AMERICAN JOURNAL OF GEOSPATIAL TECHNOLOGY (AJGT)

ISSN: 2833-8006 (ONLINE)

VOLUME 1 ISSUE 2 (2022)

PUBLISHED BY: E-PALLI, DELAWARE, USA

American Journal of Geospatial Technology (AJGT)

Volume 1 Issue 2, Year 2022
ISSN: 2833-8006 (Online)
DOI: https://doi.org/10.54536/ajgt.v1i2.907
https://journals.e-palli.com/home/index.php/ajgt

Monitoring of LULC Changes and Forest Loss Using Geospatial Technique: A Case Study from Northern Region of Bangladesh

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Article Information

Received: November 9, 2022

Accepted: November 14, 2022

Published: November 16, 2022

Keywords

Land Transformation, LULC, Forest, Remote Sensing

ABSTRACT

Monitoring changes in land use and land cover (LULC) is essential for determining the state of the environment. This study is an attempt to assessing changes in LULC patterns and forest cover at northern region (Dinajpur district) of Bangladesh for the periods 1989–1999, 1999–2010, 2010–2020 and 1989-2020. Landsat satellite images were applied and supervised classification was done. There is a noticeable change found in LULC classes (Built-up, crop/fallow, forest, homestead and water). The built-up and homestead increased by 210.36% and 134.71%; whereas the crop/fallow, forest, and water decreased by 12.27%, 74.99% and 39.77%, respectively between 1989 to 2020. Forest was narrowed as majority of forest land transferred to homestead (8089.02ha) and crop/fallow (5965.74ha) land in last three decades (1989-2020). The findings of the study help in important policy implications for the sustainable LULC management in Dinajpur region of Bangladesh.

INTRODUCTION

Changes in land use and land cover are regarded as some of the most significant environmental problems facing the world today (Guan *et al.*, 2011). Such changes are typically caused by human activity (for example, deforestation, urbanization, agricultural intensification, overgrazing, and subsequent land degradation), although natural forces can also play a role (Lambin, 1997). These anthropogenic changes may have a negative impact on the food security, with major social economic impacts for the region (Turner *et al.*, 2007). Besides it also affects from local to global environment (Minale, 2013; Meshesha *et al.*, 2016) with consequences for ecosystem functioning and ecosystem services (Meyer and Turner 1994). Although the resulting changes in land cover are crucial for development (Dhinwa *et al.*, 1992), planning and administration are thus required prior to any earth surface development (Nations, 1992).

LULC alterations may have had substantial influences on forest landscapes as well (Chen *et al.*, 2001). Deforestation, reforestation, afforestation, abandoning agricultural areas, urban sprawl, and conversion of wooded lands into cropland and grazing are all examples of LULC changes (Kilic *et al.*, 2004). For ecological, social, and economic reasons, forest ecosystems are crucial like regulation of greenhouse gas emissions, control of water resources, preservation of soil, cycling of nutrients, and diversity of species and genetics (Rao and Pant 2001).

Biodiversity loss is mostly caused by changes in forest cover (Armsworth *et al.*, 2004; Kilic *et al.*, 2004). In the course of time, the use of GIS and remote sensing technology has increased the significance of LULC change evaluation (Reid *et al.*, 2000). It facilitates in obtaining precise and timely data on land use patterns (Arveti *et al.*, 2016) and landscape transformations throughout the surface of the Earth (Estoque & Murayama, 2015). Remote sensing is the process of gathering information about certain ground-based objects without physically approaching them (Rajendran *et al.*, 2020). GIS is a concept that divides the spatial area and assembles layers of data into representations using guides and 3D scenes (Niu *et al.*, 2020). Satellite images like Landsat images namely MSS, TM and ETM+ are used for LULC change detection in everywhere in the world (Akbari *et al.*, 2006; Hereher, 2011; Baby, 2015; Chandrashekar *et al.*, 2018). When compared to point data gathered by in-situ survey devices, Landsat images with adequate spectral characteristics offer superior information on LULC changes (USGS, 2004; Kawakubo *et al.*, 2011).

The assessment of land use and cover change has drawn the scientific and research community's attention as the world's population increases (Qian *et al.*, 2007). Otherwise, it is crucial to evaluate how land use and cover have changed in order to understand the relationship between humans and nature. Monitoring the changes in land use and land cover (LULC) from the past to the present has become easier because to the collaboration of remote sensing technologies and GIS tools (Chughtai *et al.*, 2021). The supply of resources including land, forests, and water is drastically decreasing in developing nations. However, data on the pace of decline is frequently insufficient (FAO, 2009).

Moreover, there seems to be a gap between the knowledge that is provided and the national decision-making process and logical planning. So, the current research objective was to monitor how the land use land cover have been changed over time using remote sensing and GIS technology. Concurrent with this aim is to identify and

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quantify the major LULC classes, to detect changes using land conversion matrix.

METHODOLOGY

Study Area

Dinajpur district encompasses between 25°10' and 26°04' north latitudes and 88°23' and 89°18' east longitudes which covers 3437.98 square kilometer area of 13 upazilas. Irregular elevated Barind tract is found here and major rivers are the Dhepa, the Punarbhava, and the Atrai (Rana *et al.*, 2022). There are two distinct seasons in the Northwestern region's: a wet season from June to October and a dry season from November to March. The annual average rainfall is between 1500 and 3000 mm, with a regional average of roughly 1583 mm (Murad & Islam, 2011). Due to its subtropical location, Bangladesh's northwestern area experiences more extreme temperature changes. Maximum temperatures can reach as low as 25°C in January and as high as 38°C in April/May. August's lowest temperature is 20°C, while January's minimum ranges from 10 to 20°C (Islam & Miah, 1981). Due to the intense monsoon weather and diverse soil types, there is a wide range of vegetation, from grassland to deciduous, mixed, and evergreen. The dominant crop in this area is rice (Reiman, 1993). Figure 1 represents the study area map of Dinajpur district of Bangladesh.

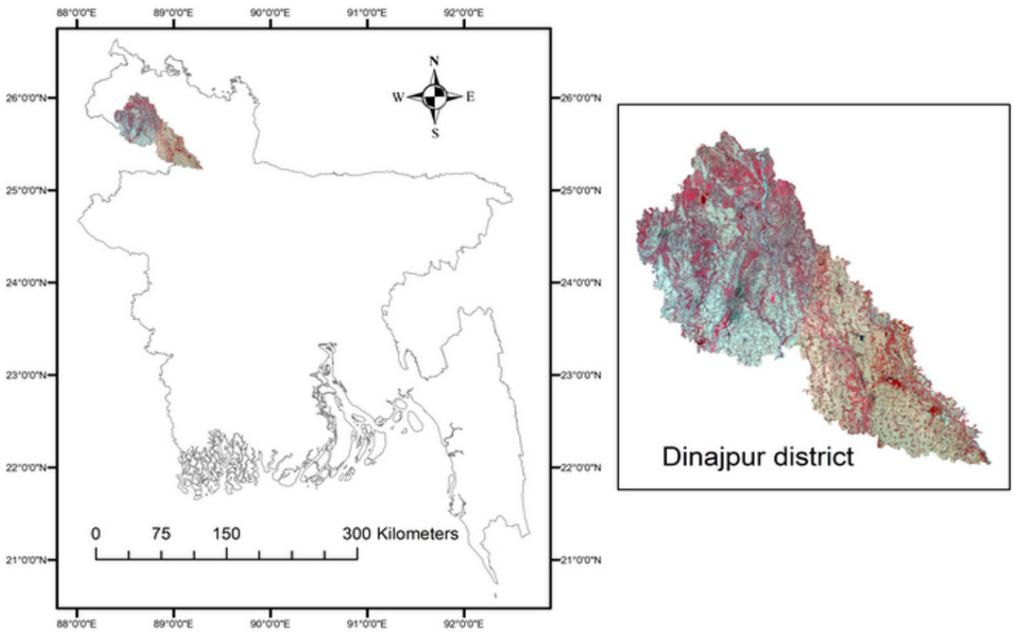

Figure 1: Study area map of Maulvibazar district of Bangladesh.

Collection, processing and classification of satellite images

By ordering ESPA (EROS Science Processing Architecture), a total of eight Landsat satellite imageries (1989, 1999, 2010, and 2020) according to specific paths and rows were obtained from Earth Explorer (earthexplorer.usgs.gov) for the evaluation of land use and land cover change of Dinajpur over a 31-year period. As the image of Dinajpur district fall under different path and row the two images of same year were mosaic through using Q GIS. Table 1 summarizes the Landsat data employed in the study. The images were prepared through Arc GIS and Q GIS. Then cross tabulation matrix of images between different year (1989-1999, 1999-2010, 2010-2020 and 1989-2020) was done. Remote sensing data classification is a difficult process

Table 1: Characteristics of Satellite Images

Sensor	Path/Row	Image acquisition date	Resolution
Landsat 4-5 TM	138/42	13-Dec-89	30m
Landsat 4-5 TM	139/42	04-Dec-89	30m
Landsat 4-5 TM	138/42	23-Nov-99	30m
Landsat 4-5 TM	139/42	23-Dec-99	30m
Landsat 4-5 TM	138/42	14-Dec-10	30m
Landsat 4-5 TM	139/42	16-Dec-10	30m
Landsat 8 OLI	138/42	02-Dec-20	30m
Landsat 8 OLI	139/42	25-Dec-20	30m

for monitoring LULC change with proper classification, suitable quantity of training sample, accuracy assessment by recognizing differences in the state of a pixel or phenomenon (Lu & Weng, 2007; Viana *et al.*, 2019).

For the time series analysis of long-term classification, atmospherically corrected surface reflectance (SR) imageries are essential. In Q GIS multiband/layer stacking was done. All of the multiband images were visualized using false color composite. In case of Landsat 4-7 TM imagery, RGB 4, 3, 2 and for Landsat 8 OLI imagery RGB 5, 4, 3 composites were used, respectively, to create false color. Dinajpur district has been chosen as an Area of Interest (AOI) and a shape file was generated in Arc GIS, clipped in Q GIS. Accurate training inputs from composite images using Q GIS software were also generated. Cross-matching was done with spectral images through high-resolution Google Earth maps. Finally, the image classification was done through R statistics package. The classes of LULC were divided into five groups described in Table 2.

Table 2: Land use land cover classification scheme

Land use/cover types	Description
Built-up	Industrial, residential, transportation, commercial
Crop/Fallow	Crop land, fallow lands, grass land
Homestead	The home surrounded by tree, pond/crop
Forest	Mainly sal forest
Water	River, streams, lakes, pond, River

The LULC classification and mapping process includes the post classification accuracy assessment, which is used to evaluate the accuracy of the classified maps (Manandhar, *et al*., 2009). The accuracy of a classified map should not be less than 80% for accurate interpretability and classification (Anderson *et al*., 1976). In Dinajpur, for the years 1989, 1999, 2010 and 2020, the overall classification accuracy was 91%, 92%, 90% and 87%, and overall kappa statistics were 0.96, 0.94, 0.91 and 0.89, respectively. Table 3 represents the value and accuracy of kappa statistic. The accuracy of classification was acceptable.

Table 3: Value and accuracy of kappa statistic

Kappa statistic	Accuracy
<0	Less than Chance Agreement
0.01-0.20	Slight Agreement
0.21-0.40	Fair Agreement
0.41-0.60	Moderate Agreement
0.61-0.80	Substantial Agreement
0.81-0.99	Almost Perfect Agreement

Source: Viera and Garrett (2005)

RESULTS

Land use land cover (LULC) map in Dinajpur

The LULC map was created to properly identify and adjust different classes in the research area. There were five LULC classes in the study area: built-up, crop/fallow, forest, homestead, and water. Figure 2 illustrates the classified LULC map for the study area.

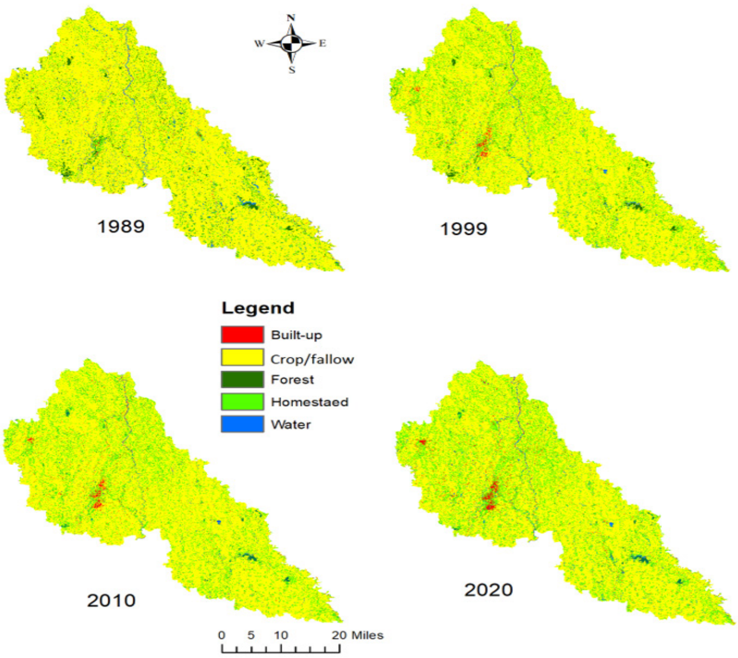

Figure 2: LULC map Dinajpur during 1989, 1999, 2010 and 2020.

Overall LULCC in last three decades

LULCC is a substantial contributor to planetary change and has a profound effect on ecosystem. Based on the supervised classification approach it is evident that forest areas have diminished remarkably over the study area during the study period. In terms of percentages, forest areas stand for 16125.66 ha (4.66%), 10119.33 ha (2.92%), 4255.92 ha (1.23%), and 4032.54 ha (1.16%) of the study area, respectively, during the years 1989, 1999, 2010, and 2020 and it was a decreasing trend. The crop/fallow areas were found to be 286025.4 ha (82.71%), 267968.61 ha (77.49%), 2529286.31 ha (74.98%), and 250921 ha (72.56%), respectively, during the years 1989, 1999, 2010, and 2020. The crop/fallow area has also decreased considerably from 1989 to 2020. The water bodies have reduced significantly over the study area from 1989 to 2020 although it was increased from 2010 to 2020. The area covering water bodies are 7487.37 ha, 3684.87 ha, 2780.01 ha, and 4509.54 ha, respectively, for the same time period. Otherwise, built-up area has increased gradually from 1989 to 2020. During the years 1989, 1999, 2010, and 2020, built-up areas were found to

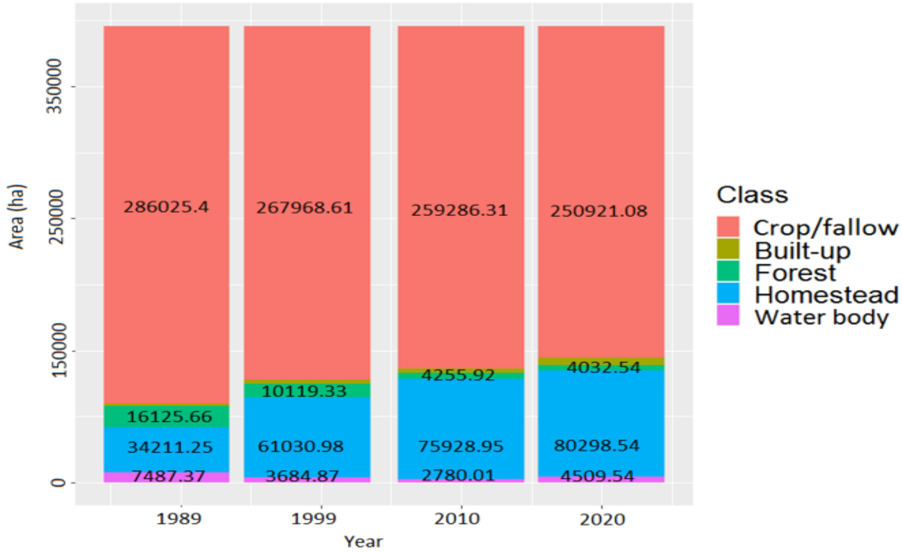

Figure 3: Land use land cover change in Dinajpur from1989 to 2020.

be 1943.28 ha, 2989.17 ha, 3541.77 ha, and 6031.26 ha, respectively (Figure 3).

Assessment of LULC change matrix from 1989 to 1999

The conversion of various land use types is known as land use and land cover change (LULCC), and it is the outcome of intricate interactions between people and the natural world. Among the different land cover classes, the persistent area of built-up, crop/fallow, forest, homestead and water were 143.28 ha, 236520.45 ha, 2340.72 ha, 12671.55 ha and 1906.83 ha, respectively from 1989 to 1999. Forest was shrunk due to maximum forest land was converted to crop/fallow (7655.31 ha) and homestead (5596.56 ha). On the other hand, crop fallow was decreased by converting maximum 41101.83 ha of homestead. Built-up increased as most of the crop/fallow (1916.37 ha) transferred to built-up followed by homestead, water and forest. In case of water, maximum water area converted to crop/fallow (3620.34 ha) (Figure 4). In this decade crop/fallow, forest and water area were decreased by 6.31%, 37.25% and 50.78%, respectively.

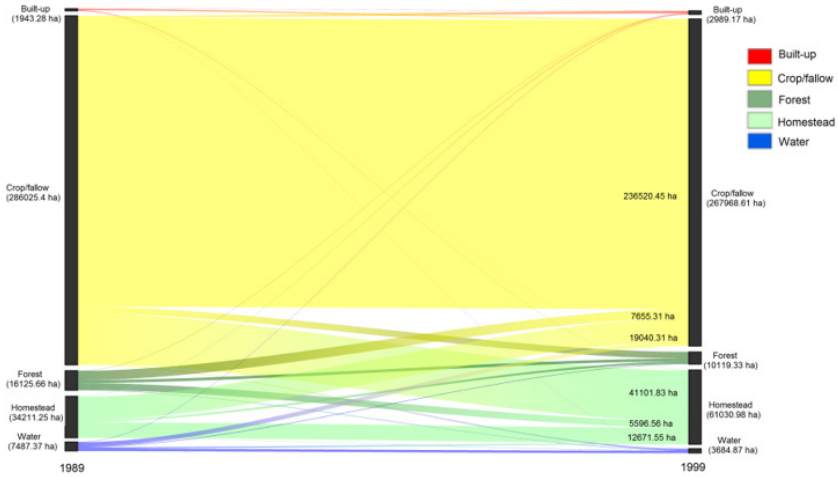

Figure 4: Sankey diagram showing Land use and land cover change matrix of Dinajpur from 1989 to 1999.

Homestead and built-up increased by 53.82% and 78.39%, respectively (Table 4). 3.4 Assessment of LULC change matrix from 1999 to 2010

From the year 1999 to 2010, homestead and built-up increased by 24.41% and 18.48%, respectively. In the mean while forest and water area were decreased by 57.94% and 24.55%, respectively (Table 4). Crop/fallow was decreased from 267968.61 ha to 259286.31

ha. Maximum area of crop/fallow was converted to homestead (40182.48 ha) whereas the persistent area of crop/fallow was 223565.49 ha. The rate of decrease of crop/fallow per year was 789.3 ha.

In case of forest, maximum area of forest transferred to homestead (4493.07 ha) and crop/fallow (3474.72 ha) followed by others classes and the persistent area of forest was 1907.55 ha (Figure 5).

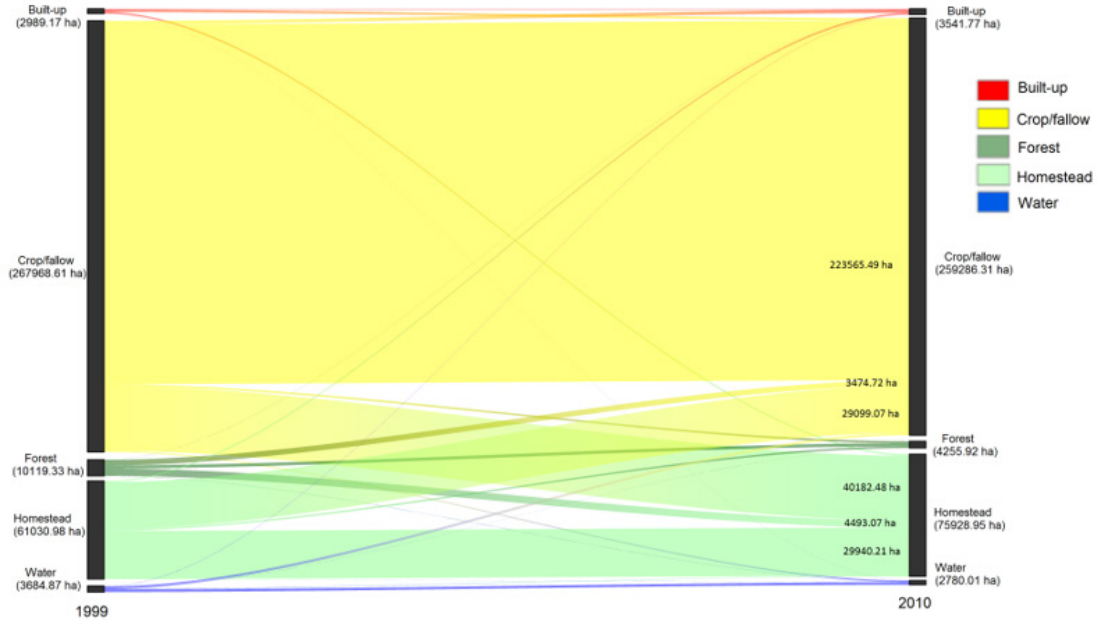

Figure 5: Sankey diagram showing Land use and land cover change matrix of Dinajpur from 1999 to 2010.

Assessment of LULC change matrix from 2010 to 2020

Between 2010 and 2020, built-up, homestead and water were increased by 70.28%, 5.75% and 62.21%, whereas crop/fallow and forest were decreased by 3.22% and 5.24%, respectively (Table 4). Around 2044.26 ha of forest land transferred to homestead and 917.64 ha of forest land transferred to crop/fallow. Besides, majority of crop/fallow land (36781.56 ha) was transferred to homestead. Furthermore, built-up was increased by converting maximum area of crop/fallow and (3176.01 ha) and homestead (2013.57 ha) to Built-up. In the

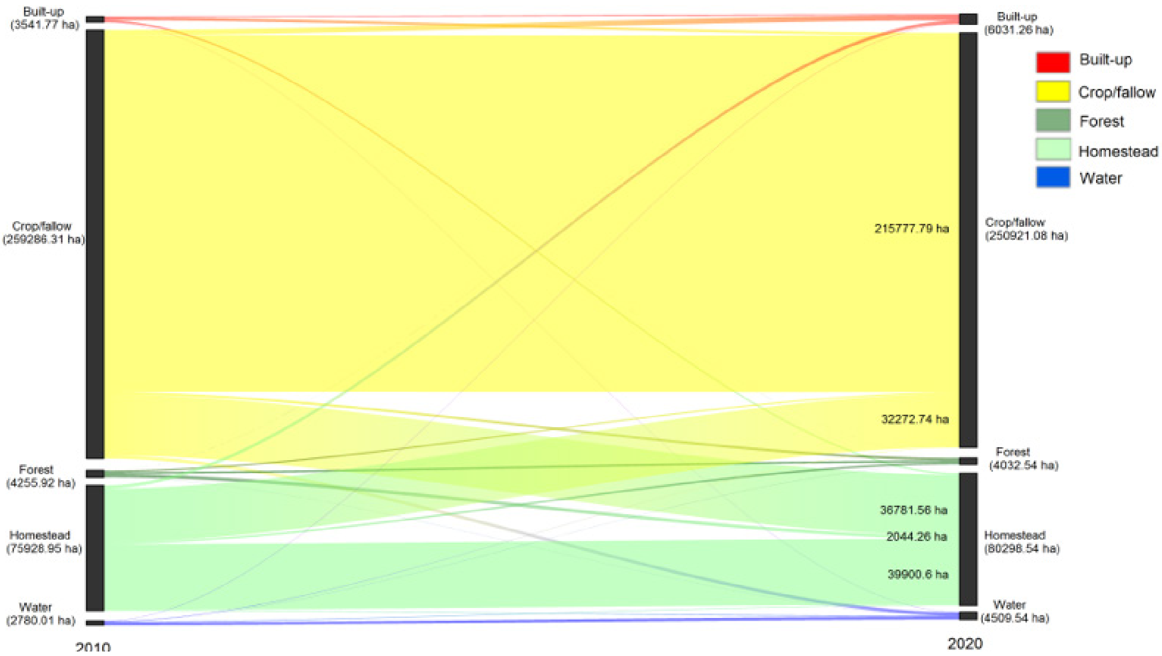

Figure 6: Sankey diagram showing Land use and land cover change matrix of Dinajpur from 2010 to 2020.

meanwhile, homestead was increased by 436.95 ha per year. The persistent area of built-up, crop/fallow, forest, homestead and water were 619.29 ha, 215777.79 ha, 1166.94 ha, 39900.6 ha and 1703.7 ha, respectively (Figure 6).

Assessment of LULC change matrix from 1989 to 2020

Forest area has decreased drastically around 74.99% from 1989 to 2020 (Table 4) due to vast homestead (8089.02ha) and crop/fallow (5965.74 ha) expansion. Within this time period, only 2105.01 ha has been added as forest area from crop/fallow. The overall rate of reduction of forest was 390.10 ha per year (Figure 7). There has been a noticeable change in crop/fallow areas over the study area that it was decreased by 12.27% (Table 4) while majority of crop/fallow converted to homestead (52322.76 ha) (Figure 7). The total loss of water body from 1990 to 2020 is 2977.83 ha which accounts for a reduction of about 39.77% over the period (Table 4). The growth of homestead area between 1989 to 2020 was about 1486.6 ha/year and the persistent area of homestead was 16506.9 (Figure 7). The rate of expansion of homestead area over the study

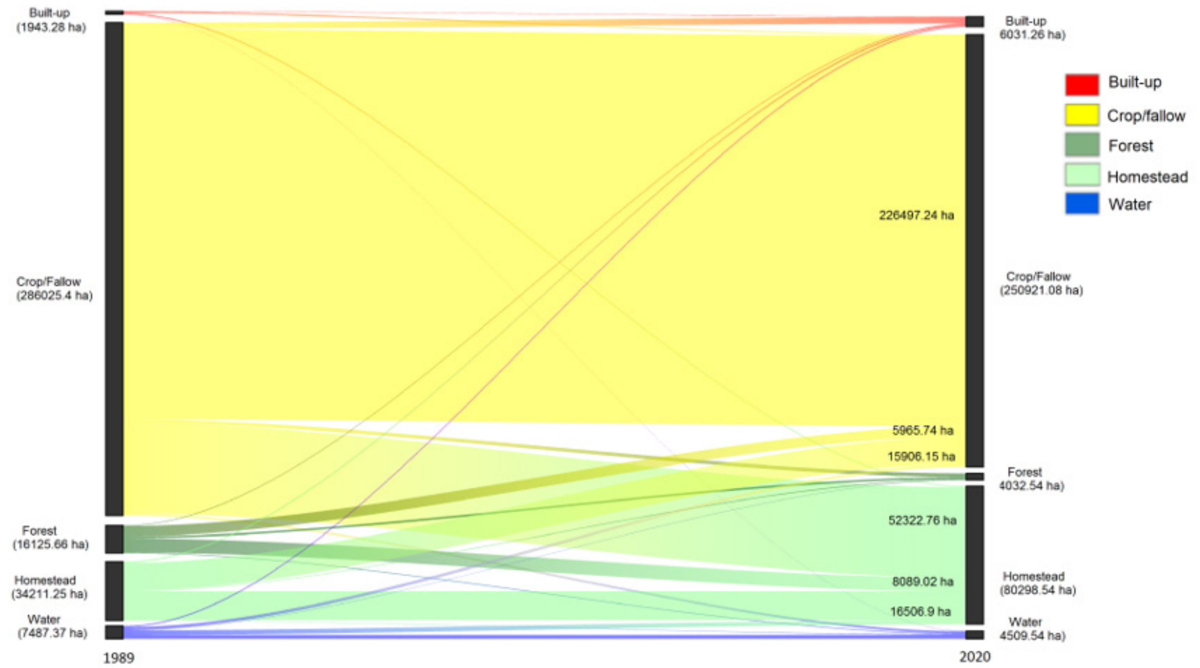

Figure 7: Shankey diagram showing Land use and land cover change matrix of Dinajpur from 1989 to 2020.

Table 4: Relative changes in land use and land cover in Dinajpur

LULC Class	Change (%)			
	1989 -1999	**1999-2010**	**2010-2020**	**1989-2020**
Built-up	53.82	18.49	70.29	210.36
Crop/fallow	-6.31	-3.24	-3.23	-12.27
Forest	-37.25	-57.94	-5.25	-74.99
Homestead	78.39	24.41	5.75	134.71
Water	-50.79	-24.56	62.21	-39.77

area indicates the growth rate has become more than double in recent years. Hence, such an unplanned built-up and homestead trend will pose a significant threat to the environment and living conditions of the study area.

DISCUSSION

This study aimed to monitor long-term changes in LULC in northern region (Dinajpur district) of Bangladesh. Satellite images were properly used to obtain the objectives. LULC was changed significantly having extreme loss of forest cover. The built-up area of the Dinajpur region has expanded over time. Population increase was a primary driver of built-up expansion. As a result of urban growth, several locations in Bangladesh have seen considerable declines in wetlands, cultivated land, vegetation, and water bodies (Dewan and Yamaguchi, 2009). A lot of factors contribute to the built-up expansion and massive flow of urban migration, including rapid and unplanned urban movement, the concentration of better employment in city areas, and biased placement of municipal infrastructure. Contemporary development of built up impacting the ecology, environment, and biodiversity in the surrounding region (Al Rakib *et al.*, 2020; Chakroborty *et al.*, 2020; Rahman *et al.*, 2018). Crop/fallow land may be termed as agricultural land was shrinking in the study area year after year. Maximum crop/fallow land was transformed to the homestead. The agricultural land in Bangladesh is reducing at 69,000 hectares per annum as a result of increasing industry, unplanned urbanization, and an increase in in rural communities. (Khan, 2020). The rapid conversion of agricultural land to non-agricultural uses threatens crop production and food security in the country (PC, 2009). According to studies, the rate of conversion of agricultural lands to non-agricultural uses is comparatively faster in the twenty-first century due to high economic expansion and infrastructural development (Hasan *et al.* 2013). The loss of agricultural land has resulted in the degradation of biodiversity and ecosystem services also (Kafy, *et al.*, 2021). Homesteads in the Dinajpur region expanded fast, with 26.41 million families in Bangladesh utilizing 0.748 million hectares of land (Mannan, 2013).

Forest land in Dinajpur was rapidly declining. The findings are consistent with Bangladesh having one of the highest rates of deforestation in South Asia, at 2600 hectares per year (Mac Dicken, 2015; Poffen berger, 2000) and this forest loss related impacts on ecosystem health (Halkos and Zisiadou, 2018). Deforestation and other disturbances cause the world's forests to release an average of 8.1 billion metric tonnes of carbon dioxide into the atmosphere each year. Southeast Asian forests have collectively become a net source of carbon emissions during the last 20 years as a result of deforestation for plantations, uncontrolled fires, and peat soil drainage (Nancy and colleagues, 2021). Biophysical and socioeconomic factors contribute to the conversion of forest to agricultural land and the conversion of agricultural land to forest in both Southeast Asia and South Asia (Xu *et al.*, 2019). According to The International Union for Conservation of Nature (IUCN, 2005), the primary accelerator of forest decline is human activities. Wasige *et al.* (2015) identified that the forest clearing occurring every year is mainly due to agriculture. According to Abdullah *et al.* (2019), forest in Gazipur region of Bangladesh have decreased by 62.67 percent. In Bangladesh, naturally regenerating forest was 1845000 ha during 1990 to 2000, but it reduced to 1816000 ha in 2010, again reduced to 1725000 ha between 2015-2020 (FRA 2020) is a major threat for future.

CONCLUSION

LULC change trends can be assessed and mapped to serve as a foundation for long term planning, monitoring, and protective actions. Besides, in order to manage and grow forest ecosystems sustainably, it is crucial to keep track of changes in forest cover and understand how it changes over time. Very high-resolution multispectral satellite images, however, may provide more information about changes in the region. The LULC change patterns were found to differ significantly between the Landsat data for the years 1989, 1999, 2010, and 2020 after LULC analyses. Built-up and homestead increased every decade from 1989 to 2020. On the other hand, crop/fallow and forest was narrowed down day by day. Forest land was mainly shrinking for maximum transformation of land to homestead and crop/fallow land. So, Stopping the growth of built- up and homestead areas that transform agricultural land and forest are all a part of a broader strategy to save this significant geographic and delicate environment. This research was conducted in small scale, but it should be done in broader aspect and also to predict the future land use, method like CA-Markov chain can be applied. Thus, the study of planetary land use patterns is critical for dealing with global climate change, achieving sustainable development and proper planning of natural resources in future.

Acknowledgments

The authors are thankful to the Ministry of Science and Technology for funding this research through the NST fellowship. We are also grateful to the United States Geological Survey (USGS) for providing the Landsat archives.

Conflicts of Interest

The authors declare no conflicts of interest.

REFERENCES

Abdullah, H. M., Islam, I., Miah, M. G., & Ahmed, Z. (2019). Quantifying the spatiotemporal patterns of forest degradation in a fragmented, rapidly urbanizing landscape: a case study of Gazipur, *Bangladesh. Remote Sensing Applications: Society and Environment, 13,* 457-465.

Akbari, M., Mamanpoush, A. R., Gieske, A., Miranzadeh, M., Torabi, M., & Salemi, H. R., (2006). Crop and land cover classification in Iran using Landsat 7 imagery. *International Journal of Remote Sensinag, 27*(19), 4117-4135.

Al Rakib A., Akter, K. S., Rahman, M. N., Arpi, S., Kafy, A-A., (2020). Analyzing the pattern of land use land cover change and its impact on land surface temperature: a remote sensing approach in Mymensingh, Bangladesh. 1st Int. *Student Res. Conf. 2020*

Anderson, J. R., (1976). A land use and land cover classification system for use with remote sensor data (Vol. 964). US Government Printing Office.

Armsworth, P. R., Kendall, B. E., & Davis, F. W. (2004). An introduction to biodiversity concepts for environmental economists. *Resource and Energy Economics, 26,* 115–136.

Arveti, N., Etikala, B., & Dash, P. (2016). Land use/Land cover analysis based on various comprehensive geospatial data sets: *A case study from Ananthapuramu area, South India. Advances in Remote Sensing, 5*(2), 73–82. https://doi.org/10.4236/ars.2016.52006

Baby, S., (2015). Monitoring the coastal land use land cover changes (LULCC) of Kuwait from spaceborne LANDSAT sensors.

Chakroborty, S., Al Rakib, A., Al Kafy, A., (2020). Monitoring water quality based on community perception in the Northwest Region of Bangladesh, in: 1st *International Student Research Conference- 2020. Dhaka*

Chandrashekar, A., Somanath, T., Praveen Kumar, R., Vikas, K., & Saumitra M., (2018). Changing land trajectories: A case study from India using a remote sensing based approach. *European Journal of Geography, 7*(2), 61–71. http://www.eurogeographyjournal.eu/articles/04_CHANGING%20LAND%20TRAJECTORIES%20A%20CASE%20STUDY%20FROM%20INDIA%20USING%20REMOTE%20

SENSING%20BASED%20APPROACH.pdf

Chen, L., Wang, J., Fu, B., & Qiu, Y., (2001). *Land-use change in a small catchment of northern Loess Plateau, China. Agriculture, Ecosystems and Environment, 86*, 163–172.

Chughtai, A. H., Abbasi, H., & Karas, I. R., (2021). A review on change detection method and accuracy assessment for land use land cover. *Remote Sensing Applications: Society and Environment, 22*, 100482.

Dewan, A. M., & Yamaguchi, Y., (2009). Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005. *Environmental monitoring and assessment, 150*(1), 237-249.

Dhinwa, P., Pathan, S., Sastry, S., Rao, M., Majumder, K., Chotani, M. & Sinha, R., (1992). Land use change analysis of Bharatpur district using GIS. J. *Indian Soc. Rem. Sens. 20* (4), 237–250.

Estoque, R. C., & Murayama, Y., (2015). Intensity and spatial pattern of urban land changes in the megacities of Southeast Asia. Land *Use Policy, 48*, 213–222. https://doi.org/10.1016/j.landusepol.2015.05.017

FAO. Sustaining Communities, Livestock and Wildlife; FAO: Rome, Italy, 2009.

FRA, (2020). GLOBAL FOREST RESOURCES ASSESSMENT 2020. Country Report Bangladesh Rome, 2020.from 29 October to 10 November 2001, *addendum, 2*.

Guan, D., Li, H., Inohae, T., Su, W., Nagaie, T., & Hokao, K., (2011). *Modeling urban land use change by the integration of cellular automaton and Markov model. Ecological Modelling, 222*, 3761-3772.

Halkos, G. & Zisiadou, A. (2018). Relating environmental performance with socioeconomic and cultural factors. *Environ. Econ. Policy Stud. 20*(1), 69–88.

Hasan, M. N., Hossain, M. S., Bari, M. A., & Islam, M. R., (2013). Agricultural land availability in Bangladesh. Dhaka: Soil Resource Development Institute.

Hereher, M. E., (2011). Mapping coastal erosion at the Nile Delta western promontory using Landsat imagery. *Environmental Earth Sciences, 64*(4), 1117-1125.

Islam, M. A., Miah, M. M. Bangladesh in maps. Univ. of Dacca (1981). 77

IUCN. Rapid Environmental Appraisal of Developments in and Around Murree Hills; IUCN Pakistan: Karachi City, Pakistan, 2005.

Kafy, A. A., Naim, N. H., Khan, M. H. H., Islam, M. A., Al Rakib, A., Al-Faisal, A., & Sarker, M. H. S., (2021). Prediction of urban expansion and identifying its impacts on the degradation of agricultural land: a machine learning-based remote-sensing approach in Rajshahi, Bangladesh. In Re-envisioning Remote Sensing Applications (85-106). CRC Press.

Kawakubo, F. S., Morato, R. G., Nader, R. S., & Luchiari, A., (2011). Mapping changes in coastline geomorphic features using Landsat TM and ETM+ imagery: Examples in southeastern Brazil. *International journal of remote sensing, 32*(9), 2547-2562.

Khan, S., (2020., November 11). *Worries over farmland depletion. The Financial Express.* Retrieved December 19, 2021, from https://thefinancialexpress.com.bd/views/worries-over-farmland-depletion-1605105883

Kilic, S., Evrendilek, F., Berberoğlu, S., & Demirkesen, A. C., (2004). Environmental monitoring of land-use and land-cover changes in Amik Plain, Turkey. In Geo-Imagery Bridging Continents, XXth *ISPRS Congress. Istanbul, Turkey.*

Lambin, E. F., (1997). Modelling and monitoring land-cover change processes in tropical regions. *Progress in Physical Geography, 21*, 375-393.

Lu, D., & Weng, Q., (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing, 28*(5), 823–870. https://doi.org/10.1080/01431160600746456

MacDicken, K. G., (2015). Global forest resources assessment 2015: what, why and how?. *Forest Ecology and Management, 352*, 3-8.

Manandhar, R., Odeh, I. O. A., & Acnev, T., (2009). Improving the accuracy of land use and land cover classification of Landsat data using post-classification enhancement. *Remote Sensing, 1*, 330–344.

Mannan, M., (2013). Plant biodiversity in the Hoar homesteads of Bangladesh. *International Research Journal of Applied Life Sciences, 2*(5).

Meshesha, T. W.; Tripathi, S. K. & Khare, D. M., (2016). Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia. *Model. Earth Syst. Environ. 2*, 1–12.

Meyer W. B. and Turner B. L. II., (1994). *Changes in land use and land cover: a global perspective*, Cambridge: Cambridge University Press, 549.

Minale, A. S., (2013). Retrospective analysis of land cover and use dynamics in Gilgel Abbay Watershed using GIS and remote sensing technique, *Northwestern Ethiopia. Int. J. Geosci. 4*, 1003–1008.

Murad, H., & Islam, A. K. M. S., (2011, January). Drought assessment using remote sensing and GIS in north-west region of Bangladesh. In Proceedings of the 3rd *International conference on water & flood management,* 797-804.

Nancy Harris and David Gibbs., (January 21, 2021). Forests Absorb Twice As Much Carbon As They Emit Each Year.

Nations, U., (1992). Agenda 21. United Nations Conference on Environment & Development Rio de Janeiro, Brazil.

Niu, B., Lan, J., Shao, Y., & Zhang, H., (2020). A dual-branch extraction and classification method under limited samples of hyperspectral images based on deep learning. *Remote Sensing, 12(3*), 536.

PC., (2009). *Steps towards change. Planning Commission, National Strategy for Accelerated Poverty Reduction II (Revised).* Dhaka: Government of the People's Republic of Bangladesh.

Poffen berger, M., (2000). Communities and forest management in South Asia. *IUCN*.

Qian, J., Zhou, Q., Hou, Q., (2007). Comparison of pixel-based and object-oriented classification methods for extracting built-up areas in arid zone. In: Paper Presented at the ISPRS Workshop on Updating Geo-Spatial Databases with Imagery & the 5th *ISPRS Workshop on DMGISs*.

Rahman, M. S., Mohiuddin, H., Kafy, A. A., Sheel, P. K., & Di, L., (2019). Classification of cities in Bangladesh based on remote sensing derived spatial characteristics. *Journal of Urban Management, 8*(2), 206-224.

Rajendran, G. B., Kumarasamy, U. M., Zarro, C., Divakarachari, P. B., & Ullo, S. L., (2020). Land-use and land-cover classification using a human group-based particle swarm optimization algorithm with an LSTM Classifier on hybrid pre-processing remote-sensing images. *Remote Sensing, 12*(24), 4135.

Rana, M. S. P., Hossain, M. A., & Nasher, N. R., (2022). Identification of groundwater potential zone using geospatial techniques of agriculture dominated area in Dinajpur district, Bangladesh. *Environmental Challenges, 7*, 100475.

Rao, K. S., & Pant, R., (2001). Land use dynamics and landscape change pattern in a typical micro watershed in the mid elevation zone of central Himalaya, India. *Agriculture, Ecosystems and Environment, 86,* 113–123.

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C.J., Mulatu, W. J. L. E., (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: *the case of southwestern Ethiopia, 15*(4), 339–355.

Reimann, K. U., & Hiller, K., (1993). Geology of Bangladesh.

Turner, B. L., Lambin, E. F., & Reenberg, A., (2007). The emergence of land change science for global environmental change and sustainability. *PNAS, 104*, 20666-20671.

USGS., (2004). Phase 2 gap-fill algorithm: SLC-off gap-filled products gap-fill algorithm methodology. Retrieved from http://www.landsat.usgs.gov/documents/L7SLCGapFilled Method.pdf (accessed 20.01.2015).

Viana, C. M., Oliveira, S., Oliveira, S. C., & Rocha, J., (2019). Land use/land cover change detection and urban sprawl analysis. *Spatial Modeling in GIS and R for Earth and Environmental Sciences*. https://doi.org/10.1016/b978-0-12-815226-3.00029-6

Viera, A. J., & Garrett, J. M., (2005). Understanding interobserver agreement: the kappa statistic. *Fam med, 37*(5), 360-363.

Wasige, J. E.; Groen, T. A.; Smaling, E.; Jetten, V., Monitoring basin-scale land cover changes in Kagera Basin of Lake Victoria using ancillary data and remote sensing. *Int. J. Appl. Earth Obs. Geoinf., 21,* 32–42.

Xu, X., Jain, A. K., & Calvin, K. V., (2019). Quantifying the biophysical and socioeconomic drivers of changes in forest and agricultural land in South and Southeast Asia. *Global change biology, 25*(6), 2137-2151.