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Estimation of Urban Land Expansion Using Remote Sensing and GIS in the Context of NDBI and Land Use Land Cover Change: A Case Study of Koshi River Basin, Bihar, India

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Abstract

Global environmental change and sustainable development have become major issues receiving worldwide attention. Land use/land cover is one of the major causes of changes in the land surface environment and has become an important component of research on global environmental change and sustainable development. A land use and land cover change are the study of changes in the land cover pattern of a particular area. This study is concerned with mapping the extent of built-up area and detection of change in land use through land cover maps and it also studies the features of course change of river basin. The study is conducted in the Koshi river basin, India. The Koshi river basin is in the middle of the Himalayas, a tributary of the Ganges River, and is a very important cross-border watershed. The movement of the river has not been gradual but of a degrading nature arising from a nodal point. For this we have used Remote Sensing Data (2000-2020), DEM (Digital Elevation Model) data, Geographic Information System (GIS) techniques for mapping, and also used statistical methods. The proposed study will provide a baseline of land use and cover. Important areas will also be identified based on the extent of built-up area and LULC changes and their impacts on the Koshi river ecosystem.

Key words: Koshi River Basin, Remote Sensing, Geographic Information System, Himalayas, Global Environment Change, Sustainable Development.

1. Introduction

Man has always depended on the terrestrial biosphere to obtain valuable resources such as food, fiber and fresh water. However, over the past three centuries, with a rapidly growing human population and increased per capita consumption of resources, the Earth's biosphere and atmospheric composition have undergone extensive modifications. Along with these changes and the resulting environmental damage, there is also increasing recognition of the rapid depletion of natural resources (Wakernagel et al., 1997). Modifications in existing land use and land cover are one of the major causes of degradation of land resources and have become an important component of research as they directly affect biological diversity around the world. It has contributed to local and regional climate change as well as to global climate warming (Houghton et al., 1999). The changing nature of the land is the primary source of soil erosion (Tolba et al., 1992). These changes are changing ecosystem services, and also affecting the ability of biological systems to support human needs (Vitousk et al., 1997).

Land use and land cover are two different terms that are often used interchangeably as land use affects land cover and changes in land cover affect land use (Dimayati et al., 1996, Ribsem et al., 1994). Land use refers to the amount of land that has been used by humans and their habitat, while land cover refers to the physical characteristics of the earth's surface such asvegetation cover, water bodies, Crop areas and other features of land(Ramachandra et al., 2004).

Humans have been modifying the land for thousands of years to obtain food and other essential commodities. The extent and intensity of current LULCC rates are driving unprecedented changes in ecosystems and environmental processes at local, regional, and global levels. These changes encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water and increase the water level discharge of the rivers as well as increase the river basin runoff etc. (Ellis, 2007). By clearing tropical forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centres, human actions are changing the world's landscapes in pervasive ways (Foley *et al.*, 2005)

Urbanization is the process of human migration from rural areas to urban areas, Land use and land cover change rapidly due to the expansion of urbanization (Entrop, 2004). Changes in forest cover to agricultural land and human settlements are the main reasons for the decline in vegetation cover (Alfan, 2003). Urban areas currently cover 3% of Earth's land surface, agricultural land and these lands are used for crop production (Bruinsma, 2009). The world lost 16.31% of agricultural land due to urban expansion. These agricultural lands are converted into built up lands (Kavita et al., 2015). 31% of the Earth's total surface area is covered by forests. Per year 3.1% of forest cover is removed from the Earth's total surface area due to natural events or urban area expansion (Hansen et al., 2010). In India, 32.37% of the land area is covered by urban land and it is the second highest urban area in the world (Robbins, 2001). Around 45% of the land across India is cultivated and 22% of the land use area is forest land. Urbanization or expansion of built-up area also affects rural areas by conversion to agricultural land or crop land (Patil et al., 2002). Urbanization alters the land use and land cover in the context of changes in catchment hydrological responses particularly changes in river course.

The river is an important resource of surface water for domestic and irrigation purposes. At present, the water quality of the river is of serious concern due to rapid increase in population, urbanization, industrialization and deforestation. Available river water resources are getting depleted and being adversely affected both qualitatively and quantitatively (Sati et al., 2008, Desai et al., 2010, Srivastava et al., 2013). River valleys are affected by land use and land cover changes.

As the world's second-largest populous country with a vast and growing economy, India's future is uncertain due to lack of food and water supplies. It is not surprising that some Indian river basins are already facing water scarcity due to the increase of urban population in the river basin area (Babur et al., 2015). Some of the affected rivers are the Ganges River of India. Indian civilization has also been affected by urbanization during the 1950s (Sinha et al., 2014). Excessive urbanization and population growth have greatly altered the landscape and caused major changes in the hydrological cycle such as large-scale removal of natural vegetation patterns and also changing the frequency of flood droughts of the Ganges River (Mishra, 2010). On the other hand, the Narmada River changes its rainfall (Mandal et al., 2015), and the Netravarthi river of Karnataka state also changes its stream flow due to changes in land use and land cover and built-up area expansion. Due to this the river has lost its forest cover, agricultural land and has also changed its water level discharge (Babar et al., 2015).

The interaction of biotic (living) and abiotic (non-living) things of a river is known as river ecosystem (Angelier, 2003). The river ecosystem provides valuable services such as settlements, infrastructure and areas for production for many years. They also provide water for drinking, cooling and irrigation, fish as a food supply and may have cultural and aesthetic value (Bock et al., 2018).

The Himalayan region is the source of the world's major river systems including the Ganges, the Brahmaputra and the Indus as well as the centre of the world's greatest biodiversity and ecosystem services. The Koshi River Basin covers the headwaters of major river systems that play an important role in drinking, agriculture, tourism and other environmental services. The Koshi river basin is an important border crossing of the central Himalayas, South Asia (Xu et al., 2017). Across the basin, there are major changes in altitude, habitat complexity, ecosystem integrity; Land cover diversity, and regional differences due to land use and land cover change. Koshi river changes its course over the last 200 years and it runs about 150 km from east to west. The change in the course of the river is due to the accumulation of large amounts of mega fans (Chakraborty et al., 2010) as well as the construction of more dams and embankments by the Indian government to slow the flow of the river. The Koshi River is also commonly known as the “Sorrow of Bihar” because of its annual floods affecting a fertile area of about 21,000 km2 of agricultural land, greatly disturbing the rural economy of the state of Bihar (Sharma, 1996).

The main objectives of the study are to assess land use and land cover change along the Koshi river basin with special reference to agricultural land and built-up land extent. To assess the change in the river course of the main stem and its impact on the flood plain area.

2. Study area

The Koshi River Basin is the most dynamic river in the world and is bordered by three countries, India, Nepal and China (Xu et al., 2017). Koshi River is known as Rigveda in Nepal and "Kaushika" in Bihar in North India and is the oldest river in India. The Koshi River originates in the central Himalayas at an altitude of more than 7000 meters above sea level. The entire Koshi River Basin (KRB) ranges from 85°22´ to 88°21 East longitude and 26°47´ to 29°12 North latitude. It extends from the Brahmaputra River in the north to the southern border of Nepal in the south and Kathmandu in the west to the eastern border of Nepal in the east. The length of the Koshi River is 729 km and it flows through an area of about 74,500 km^2 in Tibet, Nepal and Bihar. Out of the total catchment area of Koshi River, only 11,070 km^2 lies in Indian territory, and the remaining 63,430 km^2 lies on the other two bordering countries of India i.e., Nepal and China. The total catchment area up to its confluence with the Ganges River is 1, 00,800 km^2 (Nayak, 1996).

The Kosiriver basin is bounded by the Himalayas in the north, the Mahananda basin in the east, the BudhiGandak basin in the west, and the Ganges in the south. The basin in the Indian region is spread over the areas of Saharsa, Purnia, Khagaria, Madhubani, Sitamarhi, Muzaffarpur, and Darbhanga districts of Bihar state. The othersignificant rivers in this basin are the Kosi (mainstream), the Bagmati of the Kamla, Balan, andAdhwara group. The Kosi drains an area of 74,500 km^2, of which only 11,070 km^2 lies in Indian territory. Kosi is generally known for its tendency to change its course in the west direction. During the last 200 years, the river has shifted westward for a distance of about 112 km and devastated large tracts of agricultural land in Bihar.

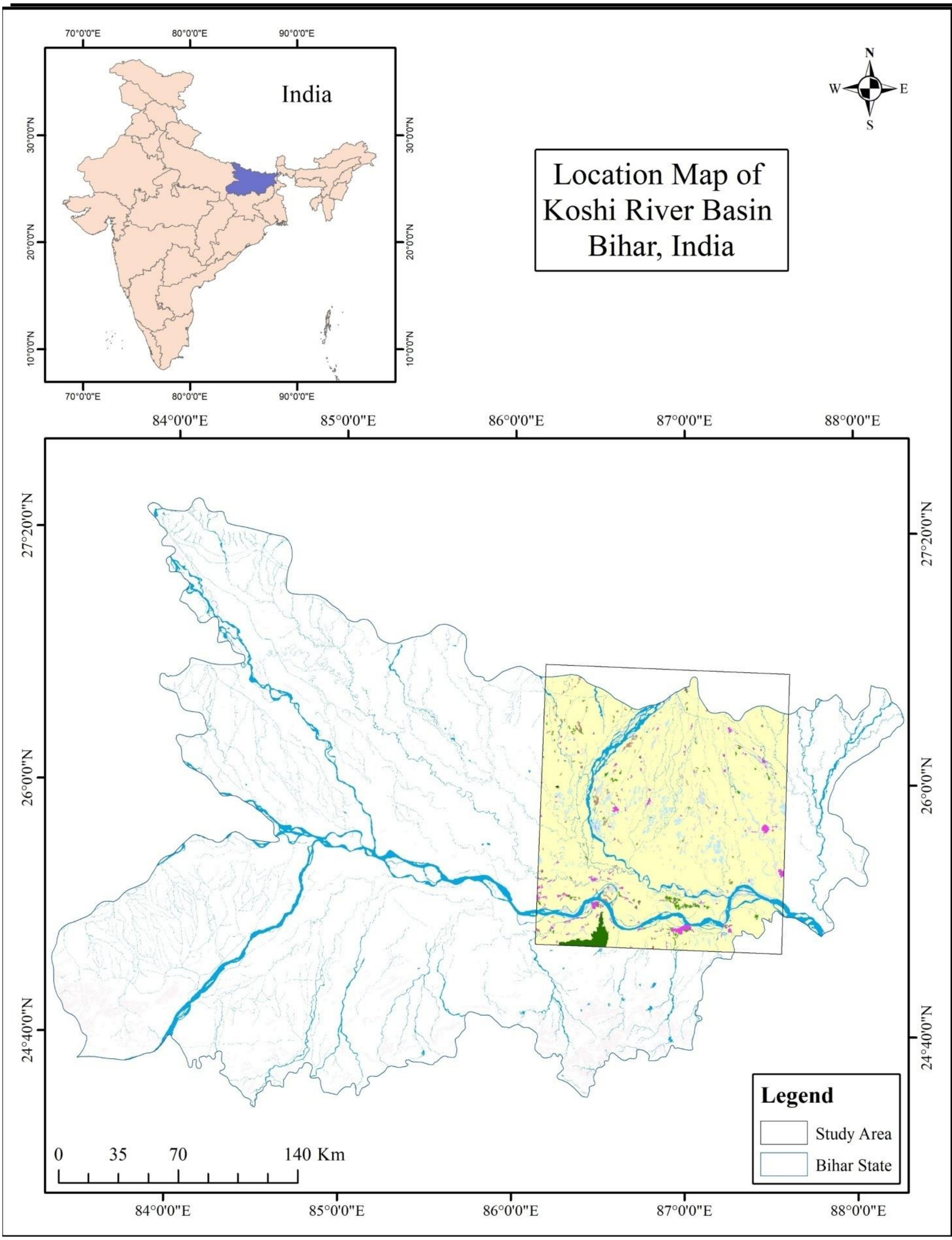

Figure 1. Study area map

3. Materials and Methods

3.1. Dataset used

The satellite images were sorted and classified for analysis and interpretation. Landsat images are among the most widely used satellite remote sensing data and their spectral, spatial and temporal resolution make them useful inputs for mapping and planning projects.Landsat Thematic Mapper 5 and 8 were used for land use and land cover classification of 2000 and 2020. Landsat-5 was used for a year of 2000 and for the year of 2020 Landsat-8 was used. The resolution of the both datasets is 30m. These datasets were downloaded from the USGS (United States of Geological Survey) site. For calculating height of the study area ASTER DEM was used at a resolution of 30m.

3.2 Data Preparation

For the data preparation two GIS softwares namelyErdas Imagine and ArcGIS were used. Data were rectified accordingly, and created mosaic files for further analysis. Dataset were clipped as per area of interest and further analysis.

3.3 Methods

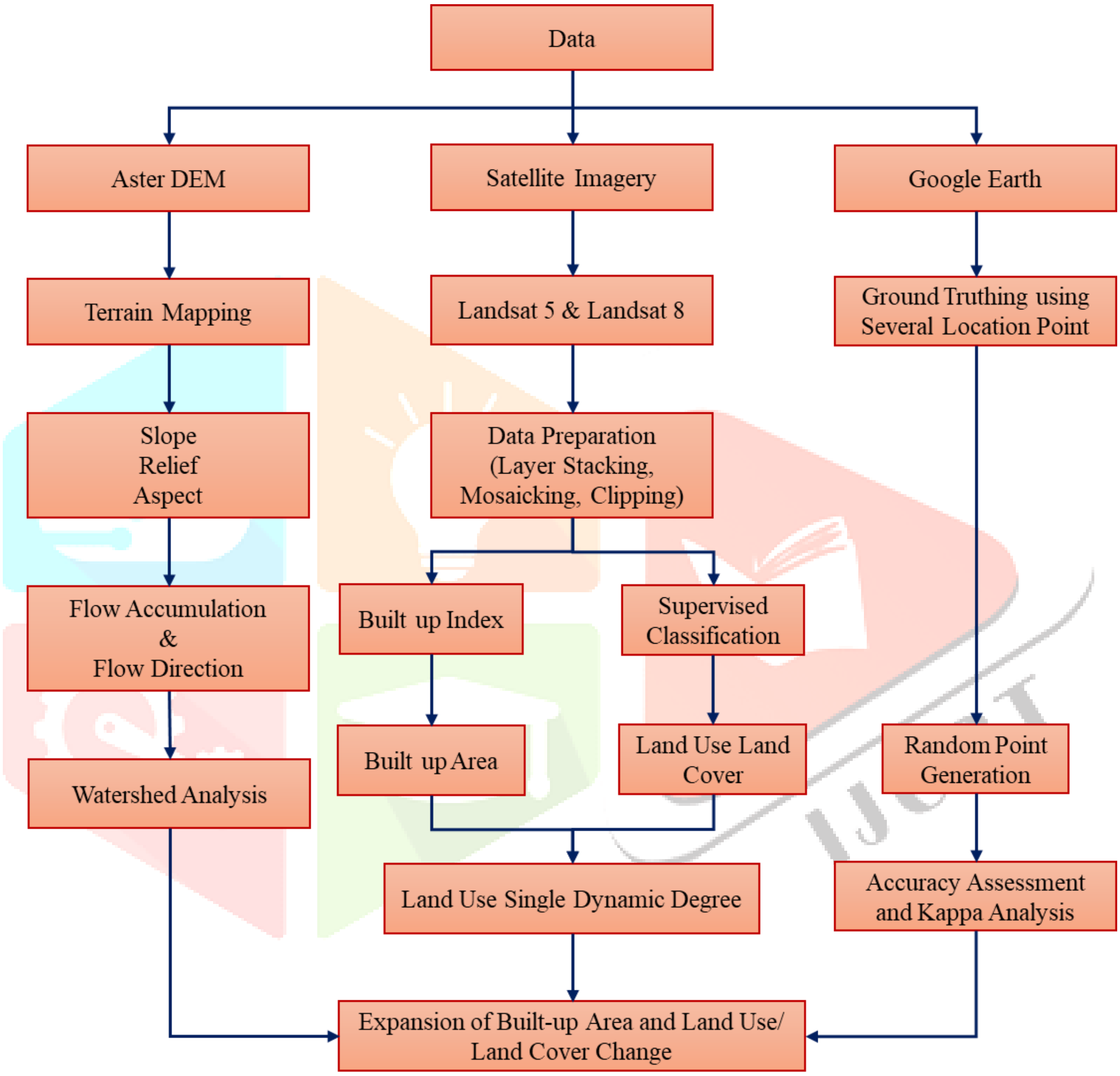

Figure 2. Methodology

3.3.1. Land use and land cover change analysis

To analyse the land use and land cover change of the Koshi River Basin Supervised classification method was applied in the ERDAS imagine software. In this method the user specifies the various pixel value or spectral signatures, which pixel values or spectral signatures associated with each respective class. This process is done by the selecting representative sites of known cover type which are known as "Training sites or Areas". This classification method has used Maximum Likelihood algorithm,a most common supervised classification method(Rawat et al., 2015).The satellite images were classified into seven respective classes these are- Water Bodies, Marshy Area, Fellow Land, Barren Land, Grass Land, Shrub Land, Dense Forest and Built-up Area.

Sr. No.	Land use/land cover class	Description
1	Water Bodies	Includes the rivers, ponds, reservoirs etc.
2	Marshy Area	Includes the areas which are always wet
3	Fellow Land	Includes the piece of land that normally used for farming but left with no crops
4	Barren Land	Includes the areas which covered by the sand.
5	Grass Land	Includes the all cultivated crops, Grass lands
6	Shrub Land	Includes the all-small plants and shrubs.
7	Dense Forest	Includes the areas which are covered by the trees.
8	Built up Area	Includes the areas of constructions, roads, bridges, houses etc.

Table 1. Description of the land use and land cover types

3.3.2. Classification Accuracy Assessment and LULCC %

In this study, classification accuracy ismeasured by a confusion matrix. The accuracy assessment replicates the difference between the classification data and the referenced data. If the reference data is very imprecise, the assessment may specify that the classification outcomes are poor and vice versa.

To calculate the LULCC (%), the initial and final LULC area coverage was compared with the help offollowing Eq. 2.

$$\text{LULCC percentage} = \frac{(\text{Present LULC area} - \text{Previous LULC area})}{\text{Previous LULC area}} \times 100 \quad (2)$$

3.3.3 Land use dynamic degree

This study is chosen Single Land Use Dynamic Degree to measure thespatial andtemporal changing characteristics of land use land cover. This degree shoes the total amount of change of land-use class in a certain period of time in the study area (Chunxiao et al., 2008). The single land use dynamic degree index can be used to quantitatively describes the changing speed of regional land use classes. This is also helpful for comparison the regional differences of land use change and analysing the change trend of land use (Li et al., 2017). If the Dynamic degrees are positive that show the number of the land use types have an upward trend in this time and vice versa.

3.4 Built-up Index: Normalised Difference Built-up Index (NDBI) is used to extract the built-up features and it ranges from +1 to -1. It is calculated by this formula:

NDBI= (SWIR- NIR)/ (SWIR+NIR)

Here, SWIR is Short Wave Infrared, NIR is Near Infrared

4. RESULT AND DISCUSSION

The result of change detection is obtained through the analysis of multi-temporal satellite imageries (2000-2020). These imageries have been classified in seven classes, namely- water bodies, marshy land, sand bars, forest, fallow land, crop land, built-up land. These imageries were diagrammatically illustrated with the help of maps and graphs.

4.1 Terrain map

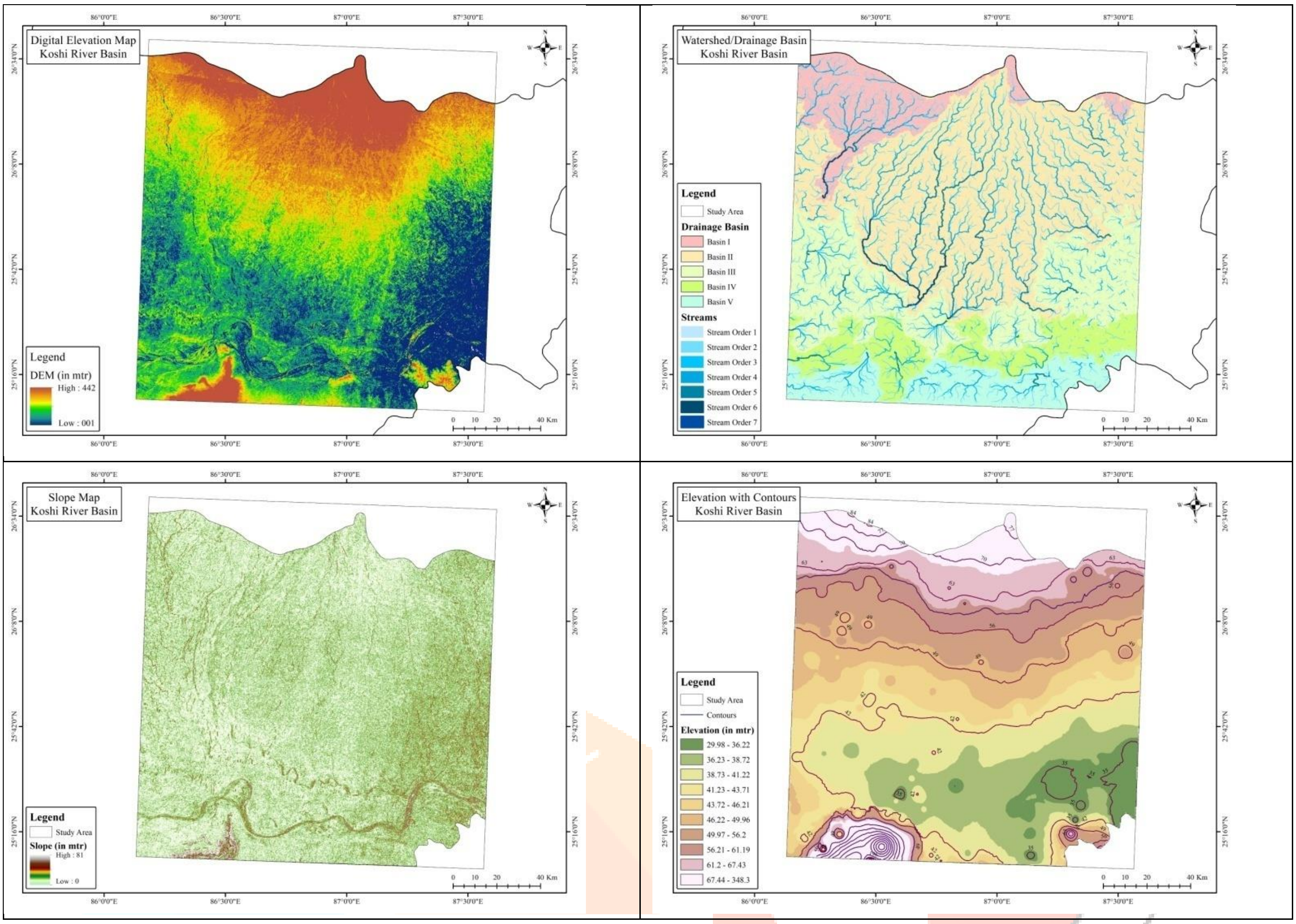

Figure 3. The Terrain map of Koshi River Basin

4.1.1. Digital Elevation Model: A digital elevation model, also known as a DEM, is a type of raster GIS layer. They are raster grids of the Earth's surface referred to in terms of vertical datums - zero height surfaces referred to by scientists, insurers, and geoscientists. DEMs typically arise from remote sensing data collected by satellites, drones, and aircraft.

4.1.2. Slope: A slope map is a topographic map showing changes in elevation on a very detailed scale. One of the foremost valuable uses of a map is to predict the flow of water. Groundwater can cause buildings and parking lots to overheat and move. A slope map can also indicate the placement of utility lines and their depth. The Slope Map has been organized with the help of the Digital Elevation Model (DEM).

4.1.3. Elevation Map: An Elevation or altitude map shows different altitudes in an area represented on a map. Altitude is usually measured in meters or feet with reference to sea level. A contour line connects points in a map representing areas of equal elevation. Elevation maps are also called topographic maps.

4.1.4. Drainage Pattern: The drainage map of the study area shows the patterns of the river or stream network. Streams and networks are administrated by the topography of the land, whether the selected area is dominated by rocks types and also the slope of the land. Drainage map is created using DEM data and hydrology tools of Arc GIS software. (See Figure 3(b)).

4.2 Land use /Land cover change analysis

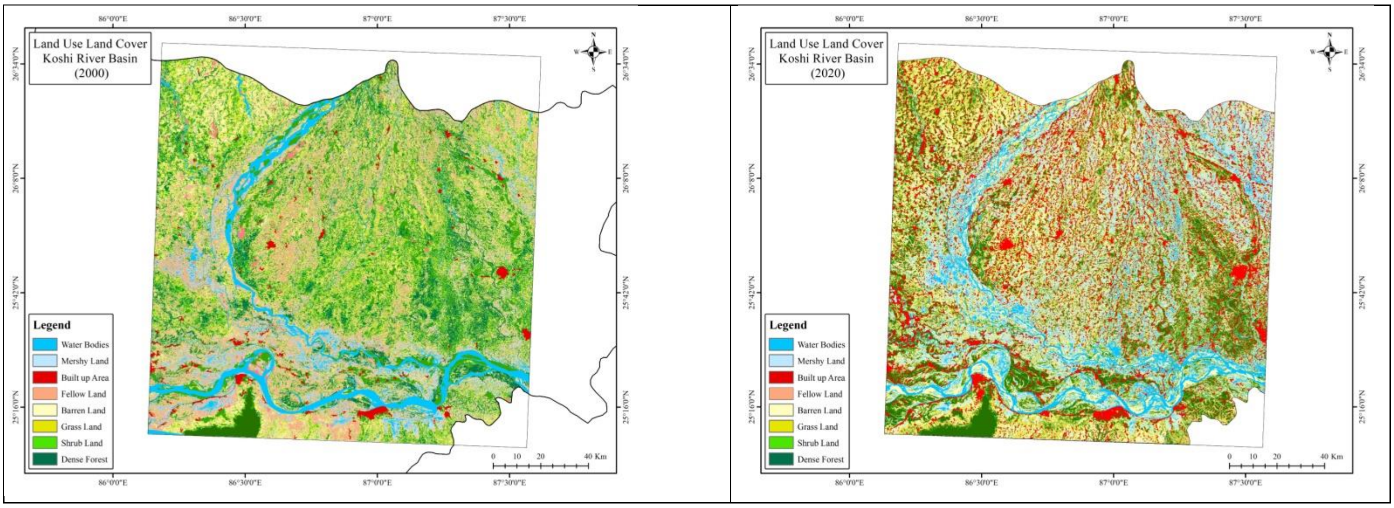

Figure 4. LULC change of Koshi River from the year of 2000 to 2020.

During the period of 2000 to 2020 all the land use/ land cover types are changed dynamically. In 2000 Water bodies covered an area about 1208.26 km² and it increased in 2020 by 1591.50 km². From the 2000 to 2020 the area of the fallow land decreased because most of the fallow land was converted into the barren land and built-up land. In 2000, fallow land covered an area about 4014.36 km² but it decreased by 3184.53 km² in 2020. While Built-up land was increased over the past 20 years because most of the forest area, grass land and fallow lands were converted. In 2000, 251.32 km² areas were covered by the built-up area and it increased by 1098.44 km² in 2020. On the other hand, forest area was decreased continuously from the 2000 to 2020 due to conversion of the lands. In 2000, forest covered an area of 3840.54 km² and it decreased in 2020, by 2372.55 km² area. Marshy land covered 979.43 km² areas in 2000 and it increased in 2020, covered an area of 2345.57 km². (Fig. 4 and Table 2)

Sr. No.	**Land use/cover categories**	**Area 2000**		**Area 2020**	
		km²	**%**	**km²**	%
1	Water Bodies	1208.26	5.83	1591.50	7.68
2	Marshy Land	979.43	4.73	2345.57	11.32
3	Fellow Land	4014.36	19.37	3184.53	15.37
4	Barren Land	4255.74	20.53	4853.37	23.42
5	Grass Land	3132.47	15.11	1879.87	9.07
6	Shrub Land	3043.20	14.68	3399.50	16.40
7	Dense Forest	3840.54	18.53	2372.55	11.45
8	Built up Area	251.32	1.21	1098.44	5.30
	Total Area	20725.33	100	20725.33	100.0

Table.2 The total area of the Koshi River Basin from 2000 to 2020

4.2.1 Accuracy Assessment:

Classified Data	Water Bodies	Marshy Land	Fellow Land	Barren Land	Grass Land	Shrub Land	Dense Forest	Built up Area	Row Total	User's Accuracy
Water Bodies	17	6	2	0	2	0	3	1	31	54.8
Marshy Land	3	18	1	0	0	1	0	0	23	78.3
Fellow Land	1	0	19	1	1	1	1	2	26	73.1
Barren Land	0	3	2	19	1	0	0	1	26	73.1
Grass Land	5	1	2	0	19	2	1	1	31	61.3
Shrub Land	1	0	0	0	1	17	1	0	20	85.0
Dense Forest	0	0	1	0	0	1	23	1	26	88.5
Built up Area	3	0	0	2	1	1	1	9	17	52.9
Column Total	30	28	27	22	25	23	30	15	200	
Producer's Accuracy	56.67	64.29	70.37	86.36	76.00	73.91	76.67	60.00		
OA = 141 / 200 = 0.705*100 = 70.5%						Kappa coefficient = 0.66				

Table.3a. Accuracy Assessment year 2000

Accuracy assessment of the LU/LC classification results obtained showed an overall accuracy 70.5% for 2000, and 81.5% for 2020. Kappa coefficients for these imageries were 0.66 for 2000, and 0.79 for 2020.

Classified Data	Water Bodies	Marshy Land	Fellow Land	Barren Land	Grass Land	Shrub Land	Dense Forest	Built up Area	Row Total	User's Accuracy
Water Bodies	23	1	2	0	0	0	0	1	27	85.2
Marshy Land	2	26	1	0	0	1	0	0	30	86.7
Fellow Land	1	0	24	1	1	1	0	2	30	80.0
Barren Land	0	0	2	19	1	0	0	1	23	82.6
Grass Land	1	1	2	0	23	2	1	0	30	76.7
Shrub Land	1	0	0	0	1	17	1	0	20	85.0
Dense Forest	0	0	1	0	0	1	18	1	21	85.7
Built up Area	0	0	0	2	1	2	1	13	19	68.4
Column Total	28	28	32	22	27	24	21	18	200	
Producer's Accuracy	82.14	92.86	75.00	86.36	85.19	70.83	85.71	72.22		
OA = 163 / 200 = 0.815*100 = 81.5%				Kappa coefficient = 0.79						

Table.3b. Accuracy Assessment year 2020

4.3 Land use/ Land cover Change %

Sr. No.	Land use/Land cover categories	Change Area (%)	Single Land Use Dynamic Degree (k %)
1	Water Bodies	31.72	1.59
2	Marshy Land	139.48	6.97
3	Fellow Land	-20.67	-1.03
4	Barren Land	14.04	0.70
5	Grass Land	-39.99	-2.00
6	Shrub Land	11.71	0.59
7	Dense Forest	-38.22	-1.91
8	Built up Area	337.07	16.85

Table 4. Land use /Land cover Change % and SLUDD of Koshi River Basin from 2000 to 2020

From 2000-2020 the area of the fallow land, Grass Land and Dense Forest, are decreased by -20.67%, -39.99%, and -38.22% and Water Bodies, Marshy land, Barren Land, Shrub land and built-up area has been increased by 31.72%, 139.48%, 14.04%, 11.71% and 337.07% (Table 4, Figure 5). From the (Table 3) we can find out that the water bodies were increased by 1.59% in each year from the 2000 to 2020, while the increasing rate of Built area development is about 16.85% per year from 2000 to 2020.

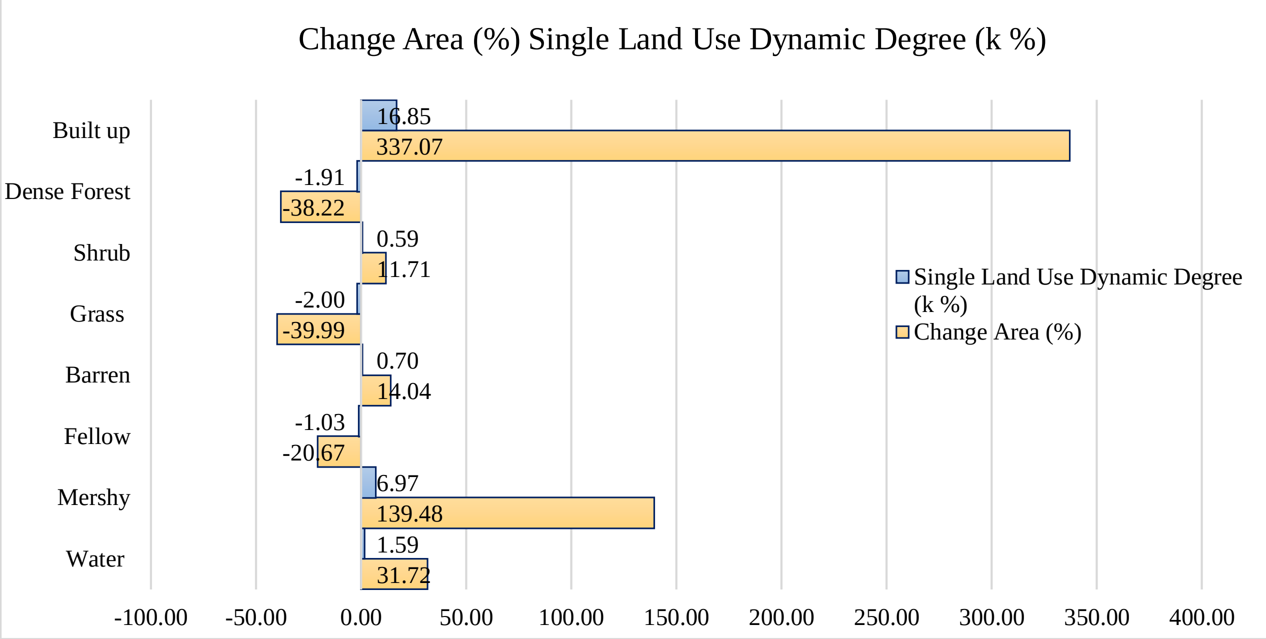

Figure 5 LULC change% and SLUDD

Figure 5 shows that the land use/ land cover change in percentage from the 2000 to 2020. Graph also shows that intensity of the single dynamic degree of the land use and land cover type from 2000 to 2020. From the result of the single dynamic degree, we have found that the built-up area was the highly increased area over the past 20 years and Dense Forest with grass land were introduced as a very highly decreased land use type during this period due to conversion of the lands into the built-up-land or urban land.

4.4 Results from Built-up Index Indices with buffer zone

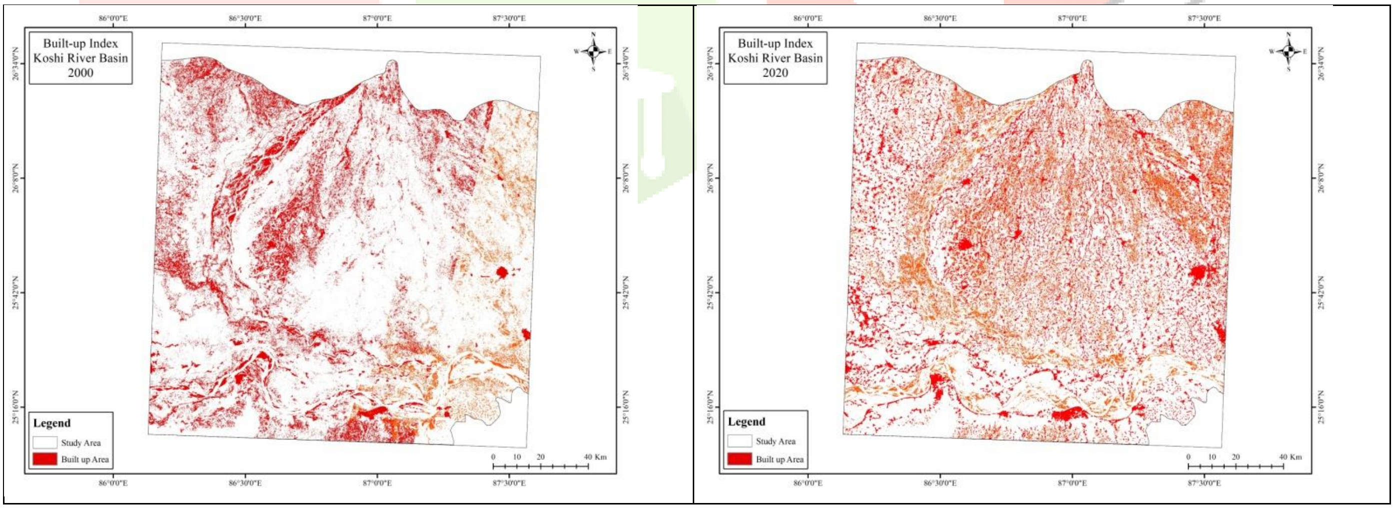

Figure 6. Changes over built-up land (2000-2020)

Figure shows that the expansion of built-up land of Koshi River Basin from 2000 to 2020 and figure 6 shows that the change the built-up land over the past 20 years.

From the result of the built-up index, we have found that the built-up land was increased from the 2000-2020. In 2000, it covered 251.32 areas but it increased in 2020 by 1098.44 km² (Figure 6).

5. Discussion:

Geographic Information Systems (GIS) combined with Remote Sensing (RS) have been widely applied to detect and analyze the spatial dynamics of the processes and patterns of urban development and LULC change at the local, regional and global levels. Recognized as a powerful and cost-effective tool. scales (Hathout, (2002), Harold, et al., 2003 and Lambin et al., 2003). Remote sensing provides valuable multispectral data sets that cover the study areas with both positional spatial extension and high temporal frequency (Xiao et al., 2006). GIS is useful for pre-processing, analysis and mapping of spatio-temporal processes and patterns of LULC change. Remotely observed data made it possible to study land use and land cover changes in a short time and provide better accuracy (Kachhawala et al., 1985).

The existing landforms in the world are being changed by anthropogenic influences. Among many factors, urbanization is one of the key drivers of LULC change that is far-reaching and destabilizing. Urbanization has also affected important river basins of the world and its effects in India are also promising. The Ganges, Brahmaputra, Narmada and Koshi rivers are the most affected rivers due to urbanization as they flow in a human-dominated landscape. Remote sensing and GIS will be the most effective tools for assessing these changes and they can provide important information for urban and conservation planning.

6. Conclusion:

The study was carried out by multi-temporal satellite imagery and Geographic Information System (GIS) techniques.The result of the work showed that the land use and land cover change every year and its area also changes every year due to the river changing its course. In 2000, the waterbodies covered an area of 1208.26 km^2 and it has increased to about 1591.50 km^2 in the year 2020. The built-up area has been increased by 847.12 km^2 which is about337.07% during the study period of 2000 to 2020. The reason behind this is that most of the forest area and and crop land gets converted into built up land every year.

From this study, it can be concluded that the land use and land cover of the Koshi river basin within the study area has changed significantly due to urban expansion from 2000 to 2020. The ecosystem of Koshi river basin is affected by changing patterns of land use and land cover.

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