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Spatio-temporal changes of forest and other land covers in the North-eastern Part (Jamalpur & Sherpur) of Bangladesh

Noor Shaila Sarmin*

Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

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Key words: Deforestation, Land-use change, Remote sensing, Urbanization

Abstract

Being a developing country Bangladesh is facing a rapid land use and land cover (LULC) change in recent few decades. The study was conducted to quantify the LULC change in the north-eastern part of Bangladesh for one decade. Landsat imageries of the study area for 2010 and 2020 were downloaded from the USGS earth explorer. The images were processed using *QGIS* and *ArcGIS* soft wares. A supervised semi-auto classification technique was applied to classify the study area into five land cover classes, i.e., forest, water, agri/homestead, fallow and built-up. Overall classification accuracies were 88% and 90% for the images of 2010 and 2020, respectively. During the studied decade, the coverage of built-up and agri/homestead showing an increasing trend in exchange of forest, water, and fallow lands which showed a decreasing trend. In one-decade period built-up area increased by 54.32% and agri/homestead area increased by 2.83%. On the other hand, fallow land decreased 50.6%. During the studied timeframe from 2010 to 2020, about 27033.75ha of forest area and 10799.19ha of fallow land area were converted to agri/homestead. However, about 3307.14ha and 5046.06ha of agri/homestead area was converted to fallow and built-up, respectively. About 312.92ha, 331.29ha and 278.1ha of forest area in 2010 was converted to water, fallow and built-up area, respectively in 2020. Different causes reported are mainly over-exploitation, illegal logging, making settlements and housing for increased population, urbanization etc.

***Corresponding Author:** Noor Shaila Sarmin ✉ noorshaila01@gmail.com

Introduction

Now a day global warming has perceived a hot topic that is closely related to carbon sequestration (Hasan *et al.,* 2020; Haiming *et al.,* 2010). Developing countries such as Bangladesh is facing a rapid land use/cover change due to different anthropogenic factors and are in a more vulnerable situation to the global warming consequences. Mitigating global warming as well as global environmental change through forestry expansion has been accepted as a good practice all over the world (Turner *et al.,* 1995; Hasan *et al.,* 2020).

Bangladesh being one of the most densely populated countries has a population of 165 million (2020) in only 147570 square km of land. Ever-increasing population causes rapid land use and land cover (LULC) change for the increasing demand for their different livelihood commodities. Among these changes, deforestation is the most critical which affects the local ecosystem both flora and fauna. The increasing demand also affects local agricultural land, aquatic environments or other land-use systems. The State of the World's Forests (FAO, 2016) listed Bangladesh among the countries that are the most vulnerable to forest and agricultural land loss. According to the Bangladesh government entire forest area is about 17%. However, World Bank 2015 reported that it is only 11%. Per capita forestland in Bangladesh has shrunk to 0.016ha, one of the lowest in the world. In the meantime, the annual deforestation rate of Bangladesh's forest was approximately 1.60 km^2 (Abdullah *et al.,* 2015). Zafar *et al.,* (2021) reported that forest degradation caused by population growth, food demand and poverty significantly affect the forest biodiversity, water quality, climate system and soil conservation. Forest cover losses, as well as land use changes, have significant importance as it contribute to global environmental change (Zafar *et al.,* 2021). The north-eastern part of Bangladesh has a rich land cover. There are different rivers passing through the area which have a huge contribution to the adjacent lands and lives. The Garo Hills are also home to different types of flora and fauna. These hills are also home to different types of tribal communities. Parts of the tropical moist deciduous forest or natural Sal (Shorea robusta) forests are situated in the study area (Sherpur and Jamalpur districts). The Gajni forest is located in the north-eastern part of the Sherpur district and has a rich ecosystem supporting different flora and fauna. This forest also has a huge contribution to the local community's livelihood and socioeconomics. There are different types of tribal communities (Garo, Hajong & Kuch) living near the hilly forest area (Rahman 2003). Although some part (100ha) of the Sherpur forest is managed as a protected forest (Madhutila Ecopark) area the rest part of the forest is not protected. A huge forested area is in the possibility of land use/cover change.

The Brahmaputra River has passed across the Jamalpur and Sherpur Districts and the River Jamuna has also passed through Jamalpur District. Over a few decades these two rivers have contributed a huge land cover change in the study area which has affected the livelihood practices of the local population.

The land use change and sand collection at different points of the Brahmaputra River in the study area must have an effect on the river bank which has affected both, directly and indirectly, the LULC in that area and also the local community's livelihood practices. According to the population census 2011, the population density in the area (Mymensingh Division) was 1100/km^2. The total population in Jamalpur and Sherpur Districts was 3,650,999 with a total area of 3479.83 km^2 and a population density of 1049.19/km^2 (BBS 2013).

The study of change detection is very important to know the current status and also the dynamics of land use/cover of the study area (Sarmin *et al.,* 2017a). The land use/cover dynamics of the area have a contribution to the local community. The forest coverage change and the change of the River banks are affecting their livelihood activities and dependencies on the ecosystem. Sarmin *et al.,* (2017b) reported that deforestation and local socioeconomics are strongly related to each other.

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites (Sarmin *et al.,* 2016a). It has been demonstrated as a powerful tool and one of the key data sources for studying the spatial and temporal changes in land resources and underlying phenomena (NASA 2008; Gómez *et al.,* 2016; Abdullah *et al.,* 2019). Satellite remote sensing is an effective tool for natural resources assessment from land to Ocean (Sarmin *et al.,* 2016b).

Remote sensing along with GIS serves many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, archaeological investigations, military observation and geo-morphological surveying, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc.

It provides a timely and complete coverage for vegetation mapping for the coastal area, hill areas or forested areas where accessibility is difficult (Ismail *et al.,* 2011). Thus, the present work has been planned to study the spatiotemporal changes of LULC in the north-eastern part (Jamalpur & Sherpur district) of Bangladesh and the anthropogenic causes of the change.

Materials and methods

Study Area

The study area is located in the northeastern part of Bangladesh. District Jamalpur and Sherpur were under the study area. The geographical location of the study area lies between latitude 24°18'-25°.26' and longitude 89°40'-90°20'. The main Rivers of the study area are Old-Bramhaputra, Bangali, Banal, Mrigi, Bhogai, Kongsho, Maharashi etc.

The main crops are rice, jute, mustard, tobacco, sugarcane, vegetables etc. The main fruits are mango, jackfruit etc. Agro-ecologically, the study area belongs to AEZ-8 (Young Brahmaputra-Jamuna Floodplains), AEZ-9 (Old-Brahmaputra floodplain) and AEZ-22 (Northern and Eastern Piedmont Plain) categories of FAO of the United Nations (FAO/UNDP 1988). Fig. 1 shows the study area.

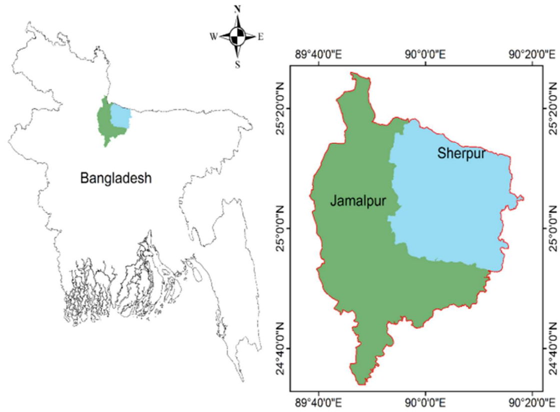

Fig. 1. Study area.

Satellite image acquisition

Landsat 5 TM and Landsat 8 OLI images were used for 2010 and 2020, respectively. To cover the study area for each year two images of path/row 138/42 and 138/43 were downloads from the USGS global visualization viewer (Glo Vis) website. Landsat data were chosen because Landsat data have higher spectral resolutions (for instance R, G, B, NIR, MIR, TIR and FIR for TM) which can be used successfully to identify certain different land cover/use types. Landsat is only medium-resolution spatial data that is available free of charge. Moreover, Landsat data have a successful record for land use change study globally since its early use started (Weng, 2002; Peijun *et al.,* 2010; Wang and Ji, 2012). All the images were chosen during the dry season (February-April) to reduce cloud per cent. The main characteristics of the remotely sensed imageries are given in Table 1.

Table 1. Image characteristics

Satellite Image and sensor	Path/Row	Resolution	Projection
Landsat 4-5 TM	138/42, 138/43	30m	UTM/WGS84
Landsat 8 OLI	138/42, 138/43	30m	UTM/WGS84

Image pre-processing

Landsat images were downloaded as surface reflectance images. For Landsat imagery, surface reflectance data were generated from the Landsat ecosystem disturbance adaptive processing system (LEDAPS), specialized software originally developed by the national aeronautics and space administration (NASA).

The software applies moderate resolution imaging spectro-radiometer (MODIS) atmospheric correction in which water vapour, ozone, geopotential height, aerosol optical thickness and digital elevation are input as Landsat data to the second simulation of a satellite signal in the solar spectrum radiative transfer models to generate top of atmosphere reflectance, surface reflectance, brightness temperature, and masks for clouds, cloud shadows, adjacent clouds, land, and water (Liang *et al.,* 2001).

As the images were downloaded as collection 1 level1 product so the images were geometrically rectified and no pre-processing was needed excepts layer stacking and clipping the study area. Multiband/layer stacking was performed in QGIS. For the Landsat imagery, band-1 (Coastal aerosol), band-2 (Blue), band-3 (Green), band-4 (Red), band-5 (Near Infrared), band-6 (Short wave Infrared-1), band-7 (Shortwave Infrared-2) and band-9 (Cirrus) were used for the layer stacking. Those bands were selected with all of their spatial resolutions in 30m. In this study "-9999" value was assigned to no data pixels. Then multiband images were performed through layer stacking in QGIS where "No data value" was set as -9999. Then the multiband images were set as False Color Composite (4:3:2) for 2010 and the image of 2020 was set as False Color Composite (5:4:3) in ArcGIS.

After layer staking image mosaics were created in Arc GIS. Mosaicking is the process of combining two or more images into a single image. Two images were adjusted for the mosaics to keep the path and row with geospatial coordinates. Then the image was clipped using the study area shape file.

Image classification

Supervised classification technique (Semi-auto classification) was applied to classify the study area into five land categories. Then the supervised classification results were assessed for the accuracy by producing confusion matrix (CM) and analyzing the kappa statistics. The overall accuracy of the classified images was above 88% of all the years and kappa statistics were 87 and 88 per cent for 2010 and 2020 (Table 2), respectively which is acceptable to satisfy the classification requirement.

Table 2. Accuracy assessment for the classified images.

Reference Year	Classified image	Overall classification accuracy (%)	Overall kappa statistics (%)
2010	Landsat 4-5 TM	88	87
2020	Landsat 8 OLI	90	88

Change detection study

Change detection analysis was done through QGIS SAGA using cross-classification and tabulation tool. Change detection procedure was done in land conversion during the interval 2010-2020.

Cross tabulation analysis on a pixel-by-pixel basis facilitated the determination of the quantity of conversions from a particular land cover class to other land use categories and their corresponding area over the period evaluated. A new thematic layer containing the combination of "from-to" change class was also produced. A flowchart of the change detection procedure is shown in Fig. 2.

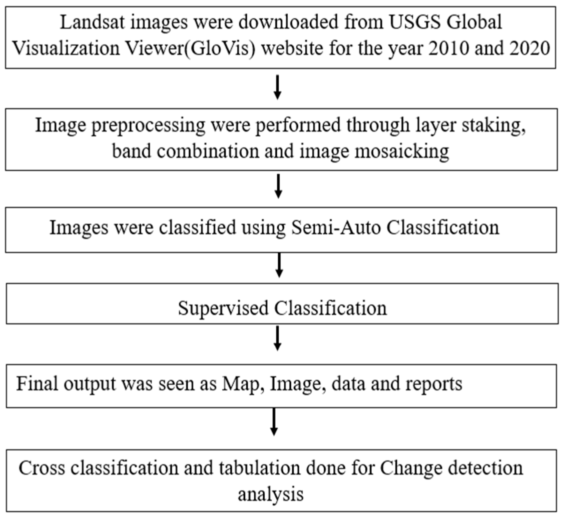

Fig. 2. Flowchart of the change detection study

Results and discussion

Land use and land cover (LULC) classification results

The study area was classified into five LULC categories. Those are forest, water, agri/homestead, fallow and built-up. Table 3 represents the area in a hectare of each LULC type for the years 2010, 2020 and area change per cent during the one-decade period.

Fig. 3 shows the land use maps of the study area for 2010 and 2020, respectively. Agri/homestead represents the largest land use type for both years covering 79.58% in 2010 and 81.83% in 2020 (Fig. 4). Homesteads with trees in the front yards or backyards are included in the agri/homestead category. That's why this class occupied the largest area coverage for all the two studied years. Major agricultural crops of the study area are rice, jute, sugarcane, mustard seed, peanut, chilli, betel leaf, vegetables etc. and major fruits are mango, jackfruit, banana etc. (BBS, 2013). Built-up and agri/homestead area increased from 2010 to 2020, however water, forest and fallow land area decreased from 2010 and 2020. During the one-decade period built-up area increased by 54.32%, agri/homestead area increased by 2.83% however; in contrast, fallow land and forest area decrease by 50.6% and 2.3%, respectively (Table 3). Rahman *et al.,* (2010) reviewed an article of present threats to the tropical moist deciduous Sal (*Shorea robusta*) forest ecosystem of central Bangladesh and reported that this forest type has been severely damaged by different anthropogenic threats. Researchers also considered urban expansion as a cause of deforestation (Zafar *et al.,* 2021).

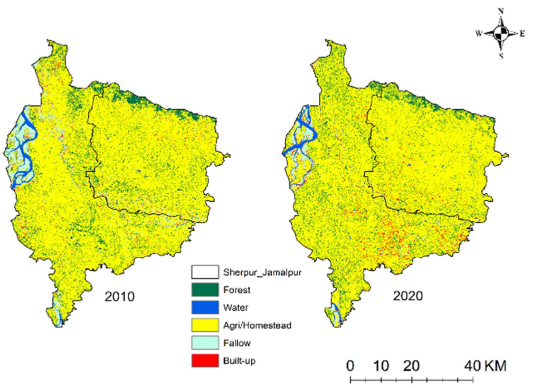

Fig. 3. Land use maps of the study area in 2010 and 2020.

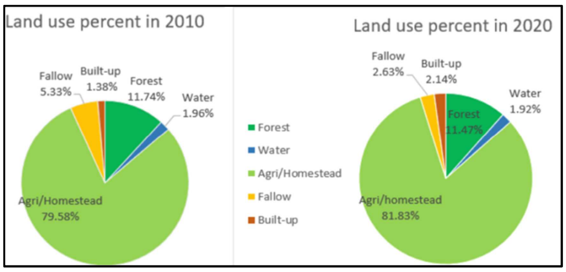

Fig. 4. Land use percent at the study area in 2010 and 2020.

According to the BBS (2013) the study area represents about 93.48% land, 2.01% reserve forest and 4.51% riverine. From the key informant's opinion, population of the study area is increasing which caused the increase of homestead/agri area. According to BBS (2013) the population of the study area increased from 2.54 million in 1981 to 3.01 million in 1991, 3.39 million in 2001 and 3.65 million in 2011. A total number of households according to the household survey 2011 was 0.9 million and the average household size 4.02. For a developing nation rapid population growth has become an important issue for landscape and land use change which is based on different driving forces, such as residential, locational, commercial forces etc. (Mallick, 2021). Zafar *et al.,* (2021) reported that forest degradation caused by population growth, food demand and poverty significantly affect the forest biodiversity, water quality, climate system and soil conservation. Holdgate (1993) also reported that the increasing population of cities in developing countries has caused rapid LULC changes and increased environmental degradation.

Table 3. LULC TYPE, AREA COVERAGE IN HECTARE (ha) and their per cent (%) in 2010 and 2020 at the study area.

LULC type	Area (ha)		Change (%)
	2010	2020	2010-2020
Forest	38206.7	37329.75	-2.3
Water	6381	6252.65	-2.01
Agri/Homestead	258913.3	266241.51	2.83
Fallow	17333.6	8563.18	-50.6
Built-up	4505.9	6953.41	54.32

LULC change detection analysis

According to the Table 4, about 10250.64ha area was under forest in both 2010 and 2020. About 27033.75ha of area that was in the forest category in 2010 was converted to agri/homestead in 2020. From 2010 to 2020 about 312.92ha, 331.29ha and 278.1ha of forest area were converted to water, fallow and built-up area, respectively. About 2177.64ha of the area was under water category in both the studied years. Whereas, 10799.19ha of the fallow land area was converted to agri/homestead from 2010 to 2020. However, about 3307.14ha and 5046.06ha of agri/homestead area were converted to fallow and built-up, respectively from 2010 to 2020 (Table 4).

Different anthropogenic activities such as over-exploitation of forest resources (Rahman *et al.,* 2010), urban expansion (Zafar *et al.,* 2021), illegal logging and forest land conversion to other land use (Chowdhury 1999; Islam and Sato 2012; Abdullah *et al.,* 2015) are reported as the main causes of forest loss or deforestation of natural Sal forests in Bangladesh.

Table 4. Cross-tabulation of LULC changes of the study area in 2010 to 2020

Class	Area (ha)					Total
	Forest	Water	Agri/Homestead	Fallow	Built-up	(2010)
Forest	10250.64	312.92	27033.75	331.29	278.1	38206.7
Water	157.86	2177.64	2472.57	1200.06	372.87	6381
Agri/Homestead	26019.9	2170.63	222369.57	3307.14	5046.06	258913.3
Fallow	601.29	1490.3	10799.19	3341.92	1100.9	17333.6
Built-up	300.06	101.16	3566.43	382.77	155.48	4505.9
Total (2020)	37329.75	6252.65	266241.51	8563.18	6953.41	325340.5

District level LULC change

The study area covers two districts, Jamalpur and Sherpur. District Jamalpur was established in 1978. Before 1984, District Sherpur was a Sub-division of Jamalpur District. District Jamalpur is larger than District Sherpur.

LULC change in Jamalpur District

The district Jamalpur lies between 24°34´ and 25°26´ north latitudes and between 89°40´ and 90°12´ east longitudes. Fig. 5 shows the land use maps of Jamalpur District in 2010 and 2020. The District consists of 7 upazilas namely, Jamalpur Sadar, Bakshiganj, Dewanganj, Islampur, Madarganj, Melandaha and Sarishabari. The total population in Jamalpur District was 1579, 1874, 2107 and 2293 thousand in the year 1981, 1991, 2001 and 2011, respectively BBS (2013). As the main industry, there are 357 rice mills, 26 steel and engineering mills, four jute mills and one sugar mill. There are more than thousands small and cottage industries of which weaving/handloom, handy, husking craft mill, gur-processing, biri-processing, pottery, dry fish processing etc. can be mentioned (BBS 2013).

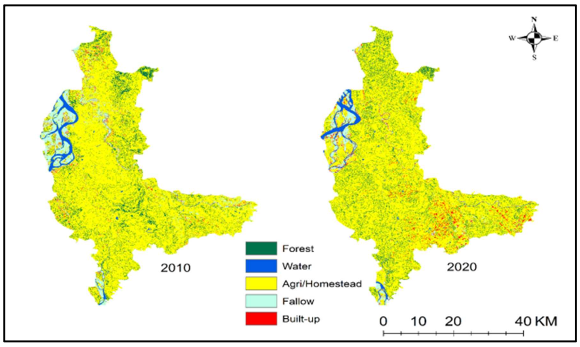

Fig. 5. Land use maps of Jamalpur District in 2010 and 2020.

Table 5 showing the area coverage in hectares of different LULC types, area per cent in 2010 and 2020 and change per cent during the decade. From Table 5, agri/homestead was found the largest LULC category representing 77.44% in 2010 and 78.71% in 2020 followed by forest, fallow, water and built-up in both the studied years. During the studied decade from 2010 to 2020, agri/homestead coverage increased by 1.64% and built-up area coverage increased by 82.84%. However, forest, water and fallow land area have decrease by 4.36%, 4.21% and 31.70%, respectively. Population pressure, urbanization and different socioeconomic activities are responsible for forest degradation and land use change in Bangladesh's perspective Abdullah *et al.,* 2019; Zafar *et al.,* 2021).

Table 5. Lulc type, area coverage, area per cent and change per cent during studied decade (2010 to 2020) in Jamalpur District

LULC type	2010		2020		Change (%)
	Area (ha)	%	Area (ha)	%	2010-2020
Forest	23949.38	12.15	22905.3	11.62	-4.36
Water	5805.72	2.95	5561.19	2.82	-4.21
Agri/Homestead	152631.9	77.44	155139	78.71	1.64
Fallow	11705.55	5.94	7995.24	4.06	-31.70
Built-up	3008.43	1.53	5500.51	2.79	82.84

LULC change in Sherpur district

Sherpur district lies between 24°18' and 25°18' north latitudes and between 89°53' and 90°91' east longitudes. Fig. 6 shows the land use maps of Sherpur District in 2010 and 2020. The District consists of 5 Upazilas, those are Jhenaigati, Nakla, Nalitabari, Sherpur Sadar and Sreebardi. The total population in Sherpur District was 958, 1139, 1279 and 1358 thousands in the years 1981, 1991, 2001 and 2011, respectively (BBS 2013).

There are 341443 households with an average size of 3.97 and a population density of 1028 per sqkm. There are different ethnic nationals such as Garo, hajong, Koch, Banai and Rajbanshi etc. (Rahman, 2003). These ethnic nationals have their own languages. The economy of Sherpur is mainly agro-based, although non-farm economic activities also performed a substantial share in a different development-oriented program of the District (BBS, 2013).

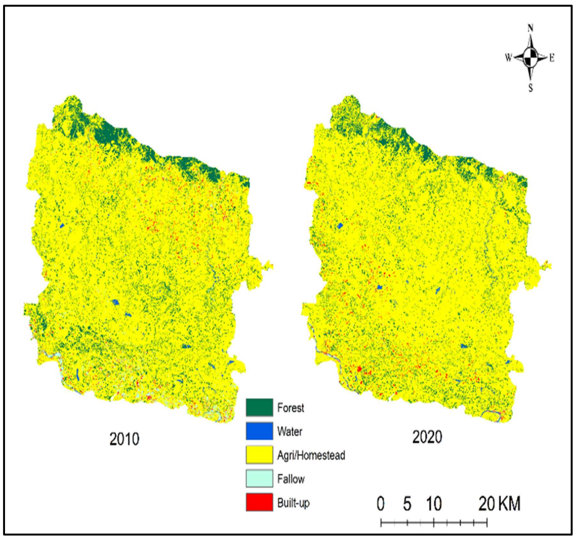

Fig. 6. Land use maps of Sherpur District in 2010 and 2020.

Table 6 shows the area coverage in hectares of different LULC types, area per cent in 2010 and 2020 and change per cent in Sherpur District. From the table, agri/homestead was found the largest LULC category representing 83.57% in 2010 and 87.29% in 2020 followed by forest area.

These results also followed the reports of BBS, 2013 where mentioned that the economy of Sherpur district is mainly agro-based (BBS, 2013) and different ethnic communities also depend on agriculture as well as the forests for livelihood. From 2010 to 2020, agri/homestead, built-up and water categories showed an increasing trend although water coverage for both the studied years was less than 1%. However, forest and fallow showing decreasing trend. During the studied time frame agri/homestead and built-up areas have increased by 4.45% and 5.90%, respectively as well as forest and fellow land decreased by 17.10% and 79.88%, respectively.

Table 6, LULC type, area coverage, area per cent and change per cent during studied decade (2010 to 2020) in Sherpur District

Lulc type	2010		2020		Change (%)
	Area (ha)	%	Area (ha)	%	2010-2020
Forest	16244.82	12.77	13467.3	10.58	-17.10
Water	569.89	0.45	789.39	0.62	38.52
Agri/Homestead	106340	83.57	111068	87.29	4.45
Fallow	2811.08	2.21	565.65	0.44	-79.88
Built-up	1276.36	1.00	1351.71	1.06	5.90

Conclusion

The study area was classified into five land cover classes namely, forest, water, agri/homestead, fallow and built-up. Agri/homestead was found the major land use category in the study area and for Jamalpur and Sherpur as well. The coverage of built-up and agri/homestead shows an increasing trend in the exchange of forest, water, and fallow lands which shows decreasing trend during the studied decade. Sherpur District has a larger forest area than Jamalpur and the loss was found more in Sherpur District (17.10%) than Jamalpur (4.36%).

The results reveal that the land use of the study area is changing and more than 50% change is the conversion of built-up from mainly fallow, forest and water area. These changes might be an indicator of the recent development of different infrastructural, industrial and settlements in the study area. The data derived from the study could serve as baseline information for the study area. Land use planners, policymakers, social scientists, and researchers may use the derived information and land use maps.

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