The built-up area will likely grow only 8.79% more than the development plan, which is much less than the difference value for the unconstrained growth. This observation is also applicable to agricultural land and water body.

For Rajoir upazila, noteworthy differences can be seen between the development plan and the predicted map. According to the unconstrained model prediction, the built-up area of Rajoir upazila will grow up to 52.81 km^2, which is approximately 47.80% more than the allotted lands in the development plan. This surplus amount of land will eventually contribute to the decline of agricultural land and water body, as predicted by the MLP_Markov model. Predicted maps have allocated 159.47 km^2 and 17.72 km^2, whereas the development plan of Rajoir upazila has allocated 171.52 km^2 and 22.50 km^2 for agricultural land and water body respectively (Table 3). On the other hand, the guided model simulation shows that difference between the simulated growth and the development plan can be significantly reduced. Built-up area will grow up to 39.59 km^2 in a controlled scenario, which is only 10.80% more than the planned built-up area.

Spatial Comparison

A spatial comparison between the predicted map and the development plan of Madaripur upazila and Rajoir upazila is a key element of the assessment. Figure 9 illustrates the spatial distribution of agreements and disagreements of the land cover categories of Madaripur. These maps explain the spatial comparison by delineating the study area into three zones: Areas in both maps, Areas only in the model predicted map and Areas only in the development plan. Areas in both maps are the locations of the corresponding land cover category that have been agreed upon by both maps. The spatial comparison maps are created for both unconstrained and guided model prediction.

For the unconstrained growth scenario, it is observable that there are some agreements and disagreements between the predicted map and the development plan. Though, the agreed built-up areas are mostly located in and around the Madaripur municipality, there are mismatches in the distribution of urban fringe area and rural settlements. Also, the pattern of built-up area growth in Madaripur upazila is predicted to be sporadic and spontaneous. In both maps, agricultural lands are found to be consistent throughout the upazila. Nevertheless, model predicts agricultural lands are likely to decrease due to uncontrolled growth of settlements, especially in the outskirts of the settlement area. Although the development plan and the predicted map have substantial agreement over the large water bodies such as the Arial Khan River, the model predicts that small water bodies like canals and ponds will experience shrinkage due to overwhelming growth of the settlements. This prediction differs from the development plans, as in the development plan, such water bodies are planned to retain their present state till the year 2035.

For the guided predicted maps, disagreements with the development plan are much less. Most built-up areas are close to the central area where Madaripur municipality is located. The protected areas of agricultural lands and water bodies are not hampered in the guided simulation; thus, the growth pattern is more regulated and less spontaneous.

Spatial attributes of the assessment procedure of Rajoir upazila can be perceived from the illustrations provided in Fig. 10. Visual impression of the maps reveals that there are some agreements and disagreements between the unconstrained predicted map and the development plan. Inside the municipality boundary, both datasets are in substantial agreement that most of the land areas will be built-ups by 2035. Aside the core urban areas, the development plan and the model prediction differ on the growth of built-up areas in rural areas. While most lands for future settlements are provided in proximity to present urban areas in the development plan, the unconstrained MLP_Markov model indicates that settlement will grow sporadically and spontaneously. Agricultural lands are largely consistent throughout the study regions in both datasets.

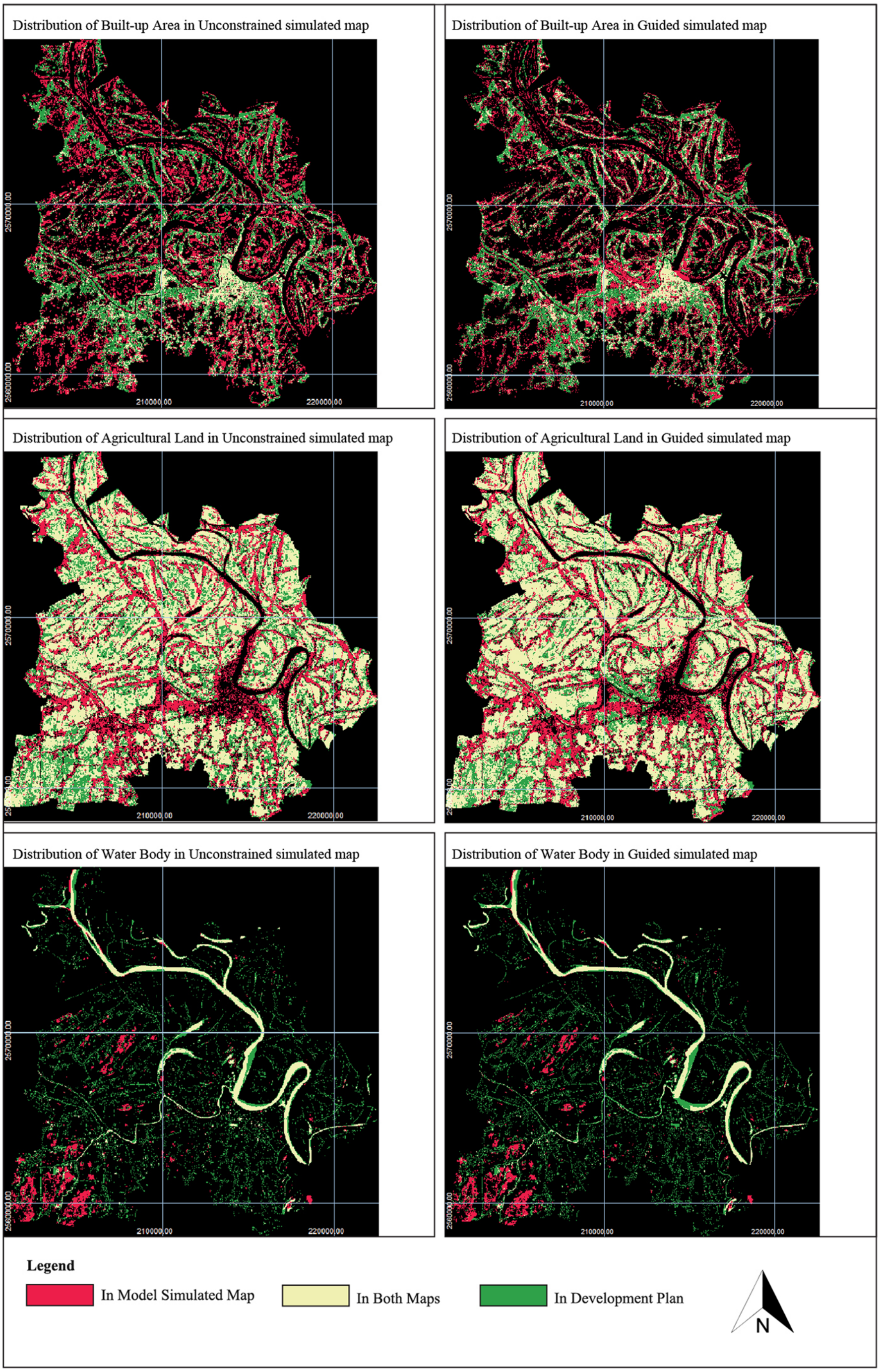


Fig. 9 Spatial comparison between the development plan and simulated maps of Madaripur

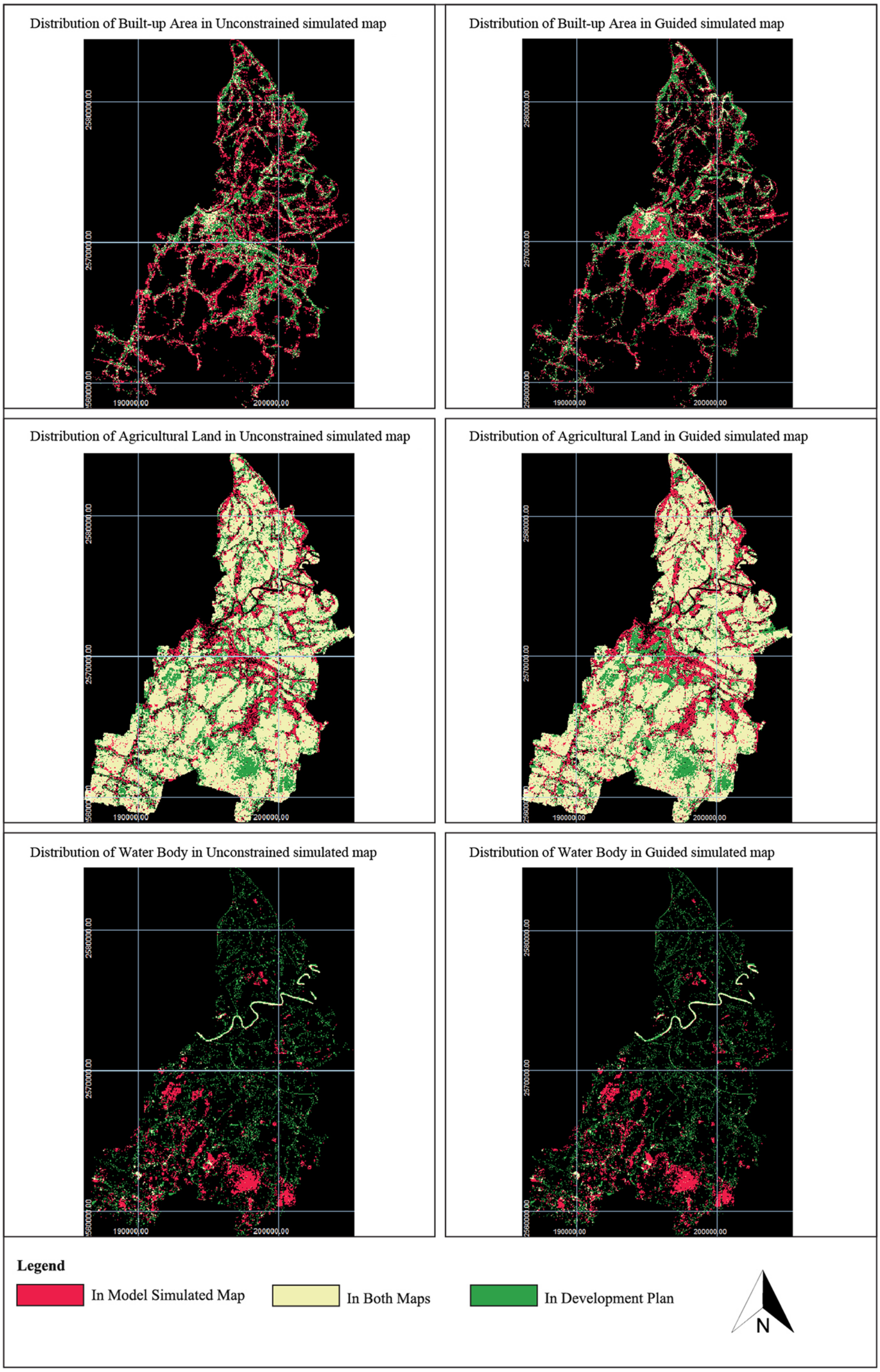


Fig. 10 Spatial comparison between the development plan and simulated maps of Rajoir

In the guided model prediction, built-up area growth is compact and situated in close proximity to the road networks. As observed from the maps, the compactness of the built-up areas will likely ensure protection for undesired loss of agricultural lands and water bodies.

Degree of Conformance

For measuring the degree of conformance between the development plans and model predicted maps, three parameters of conformity have been determined, as shown in Table 4: Accordance, Unfulfillment and Deviation. Definition of these parameters are explained in Appendix 3.

Based on the unconstrained growth simulation, an overall conformance has been calculated for the Madaripur development plan and the model prediction. The results show 37% accordance between the two datasets. Accordance values of built-up area and water body are largely responsible for this low level of overall accordance. On the other hand, guided growth can elevate accordance value up to 59.52%, also resulting 20.88% of unfulfillment and 19.60% of deviation of the development plan.

Table 5 shows the conformity parameters between Rajoir upazila development plan and the model predictions. Here, built-up areas have very low level of accordance and high level of deviation, that correspond to 17.14% and 54.38%. Water bodies have the lowest accordance value of 8.57% and a high deviation of 52.43% as well. Although agricultural lands have relatively higher accordance, the overall accordance is identified as 43.45%. In comparison with the unconstrained model prediction, developments in Rajoir upazila are likely to stay unfulfilled at 21.60% and deviate 34.95% from the development plan. Based on the guided model simulation, the development plan's accordance is likely to be 63.23%. Guided development can also help to reduce unfulfillment and deviation from the development plans, estimated about 20.06% and 16.71% respectively.

Table 4 Degree of conformance for Madaripur upazila development plan

Conformance based on unconstrained model simulation			
Category	Accordance	Unfulfillment	Deviation
Built-up Area	17.51%	28.45%	54.04%
Agricultural Land	48.55%	24.04%	27.41%
Water Body	27.87%	17.71%	54.42%
Overall	37.00%	24.74%	38.26%
Conformance based on guided model simulation			
Category	Accordance	Unfulfillment	Deviation
Built-up Area	42.84%	29.33%	27.83%
Agricultural Land	72.02%	12.98%	15.00%
Water Body	38.25%	40.88%	20.87%
Overall	59.52%	20.88%	19.60%

Table 5 Degree of conformance for Rajoir upazila development plan

Conformance based on unconstrained model simulation			
Category	Accordance	Unfulfillment	Deviation
Built-up Area	17.14%	28.48%	54.38%
Agricultural Land	58.51%	16.21%	25.28%
Water Body	8.57%	39.00%	52.43%
Overall	43.45%	21.60%	34.95%
Conformance based on guided model simulation			
Category	Accordance	Unfulfillment	Deviation
Built-up Area	39.81%	25.66%	34.53%
Agricultural Land	75.96%	13.44%	10.60%
Water Body	30.13%	48.73%	21.14%
Overall	63.23%	20.06%	16.71%

Effects on the Protected Area

As described by UDD (2015), the Urban Promotion Control Area (UPCA) is the protected zone for agricultural lands and water bodies, where future urban development is discouraged. From the results of MLP_Markov prediction, possible encroachment within these protected areas has been identified and shown in Fig. 11.

Approximately 200.85 km^2 of land is demarcated as UPCA in Madaripur upazila development plan (2015–2035). According to the model estimation, about 52.87

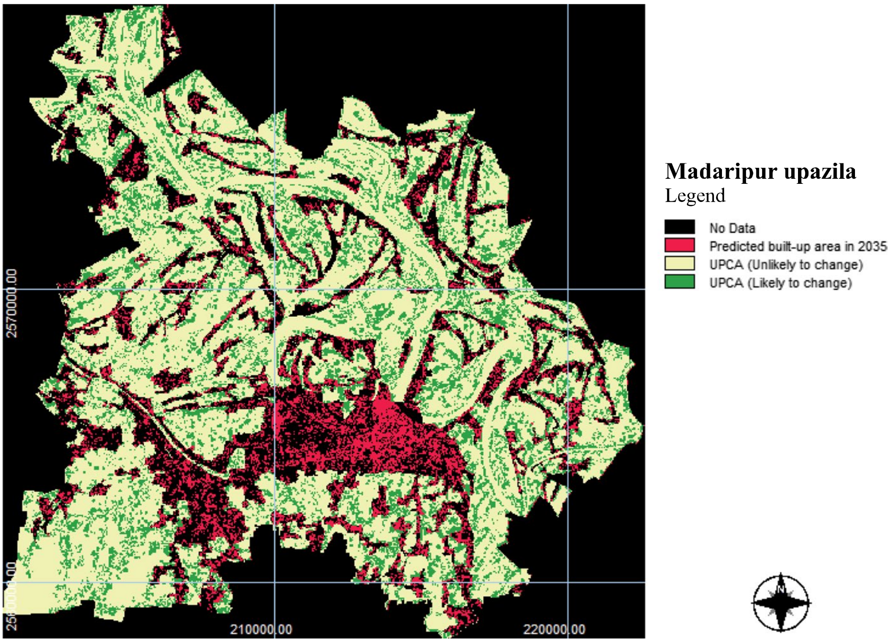


Fig. 11 Predicted scenario of UPCA of Madaripur upazila in 2035

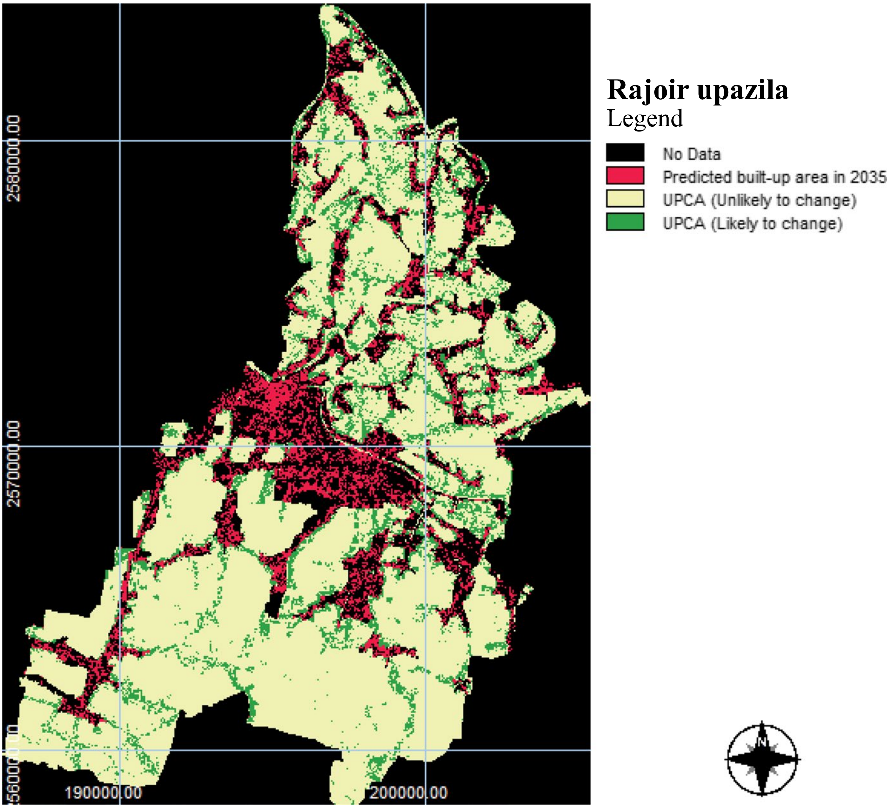


Fig. 12 Predicted scenario of UPCA of Rajoir upazila in 2035

km^2 of UPCA will be transformed into built-up area before year 2035. The effected portion is significantly large, as it shares 26.37% of the total UPCA.

Figure 12 shows the possible affected areas within Urban Promotion Control Area (UPCA) of Rajoir upazila in reference to the model prediction. In the development plan, 171.79 km^2 of land has been designated as UPCA in Rajoir upazila. As per model prediction, approximately 29.19 km^2 of land within the UPCA are likely to convert into built-up area before year 2035. This implies that about 17% of the UPCA are at risk of being converted to built-up area within the effective years of the development plan.

Discussion

The highlights of the assessment results for the development plans of Madaripur upazila and Rajoir upazila are the differences in the land cover classes in comparison with the model predictions. Spatial aspects of the assessment have been an essential discussion in this study. The presented maps show the extent of the uncontrolled urban growth in the study areas and the areas that are likely to be transformed.

Like the spatial and quantitative differences, the conformance assessment has also underlined notable differences. The overall accordance values for the study areas are quite low, while the values of unfulfillment and deviation are significant. For the guided scenarios, the accordance value is much higher, while percentages of deviation and unfulfillment are likely to reduce notably. The assessment results have also demarcated the possible affected areas within the UPCAs, which are largely preserved for agricultural lands and water bodies. These disagreements between the development plans and model-predicted maps are unsurprising, as the model trains its algorithm based on the data received from previous growth trends while the development plans are formulated with the aim of controlling that trend.

The quantification of the differences could become essential to the policy-making process. Quantitative and spatial assessment of development plans enables measuring the discrepancies and specifying the affected land uses with precision. Components of a development plan that require specific data, such as a detailed area plan or action area plan can be supported by such analytical assessment. In addition, the assessment results can be interpreted into various formats by applying geospatial techniques such as data visualization and cartography. Such interpretations can help the planning process reaching out to larger audiences, from the central government, and local authorities to the communities. With the ease of communication between the stakeholders, participation at various stages of the planning process may be increased. The representation of geospatial analysis has the ability to bridge the gap between planning and implementation of a development plan.

The approach presented in this study may also add to the responsibilities of the planning professionals. Parallel to the conventional planning process, Spatio-temporal modeling can be perceived as an understanding of urban and regional growth dynamics from a different perspective. This can enhance the planners' knowledge and perception of the context. The disagreements reported in the assessment can make the planners revisit their policy, either to modify the proposed plan or to impose a stricter policy if required, to achieve planning objectives. The implication of an urban growth trend may also have some underlying explanation, such as economic, geographical, or environmental advantages, that can be further studied and researched. Planners can intervene at the locations that are of low and high discrepancies between what was expected in the plans and what is predicted by the models.

Similarly, the possible affected areas of the UPCAs are also subject to intervention by the planners. As the presented assessment process depends on the historical growth trend of a particular area or region, it may encourage planners to formulate more context-specific plans, rather than following a prescribed way of planning. The assessment procedure can be applied during the formulation stage, at the end of the effective period, as an interim assessment, or maybe as a monitoring procedure of the development plans.

Conclusion

In this research, assessment of the development plans of Madaripur upazila and Rajoir upazila has been carried out from quantitative, spatial, and temporal perspectives of the regions. The assessment proceedings are executed based on historic growth trends of the study areas, assuming these trends to continue during the target period. Guided model simulation has also been performed for both study areas to understand the future land cove scenario after the implementation of the development plans. This research designates the MLP_Markov model's results as near representation of the growth trend of the study areas by applying model validation techniques. Though the present development plans of Madaripur upazila and Rajoir upazila are aimed at controlling rapid and haphazard land cover changes, the MLP_Markov model prediction has identified notable mismatch between the development plans and the current growth trend. However, the change is much less in a guided MLP_Markov simulation.

Application of GIS and RS in development plan assessment is an opportunity that has not been used frequently by the policy makers. Not only does this provide easy access to authentic databases of satellite imagery, but it also opens provision for easy interpretations of the analysis for the stakeholders. MLP_Markov model has performed quite well for this study and the results can be accepted for understanding the change dynamics. However, higher resolution satellite images can significantly improve the accuracy of the classification process and thus produce better prediction results. Although modelling of complex urban systems is a growing interest in academia, its practical application is yet to reach general acceptance. Technical advancement of land use land cover modelling is continuously going forward and is constantly changing. Our renewed understanding of the land covers is paving way for new theories and approaches. Future research are expected to incorporate these changes and will be able to model more complex scenarios.

Importance of assessing the development plans is discussed in many studies and regarded as a coherent part of the planning process. The method followed in this research can be considered as a useful empirical way to assess the development plans. This study also implies that historic growth patterns of such areas should be a consideration for preparatory phases of development plans. In Bangladesh context, this method has resulted in considerably acceptable for the small urban areas and can be viewed as a development plan assessment tool for other cities also. In addition, the presented technique can be collaborated with the traditional planning process as a decision support tool, at both the preparation phase and the working phase. During preparation of any development plan, these models can be used for prediction purpose, which will save valuable resources and strengthen the logic behind the undertaken decisions. At working phase, these models can be used for assessment and monitoring of the development plan, and timely intervention where necessary to follow proposals of development plan, particularly for protected areas. To enhance this method's performance, driver variables from other related disciplines should also be included in the assessment method. Such multidisciplinary approaches towards development plan assessment can become an indispensable tool for planning for a better living environment.

Appendix 1

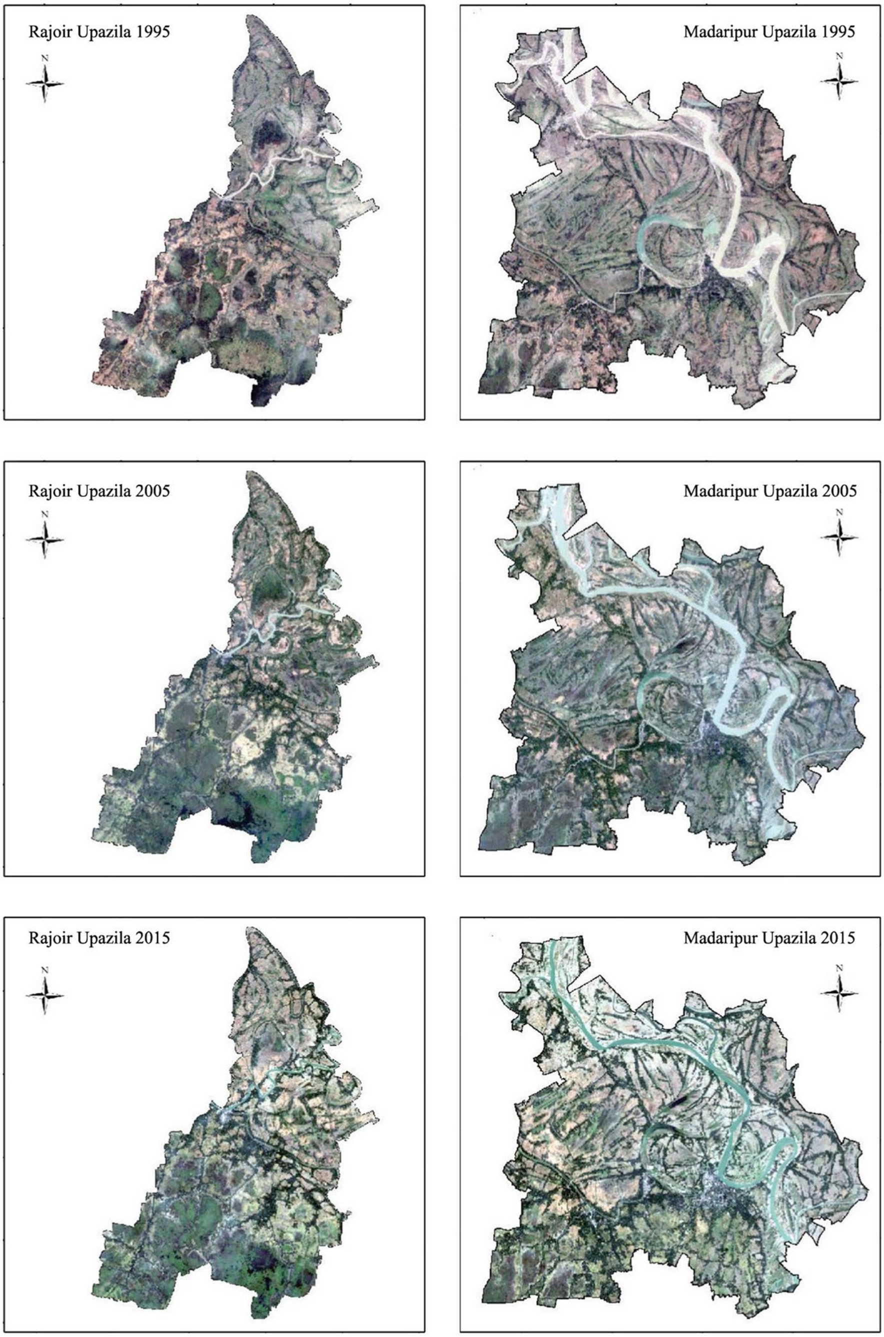


Fig. 13 Multispectral satellite images of Madaripur upazila and Rajoir upazila

Table 6 Details of land cover types

Serial no	Land cover	Description
1	Built-up area	Human settlements and physical infrastructures
2	Fallow land	Fallow land, uncultivated Chars (mud accretion in a river course), earth and sand in fillings, open space, bare and exposed soil, construction sites
3	Vegetation	Household trees, shrub lands, semi natural vegetation, gardens
4	Agricultural land	Crop field, marshy land, swamp, low lying areas
5	Water body	Rivers, natural and artificial lakes, permanent waters, ponds, canals

Table 7 Classification accuracy measures (Madaripur upazila)

Year	Class name	Reference totals	Classified totals	Number correct	Producer's accuracy	User's accuracy
Classified data of 1995	Built-up area	33	32	26	78.78%	81.25%
	Fallow land	11	11	9	81.81%	81.81%
	Vegetation	50	53	43	88.00%	83.01%
	Agricultural land	139	136	124	89.21%	91.17%
	Water body	20	21	19	90.00%	85.71%
	Totals	253	253	221		
	Overall accuracy of the classified data = 87.35%					
	Kappa coefficient = 0.8018					
Classified data of 2005	Built-up area	30	29	26	86.66%	89.65%
	Fallow land	20	21	17	85.00%	80.95%
	Vegetation	58	57	50	86.20%	87.77%
	Agricultural land	120	122	109	90.83%	89.34%
	Water body	28	27	20	71.43%	74.07%
	Totals	256	256	222		
	Overall accuracy of the classified data = 86.72%					
	Kappa coefficient = 0.8088					
Classified data of 2015	Built-up area	36	38	30	83.33%	78.95%
	Fallow land	23	24	21	91.30%	87.50%
	Vegetation	44	47	38	86.36%	80.85%
	Agricultural land	129	122	110	85.27%	90.16%
	Water body	19	20	13	84.21%	80.00%
	Totals	251	251	215		
	Overall accuracy of the classified data = 85.66%					
	Kappa coefficient = 0.7893					

Table 8 Classification accuracy measures (Rajoir upazila)

Year	Class name	Reference totals	Classified totals	Number correct	Producer's accuracy	User's accuracy
Classified data of 1995	Built-up area	23	22	18	78.26%	81.82%
	Fallow land	10	10	9	90.00%	90.00%
	Vegetation	46	49	40	86.96%	81.63%
	Agricultural land	158	157	145	91.77%	92.24%
	Water body	22	21	18	81.82%	85.71%
	Totals	259	259	230		
	Overall accuracy of the classified data = 88.80%					
	Kappa coefficient = 0.8072					
Classified data of 2005	Built-up area	30	29	26	86.66%	89.65%
	Fallow land	20	21	17	85.00%	80.95%
	Vegetation	58	57	50	86.21%	87.72%
	Agricultural land	114	116	103	90.35%	88.79%
	Water body	28	27	20	71.43%	74.07%
	Totals	250	250	216		
	Overall accuracy of the classified data = 86.40%					
	Kappa coefficient = 0.8065					
Classified data of 2015	Built-up area	23	25	20	86.96%	80.00%
	Fallow land	12	12	10	83.33%	83.33%
	Vegetation	42	44	40	95.24%	90.91%
	Agricultural land	152	149	142	93.42%	95.30%
	Water body	21	20	17	80.95%	85.00%
	Totals	250	250	228		
	Overall accuracy of the classified data = 91.60%					
	Kappa coefficient = 0.8576					

Appendix 2

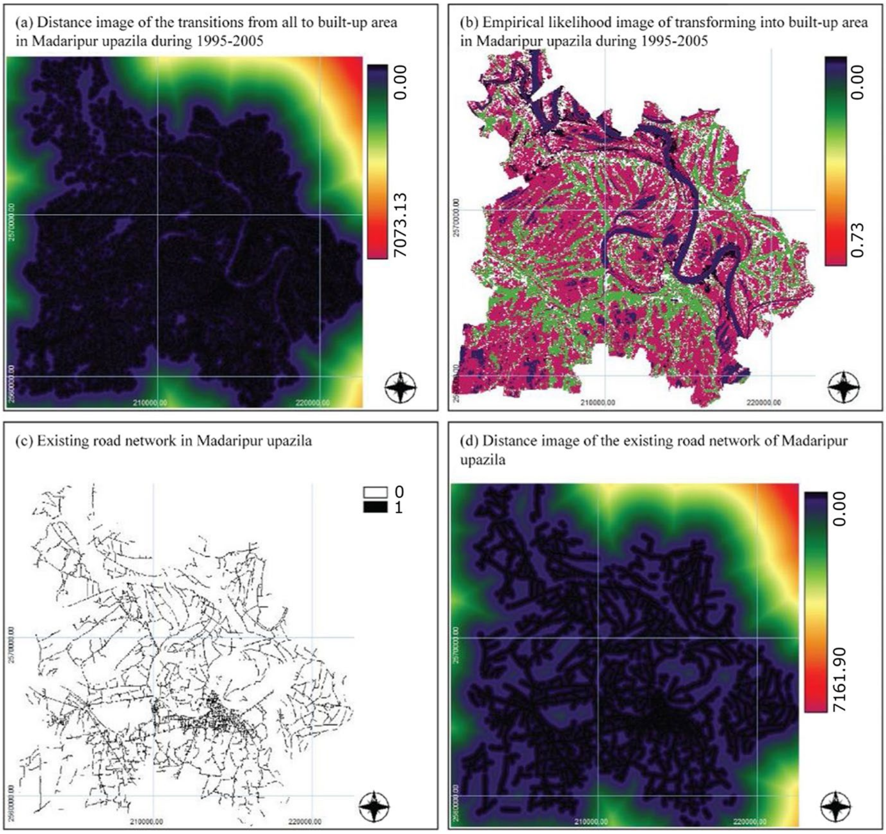


Fig. 14 Driver variables of MLP_Markov model validation for Madaripur

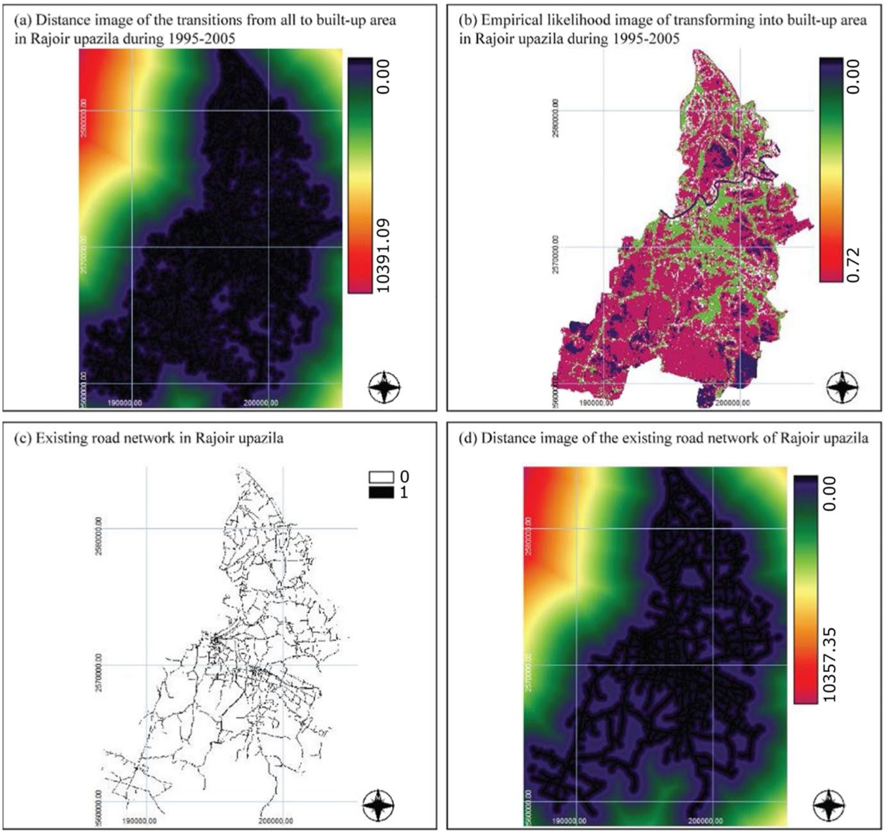
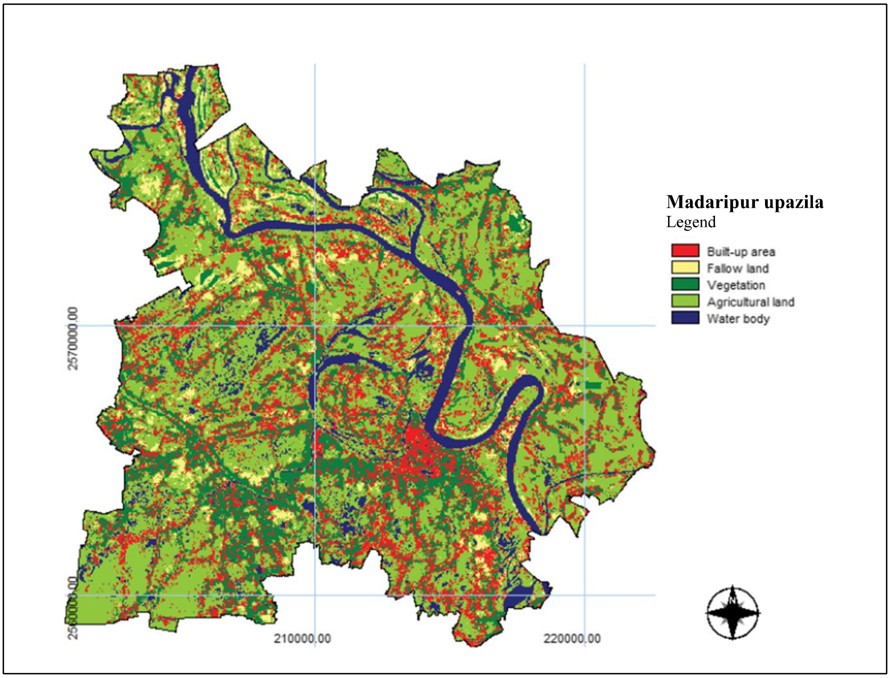


Fig. 15 Driver variables of MLP_Markov model validation for Rajoir



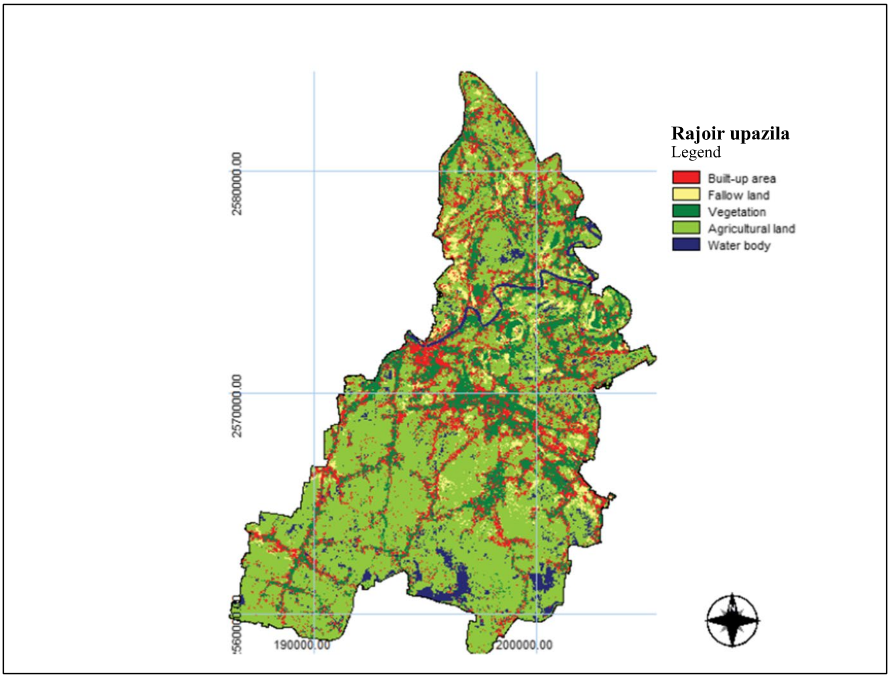


Fig. 16 Final maps for MLP_Markov model validation

Table 9 Contingency Tables for Model Validation Through Kappa Index of Agreement

MLP_Markov simulation vs Actual land cover data matrix for Madaripur						
Sim\Actual	Class_1	Class_2	Class_3	Class_4	Class_5	Cumulative value
Class_1	51,747	1029	1179	8223	345	**62,523**
Class_2	864	12,160	159	1251	508	**14,942**
Class_3	3234	828	57,972	9013	361	**71,408**
Class_4	2707	1524	4778	125,203	277	**134,489**
Class_5	1331	960	618	10,714	20,398	**34,021**
Cumulative value	**59,883**	**16,501**	**64,706**	**154,404**	**21,889**	**317,383**
MLP_Markov simulation vs Actual land cover data matrix for Rajoir						
Sim\Actual	Class_1	Class_2	Class_3	Class_4	Class_5	Cumulative value
Class_1	24,104	941	2444	5558	344	**33,391**
Class_2	482	5337	190	1687	62	**7758**
Class_3	920	62	33,753	7086	278	**42,099**
Class_4	5660	1417	5796	136,186	5366	**154,425**
Class_5	196	454	57	2758	14,181	**17,646**
Cumulative value	**31,362**	**8211**	**42,240**	**153,275**	**20,231**	**255,319**

Appendix 3

Components of deriving degree of conformance are presented here (Tian & Shen, 2011).

Map A: Actual land use of start year
Map B: Actual land use of end year
Map C: Planned land use for the end year

Type of Accordance:

- If the use of a piece of land in Map A, Map B and Map C in consistent
- If the use of a piece of land in Map B and Map C is consistent, but different from the use in Map A

Type of Unfulfillment:

- If the use of a piece of land in Map A and Map B is consistent, but different from the use in Map C

Type of Deviation:

- If the use of a piece of land in Map A, Map B and Map C is different
- If the use of a piece of land in Map A and Map C is consistent, but different from the use in Map B

Declarations

Ethical Approval The study titled "*Assessment of Development Plans for Small Urban Areas of Bangladesh: Remote Sensing and GIS-based Approach*", was carried out under the Master of Urban and Regional Planning (MURP) program of Bangladesh University of Engineering and Technology (BUET). Financial support for the research was received from BUET upon approval from the Committee for Advanced Studies and Research (CASR), BUET.

The authors declare that the manuscript has been prepared for journal publication with prior consent from the Department of Urban and Regional Planning, BUET. The authors also declare that they have no conflicts of interest. This article does not contain any studies involving animals or human participation, performed by any of the authors.

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