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Journal of Agricultural Engineering

Vol. 57 (4): October-December, 2020

Assessment of Land Use/Land Cover Change using Geo-informatics in Catchment of Burhi Gandak River, Bihar

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Article Info

Manuscript received:
June, 2020
Revised manuscript accepted:
October, 2020

Keywords: Land use/land cover (LULC) change, watershed delineation, catchment

ABSTRACT

Land use/land cover (LULC) information is essential for proper management, planning and monitoring of natural resources of any region. The present study delineated the catchment of a part-length of Burhi Gandak river falling under Samastipur district of Bihar, estimated its area and LULC change over a period of ten years (2008-2018) using Remote Sensing (RS) and Geographic Information System (GIS) techniques. LULC mappings were done by supervised classification technique using GIS. Overall accuracy of image classification processes was 79.07 % and 75 %, whereas Kappa coefficients were found to be 0.71 and 0.68 for the year 2008 and 2018, respectively. Over the 10-year period, the area under agricultural land increased by 3,329 ha (6.51 %), settlement increased by 4,554 ha (58.20 %), and wasteland (barren and sand) increased by 685 ha (34.05 %); while natural vegetation cover reduced by 6,523 ha (33.58 %) and water bodies reduced by 2,045 ha (54.23 %). Hence, a significant portion of land under natural vegetation and water bodies in the catchment had been converted into either agricultural land or settlement (e.g. buildings) during the period. This change might affect the ecosystem of the area.

Land use/land cover (LULC) changes affect a wide range of processes related to earth sciences and agriculture, such as the movement of soil and water as well as the movement of nutrients through plants, soil, water and the atmosphere (Schilling *et al.,* 2008; Badar *et al.,* 2013). Land cover changes have major consequences for living organisms, for example, clearing of vegetation may result in changes in animal habitats, which in extreme cases may cause extinction (Titeux *et al.,* 2016). Other impacts of land cover change include increased risk of salinity due to vegetation loss (especially trees) and changes in biodiversity. LULC information is required by central, state and local agencies for water-resource inventory, flood control, water-supply planning, and waste-water treatment (Desalegn *et al.*, 2014; Singh *et al.*, 2018). It is also required in order to make national summaries of land-use patterns changes for national policy formulation, to prepare environmental impact statements and assess future impacts on environmental quality.

Remote sensing (RS) and Geographic Information Systems (GIS) hold great promises for improving the convenience and accuracy of spatial data, more productive analysis and improved data access (El Baroudy, 2016). The RS technique has reduced field work to a considerable extent, and land boundaries are more precisely delineated than in conventional methods. It provides reliable and accurate basic information for land-use mapping. The GIS is a tool for the integration and analysis of geographically-referenced data. The operational applications are firmly established in the field of agriculture, forestry, range management, geology, water resources and infrastructure mapping in urban environment. LULC mapping technology has been directly linked to the socio-economic programmes (Dlamini and Mabaso, 2011; Basha *et al.*, 2018).

Ashraf (2014) prepared an LULC map for Patna and assessed the LULC changes in Patna Municipal Corporation area using LANDSAT satellite images of the base years 1989 and 2014. In this study, land cover classification was done with the help of survey of India topo-sheet and satellite images; and ground referencing was also done to check the accuracy of the classification. The study indicated that the urban built-up area nearly doubled in the last 25 years (1989-2014), water body nearly halved, while the forest cover increased by 1.17 per cent. Uniyal *et al*. (2014) studied the LULC changes in Udham Singh Nagar, Uttrakhand state over 24 years (1990-2014), and found GIS as an effective tool for change analysis. Islam *et al.* (2018) assessed land-use changes of Chunati wildlife sanctuary, Bangladesh, occurring from the year 2005 to 2015 using LANDSAT TM and LANDSAT 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) images. They found increase in deforested land by 71.9 %, which is a serious concern for wildlife sanctuary. The LULC change analysis of Patiala-Ki-Rao watershed in Shivalik foot hills was done by Sushanth *et al.* (2018) using Landsat imageries for the years 2006 and 2016 with overall classification accuracy and Kappa statistic of above 90 % and 0.9, respectively. The analysis of land-use maps indicated that the area under all land-uses decreased over a decade, except built-up land that increased by 372.27 ha (112.04 %), mainly due to urbanisation in the watershed. Alam *et al.* (2020) used LANDSAT5 data for assessing LULC of Kashmir valley over three periods (1992, 2001 and 2015) along with checking accuracy of the classification using Kappa coefficient. Maximum likelihood supervised classification was done for the three years, and the Kappa coefficient values were 0.87, 0.88 and 0.90, respectively. Similarly, many researchers conducted studies for different purposes and areas across the globe (Jaiswal *et al.,* 1999; Chitade and Tiwari, 2008; Reis, 2008; Sharma e*t al.*, 2009; Nagarajan and Poongothai, 2011; Kafi *et al.,* 2014; Vishwakarma *et al.*, 2016; Liu *et al.,* 2017).

The above discussion indicates that the LULC information is essential for proper management, planning and monitoring of natural resources available in a particular region. It helps in developing strategies for proper development of the region. In the catchment of Burhi Gandak River falling under Samastipur district of Bihar, a change in LULC pattern was realized. However, no study has been reported on assessment of LULC changes over a recent period. Therefore, the present study was undertaken with the objective of assessing the LULC changes in catchment of part of Burhi Gandak River located in Samastipur district (Bihar) using RS and GIS/geo-informatics techniques.

MATERIALS AND METHODS

Study Area

The catchment of the part of Burhi Gandak River in Samastipur district of Bihar, located at 85°36’51”E to 86°0’28”E longitude and 25°43’55”N to 26°0’41”N latitude, was selected for the study. The study was conducted by the Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur. The study area included Pusa, Kalyanpur, Samastipur, Sarairanjan, Ujiarpur, Bibhutpur, Khanpur, Warisnagar, Tajpur, Rosera and Dalsinghsarai blocks of Samastipur district.

The district lies in the monsoon tropical zone, and is characterized by semi-arid to sub-tropical climate (CGWB, 2013). The soil is sandy loam with moderately high organic matter, and is suitable for vegetables and spices cultivation. Samastipur district is known for its fertile alluvial soil, its *Rabi* crops and for the production of spices, especially turmeric and garlic. It comes under the agro-ecological zone-I (North-west alluvial plains) of the state. The average annual rainfall of the area is 1,270 mm, and is mostly received during monsoon months. The temperature ranges from minimum 6^{o}C in the month of January to maximum 43^{o}C in the month of June. The location map of study area is shown in Fig. 1.

In Bihar, Burhi Gandak River starts from West Champaran district from the spring of Someshwar hills and drains into River Ganga about 7 km east from the district Khagaria. It covers West Champaran, East Champaran, Muzaffarpur, Vaishali, Samstipur, Begusarai, and Khagaria districts of Bihar state. The catchment of the part of the river spread over Samastipur district mainly falls in Samastipur district. However, some part of the catchment in the downstream side falls under Begusarai district.

Data and Software

Shuttle Radar Topography Mission (SRTM) - Digital Elevation Model (DEM) data of 30 m x 30 m resolution was downloaded from United State Geological Survey (USGS) Earth explorer (https://earthexplorer.usgs.gov) for the present study. The generated DEM of the study area was used for delineation of the catchment of Burhi Gandak River. Landsat-5 TM data (30 m x 30 m resolution) of the year 2008 and Landsat-8 OLI/TIRS data (30 m x 30 m resolution) of the year 2018 of the study area were downloaded from USGS Earth

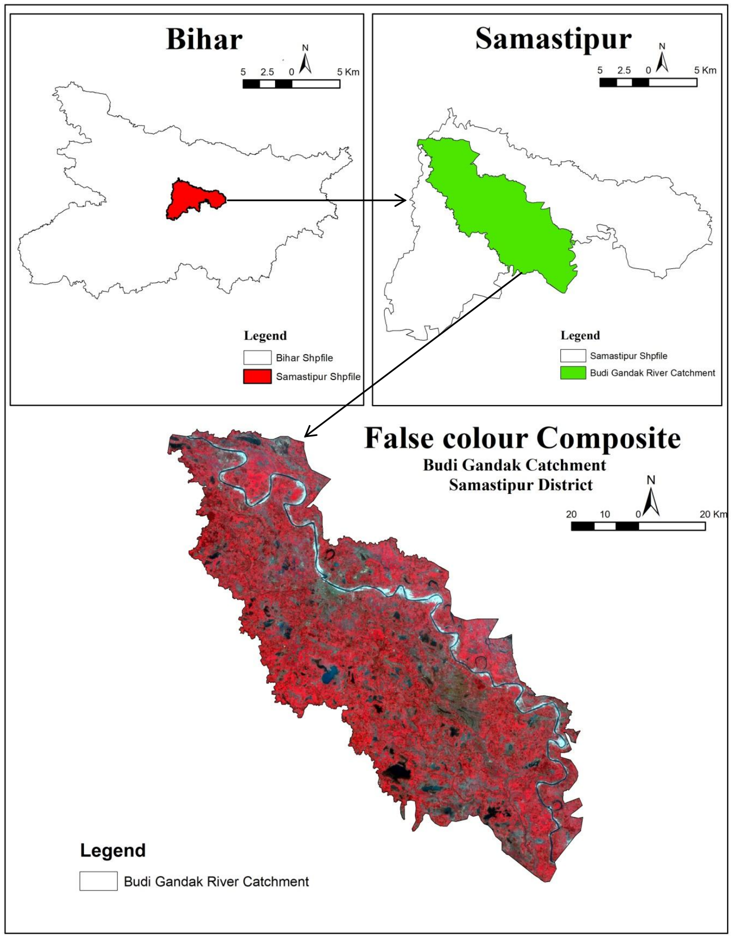

Fig. 1: Location map of study area

explorer site (https://earthexplorer.usgs.gov) for the LULC change analysis. The types of data collected for the present study is listed in Table 1.

ARC-GIS 10.1 software was used for catchment delineation, selection of training sample, classification and accuracy assessment.

Watershed Delineation

The catchment of Burhi Gandak River was delineated by using 'Hydrology tool' under 'Data Management' option in ArcHydro module of ArcGIS software. For delineation of the catchment, SRTM DEM was processed, and flow accumulation grid was generated. Using 'pour point option' outlet of the river was located, and later delineated catchment was converted from raster to polygon.

Land-use/Land-cover Mapping

The LULC maps for the years 2008 and 2018 were prepared from satellite images using supervised image classification technique. The overall accuracies and Kappa coefficient were derived to assess accuracy of the classification of maps.

Table 1. Data acquired for the study

Sl. No.	Data	Path/ Row	Date	Resolution
1.	SRTM DEM	140/42	2015	30 m
2.	LANDSAT 5 (TM)	140/42	14/01/2008	30 m
3.	LANDSAT8 (OLI/TIRS)	140/42	25/01/2018	30 m

Source: https://earthexplorer.usgs.gov

Supervised Classification

The satellite data (imageries) collected from USGS Earth Explorer having the bands in Landsat-5 (8 band) and Landsat-8 (11 bands) was imported into ArcGIS Desktop, and then composited for setting false colour combination (FCC). Then, the FCC image was classified by drawing training sample (ranging from 25 to 40 for each class) of various classes, and maximum likelihood classification was adopted for image classification. Based on information on dominant classes of land uses in the study area, five classes were identified to prepare the LULC map using supervised classification. The five classes identified were (i) agricultural land, (ii) settlement (built-up area), (iii) natural vegetative cover, (iv) waterbodies, and (v) sand and barren land.

Change Detection Technique

After LULC classification of LANDSAT 5 and LANDSAT 8, attribute table was imported into MS-Excel and error matrices for LULC classes for both the years (2008 and 2018) were prepared. Finally, changes in all five classes of LULC were detected by analysing the obtained data.

Accuracy Assessment

An accuracy assessment of the classification results was performed using LULC data from prepared LULC maps; and reference data taken from Google Earth for the year 2008 and ground truth data collected by physical visits for the year 2018. Ground-data of different LULC classes were collected from field using global positioning system (GPS) and visual observations. Using spatial analysis tool, the refercence data collected from field and the classified data from prepared LULC maps were superimposed and compared. Using data management tool, the two data were compared, and resulting error matrix was prepared separately for both years.

In the present investigation, the accuracy assessement of classification was done by computing overall accuracy and Kappa coefficient (Jensen,1996). In the error matrix, the values in the cells represented number of pixels under verification. The columns always represented the reference data or the data that is known to be true or corrects. The rows were the mapped classes that were generated from the remote sensing data. Cells located in the diagonal of the error matrix were the number of correctly classified pixels.

From the error matrix, overall accuracy was computed by the following formula (Bogoliubova and Tymków, 2014):

$$\text{Overall accuracy} = \frac{\sum D_{ii}}{\text{N}} \times 100 \qquad \ldots(1)$$

Where,

$\sum D_{ii}$ = Total number of correctly classified pixels, and

N = Total number of pixels in the error matrix.

Kappa analysis technique depends on K statistic, and has been recommended as a suitable measure of thematic classification because it takes into account the whole error matrix instead of the diagonal elements (Stehman, 1997).The Kappa coefficient is a measure of association of two catagorial variables, and is used to measure agreement between classification approach and the actual answers.

Kappa coefficint (K) is given by (Stehman, 1996):

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \qquad \ldots(2)$$

Where,

r = Number of rows in the error matrix,

x_{ii} = Number of observations in row i and column i (on the major diagonal),

x_{i+} = Total number of observations in rows i (shown as marginal total to right of the matrix),

x_{+i} = Total number of observations in column i (shown as marginal total at bottom of the matrix), and

N = Total number of observations included in matrix.

Kappa is a real dimensionless number between (-)1 to 1.The value close to 1 shows maximum agreement, while value of (-) 1 is totally disagreement. In the present study, the Kappa coefficients for both the years (2008 and 2018) for accuracy assessment were computed by using Arc GIS 10.1. The ranges of K for different levels of agreement are presented in Table 2 (Landis and Koch, 1977).

RESULTS AND DISCUSSION

Land-use/Land-cover Assessment

The delineated catchment of the study area is shown in Fig. 2. The catchment area was estimated to be 84,162 ha. LULC classification maps obtained for the years 2008 and 2018 are shown in Figs. 3 and 4, respectively.

Table 2. Interpretation of Kappa value

Sl. No.	K-Value	Rating	Agreement
1.	≥ 0.81	Excellent	Almost perfect agreement
2.	0.81-0.61	Good	Substantial agreement
3.	0.61-0.41	Moderate	Moderate agreement
4.	0.41-0.21	Poor	Fair agreement
5.	0.21-0	Bad	Slight agreement
6.	<0	Very Bad	Less than chance agreement

Source: Landis and Koch (1977)

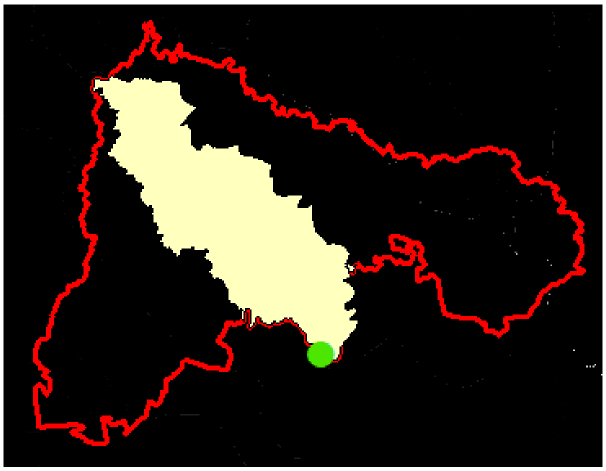

Fig. 2: Delineated catchment under Samastipur district of Bihar state

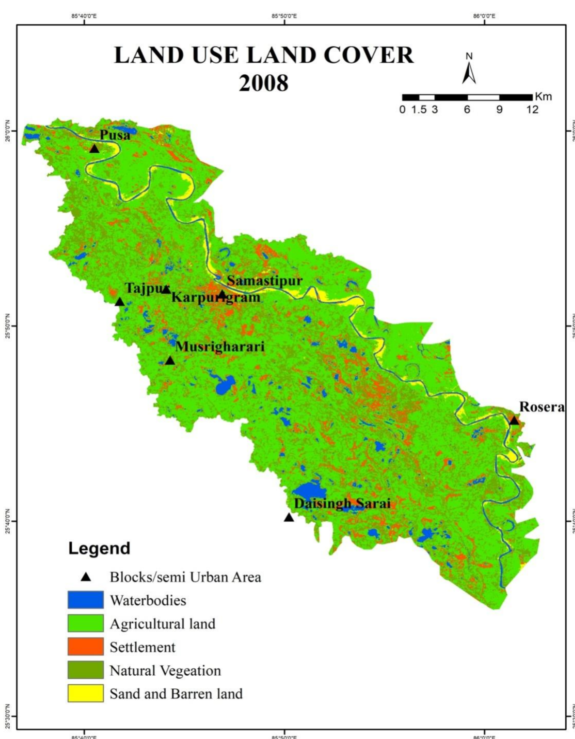

Fig. 3: Land-use/land-cover map of study area in the year 2008

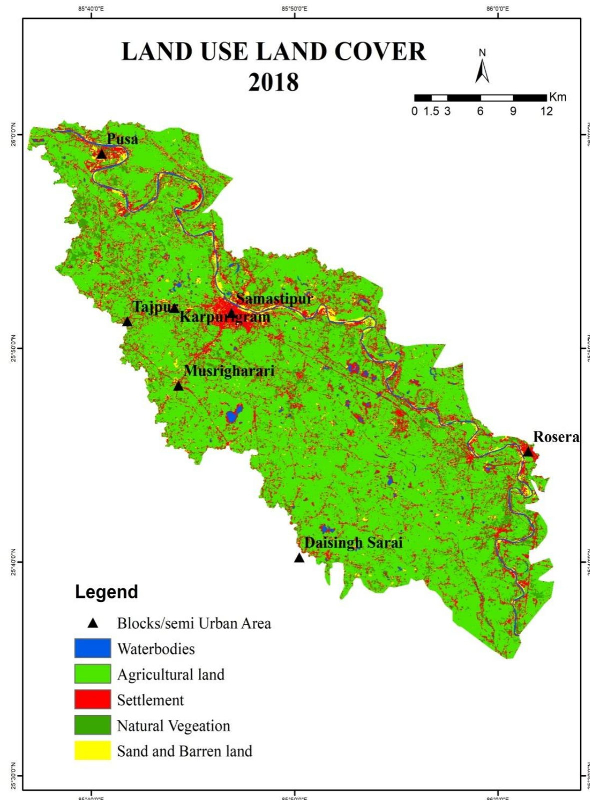

Fig. 4: Land-use/land-cover map of study area for the year 2018

The land-use characteristics of the study area exhibit two distinct patterns: (i) specific or defined land-use, and (ii) mixed land-use. The defined land-use was predominant in city/semi-urban areas of Samastipur, Rosera, Pusa and Tajpur blocks (Figs. 3, 4). The central area was built-up land with mixed land-uses of commercial, residential and industrial activities.

The distribution of areas under the different LULC classes for the two years (2008 and 2018) and the percentage changes in areas of those classes over the period of the ten years are presented in Table 3. It is evident that in the year 2008, the area under agricultural land-use was 51,129 ha (60.74 %) and under settlement was 7,825 ha (9.2 %), while natural vegetation coverage was 19,425 ha (23.08 %). In addition, the water bodies were spread in 3,771 ha (4.48 %), while the area under sand and barren land was computed to be 2,012 ha (2.4 %). On the other hand, after the ten years (year 2018) the study area consisted of 54,458 ha (64.71 %) agriculture land, 1,726 ha (2.05 %) water bodies, 12,902 ha (15.33 %) natural vegetation, 12,379 ha (14.71 %) settlement, and 2,697 ha (3.20 %) sand and barren land.

Table 3. Areas under different LULC classes for the years 2008 and 2018 and the changes in areas over the ten year (2008-2018) period

Land-use/Land-cover class	Area (2008)		Area (2018)		Change in area	
	ha	%	ha	%	ha	%
Water bodies	3771	4.48	1726	2.05	(-)2045	(-)54.23
Agricultural land	51129	60.74	54458	64.71	3329	6.51
Settlement	7825	9.29	12379	14.71	4554	58.20
Natural vegetation	19425	23.08	12902	15.33	(-)6523	(-)33.58
Sand and barren land	2012	2.39	2697	3.20	685	34.05
Total	84162	100	84162	100		

Accuracy Assessment

The classification of error matrix for each category of LULC classes for the year 2008 is presented in Table 4, while that for the year 2018 is presented in Table 5. It is evident from Table 4 that the total number of correctly classified pixels under the LULC class of water bodies was 6 out of total 7 pixels of such class. Thus, the prediction accuracy of the generated map was 85.71 % for the LULC class of water bodies. It was seen from this table that the generated map for the year 2008 had correctly predicted all pixels corresponding to settlement class; thus, prediction accuracy for the class was found to be 100 per cent. In case of agricultural land, the generated LULC map had correctly predicted 16 pixels out of 22 pixels. Similarly, for other LULC classes, good prediction could be observed (Table 4). On the other hand, Table 5 indicated that the generated LULC map from remotely sensed data for the year 2018 had correctly classified all pixels under the classes of water bodies as well as of settlement.

The overall accuracy of the LULC classification for the year 2008 was computed to be 79.07 %, and Kappa coefficient was found to be 0.71; while these values

Table 4. Error matrix of supervised classification of LULC for the year 2008

		Reference data					
	Land-use/land-cover class	Water bodies	Agricultural land	Settlement	Natural vegetation	Sand and barren land	Total
Classified data	Water bodies	6	2	0	0	0	8
	Agricultural land	0	16	0	1	1	18
	Settlement	0	2	4	0	0	6
	Natural vegetation	1	0	0	4	0	5
	Sand and barren land	0	2	0	0	4	6
	Total	7	22	4	5	5	43

Table 5. Error matrix of supervised classification of LULC for the year 2018

		Reference data					
	Land-use/land-cover class	Water bodies	Agricultural land	Settlement	Natural vegetation	Sand and barren land	Total
Classified data	Water bodies	6	2	0	1	0	9
	Agricultural land	0	11	0	0	0	11
	settlement	0	5	7	3	2	17
	Natural vegetation	0	0	0	14	0	14
	Sand and barren land	0	1	0	0	4	5
	Total	6	19	7	18	6	56

for the year 2018 were computed to be 75 % and 0.68, respectively. As the K-value was more than 0.61, the agreement was good (Table 2) (Landis and Koch, 1977). The computed values of overall accuracies and Kappa coefficients indicated that the classification obtained by using geo-informatics was good.

Land-use/Land-cover Change Analysis

Table 3 indicates that the agricultural land-use had a positive change with the land under agriculture increasing by 3,329 ha (6.51 %) over the 10-year period (2008-2018). The reason behind increase in agricultural land might be the fact that the demand of food increased due to increasing trend of population in Samastipur district as reported by Mishra and Mishra (2018). Further, comparison of the LULC maps of the years 2008 and 2018 indicated that some part of natural vegetation area had been converted into agricultural land in staggered manner. The reduction in area coverage under natural vegetation might disturb the food chain, and thus might adversely affect the ecosystem. Hence, there is a need to give proper attention towards conservation of natural vegetation cover in the catchment. The need of conservation of natural vegetation, especially medicinal plants, in Bihar had been felt by Ambast *et al.* (2016).

The area of water bodies comprises areas of surface water either impounded in the form of lake, ponds and *chaur* area (a lowland area having water stagnation for most period of year) or flowing streams, rivers, canals, etc. The water bodies showed a negative change in terms of area spread over the period of ten years (2008-2018). Table 3 indicated that the area occupied by water bodies in the year 2008 in the catchment was 3,771 ha, which reduced to 1,726 ha in the year 2018. Hence, the area occupied by water bodies in the catchment reduced by 54.2 % (2,045 ha) during the period. This large reduction in the spread area demands attention of water management scientists towards research and implementation of appropriate water management techniques in the study area.

Table 3 indicates that there was a positive change in the settlement land during the study period. The total area under settlement had increased by 4,554 ha (58.20 %) over the ten years. The settlement area increased at Rosera, Pusa, Samastipur, Karpurigram, and Tajpur blocks/semi-urban areas. Educational factors could be the dominating forces behind the growth of the urban/semi-urban area. The residential area or built-up area had almost filled up at Samastipur city (district headquarter).

Wastelands (sand and barren lands) are described as degraded lands that can be brought under vegetative cover or under built-up area. The total area under wasteland was estimated as 2,012 ha in the year 2008, and slightly increased to 2,697 ha in the year 2018. This might be attributed to the decreasing trend of annual rainfall in the catchment (Bera, 2017).

The above discussion indicates that over the ten-year period (2008-2018), the land area under agriculture in the catchment increased by 3,329 ha (6.51 %), land occupied by water bodies reduced by 2,045 ha (54.2 %), area under settlement expanded by 4,554 ha (58.2 %), area covered by natural vegetation reduced by 6,523 ha (33.58 %), and the area under waste land increased by 685 ha (34.05 %). Hence, the land area under settlement was found to have undergone highest percentage of change. It seems that a considerable portion of the natural vegetation area in the catchment had converted into either agricultural land or settlement during the 10 year period, indicating need of conservation of natural vegetation in the study area.

CONCLUSIONS

The study presents delineation of the catchment of Burhi Gandak river falling under the Samastipur district of Bihar, estimated its area and then assessed LULC change over a period of ten years (2008-2018) using Remote Sensing and Geographic Information System techniques. The area of the catchment under the study was 84162 ha. The land under agriculture increased by 3,329 ha (6.51 %) in the catchment over the 10 year period, while the land area occupied by water bodies reduced by 2,045 ha (54.2 %). Area under settlement (built-up) expanded from 7,825 ha to nearly 12,379 ha in the year 2018, showing an increase by 58.2 per cent. Area under settlement increased at Rosera, Pusa, Samastipur, Karpurigram, and Tajpur blocks. The area covered by natural vegetation reduced by 33.58 % in 2018 as compared to that in 2008, while the area under waste land increased by 34.05 % in this period. A considerable portion of the natural vegetation area in the catchment had converted into either agricultural land or settlement during the 10-year period. The study thus inferred that there is a need to give proper attention towards conservation of natural vegetation cover in the catchment.

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