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Land Use/Land Cover Change Detection Study Using Remote Sensing and GIS Technique in Puthimari River Basin - A Transboundary Basin Between Bhutan and India

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ABSTRACT

Using remote sensing and GIS technique, we analyse the change detection of different land use/land cover (LULC) types that has taken place in Puthimari river basin during a two-decade period from 1999 to 2019. Supervised classification method with maximum likelihood algorithm have been applied to prepare the LULC maps. The LULC change detection has been performed employing a post-classification detection method. Puthimari is a north bank sub-catchment of River Brahmaputra, the northern part of which falls in Bhutan and the rest falls in the Assam state of India. The primary LULC types of the basin are, dense vegetation which is predominant in the upper catchment, crop land and rural settlement. Thus, five different classes have been considered for the analysis, viz., dense vegetation, water bodies, silted water, cropland and rural settlement. The results showed that the rural settlement and water bodies in the basin increased by 42.70% and 30.31% from 1999 to 2019. However, dense vegetation, silted water and cropland decreased by 9.24%, 27.47% and 28.10% during these two decades.

Keywords : Supervised classification, LULC, Maximum likelihood, Landsat, Puthimari, Change detection

I. INTRODUCTION

"Land use" and "land cover" are commonly termed as LULC that provide useful topographical information about the surface of the earth and the associated anthropogenic activities [1]. Assessment of LULC has become one of the most important parameters for proper and meaningful management of land resources. LULC changes are primarily driven by both natural phenomena and human activities, and are widespread and accelerating processes with obvious impact on the environment [2, 3]. LULC change detection is important as it is an indicator of climate change. Also, over a particular time period, the landscape dynamic of any area can be better understood with the help of such study.

Sensing is a powerful but low-cost tool to monitor land-use change with high temporal resolution [4]. There are three major advantages of remote sensing data. These are, the data are acquired on real time, it covers the same area repetitively which helps in temporal variation study, and synoptic view of an area is possible through remote sensing data. If knowledge of the area to be classified as well as knowledge of reflectance properties of the ground materials is already known, then manual classification technique is considered as an effective method for classification. Supervised classification, which according to [5], can be defined as the process by which pixels of unknown identity in an image can be classified from samples of known identity in specified locations which are termed as training sites. One of the widely used supervised classification methods is "*parallelepiped method*" wherein an unknown pixel in an image is assigned a class based on its data values, which are compared to an existing data set with known threshold values of all signatures in every band. For that pixel to get assigned to a specific class, its data values should fall within the threshold of that class of signature for each band. Maximum likelihood algorithm is based on the probability that a pixel has to belong to a particular class. The assumptions of this algorithm are that the probabilities are equal for all classes and the input bands have normal Gaussian distributions [6]. Heavy reliability on the normal distributions of the data in input bands and long computational time are on the other hand two major disadvantages of maximum likelihood algorithm. Also, this method requires long computational time. Unlike the supervised classification approach, the unsupervised classification approach doesn't use *a priory* information, rather scrutinize the pixels in an image and then based on natural groupings, combine them into number of different classes. Knowledge Base Classification (KBC) method is useful when for classification, only spectral information is not enough [7, 8]. In fuzzy classification technique, fuzzy logic concept is employed to address the problem of mixed pixels that assigns a degree of membership of each pixel to each class [9].

There are two basic methods to study the LULC change detection: post-classification comparison and pixel-to-pixel comparison [10], among which post-classification comparison is known to be one of the most accurate methods for change detection [11]. In this commonly used method, two or more images of different dates are first classified separately and then are compared [12, 13]. [14] compared five different methods to study the LULC changes and reported that each of these methods have merits of their own. The methods they employed were, post-classification cross tabulation, cross-correlation analysis, neural networks, knowledge-based expert systems and image segmentation and object-oriented classification. In a study on LULC mapping of three different districts of Haryana, India, [15] reported that the changes in LULC in these districts is mainly due to heterogeneous climate and physiographic conditions. Based on statistics extracted from four LULC maps using GIS, [16] presented the change analysis of Kathmandu Metropolitan. According to this study, transition matrices and land use statistics are two important information to analyze the land use changes. [17] analyzed land cover changes of Bombana, Indonesia due to gold mining using sentinel 1A data. [18] integrated Sentinel 2B and Sentinel 1A data using Gram-Schmidt method to prepare the LULC map of Kirkuk city of Iraq.

Landsat-TM images are the source of continuous records and information of the surface of the earth [19] which in turn is helpful to identify the environmental changes that take place due to both natural and anthropogenic causes [20]. To map and monitor land cover changes in the seven-country Twin Cities of Minnesota Metropolitan Area for the years 1986, 1991, 1998 and 2002, [21] developed a methodology using multi-temporal Landsat TM data. A post-classification method with maximum likelihood classifier algorithm was adopted by [22] to examine rapid urbanization mediated LULC changes in Lagos during a two-decade period. [23] applied two different change detection techniques namely, comparison of classification and multivariate alteration detection (MAD) to assess land cover changes in El Rawshda forest, Sudan by using Landsat ETM+ and ASTER imageries. In the north-eastern part of India, [24] studied the impact of coal mining on LULC in Jaintia hills district of Meghalaya using Landsat data for four different years from 1975 to 2005 They concluded that during this period, the mining area had been increased by four times while the forest area decreased by three times. [25] studied the LULC change detection in the Dehradun valley, India between 2000 and 2009 using satellite data of Landsat, LISSIII, SRTM and digital SOI topographic maps. In an arid environment of the Kutch, Gujarat, [26] conducted LULC study during 1999 to 2009 using a combined method of remote sensing and GIS. [27] introduced land consumption rate and land absorption coefficient for change detection analysis in Bhagalpur, Bihar, India during 1976 to 2008. [28] studied the LULC changes in Orr watershed located in the Ashok Nagar district of Madhya Pradesh, India using Landsat-8 data. [29] used Survey of India toposheets for the year 1967-68 and Landsat (ETM+) for the year 2014 to study the changes in LULC in the Kolong river basin of Assam, India. They found that 767.57 km^2agricultural land has been decreased and 769.79 km^2built-up area has been increased during the period from 1967-68 to 2014.

Puthimari is one of the major north bank tributaries of river Brahmaputra that originates in the Bhutan Himalaya at an altitude of 3750m [30]. Out of the total area of approximately 1500 km^2 of the Puthimari basin that lies between 26°10′N-27°18′N latitude and 91°27′E-91°50′E longitude, 710 km^2 (≈47%) falls within Assam, India covering three districts namely Nalbari (46 km^2), Kamrup (525 km^2) and Darrang (139 km^2). The rest of the catchment falls in Bhutan. The upper part of the catchment in Bhutan is mainly covered by forest, while the plain areas in Assam are mainly covered by rural settlements and agriculture. In the present study, LULC change detection has been analyzedin the Puthimari basin during a two-decadal period from 1999 to 2019. Figure1 shows the catchment area of Puthimari basin.

II. MATERIALS AND METHODOLOGY

Remote sensing and GIS techniques have been employed to delineate the watershed and to prepare the LULC maps of the study area. The watershed has been delineated using ASTER GDEM of 30m resolution in ArcGIS version 10.2.2 software. LANDSAT5-TM data of 30m resolution have been used for the years 1999 and 2009. For 2019, Landsat-8 data of 30m resolution has been considered. The LANDSAT data sets were imported in ERDAS Imagine version 2013remote sensing software where the false color composite (FCC) images have been created. The LULC classification for different years has been carried out using supervised classification method with the maximum likelihood classifier algorithm. Different polygons have been digitized in the image for different LULC types to collect spectral signatures from the training sites which then are used for classification of all other pixels in an image. Five different LULC types have been considered in the study area viz., dense vegetation, surface water bodies, silted water, cropland and rural settlement. To perform the LULC change detection, a post-classification detection method has been taken into consideration. Classified images of different years were compared in order to determine quantitative aspects of the changes for the periods from 1999 to 2019. In this regard, percent of total area covered by different classes have been compared in each year. The increase and decrease in area for each category of LULC were then determined and compiled for three different periods, 1999-2009, 2009-2019 and 1999-2019.

III. RESULTS AND DISCUSSIONS

The delineated Puthimari catchment is shown in Figure 1. While delineating the watershed in ArcGIS software, the total area of the Puthimari basin has been calculated as 3225.47 km^2.

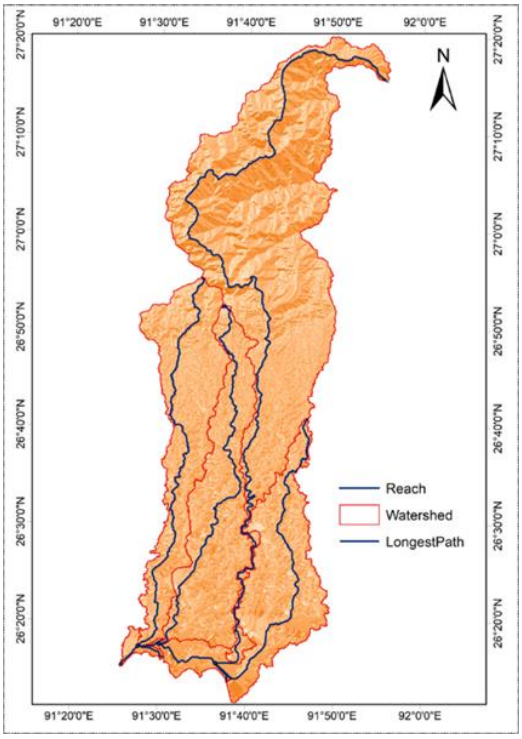
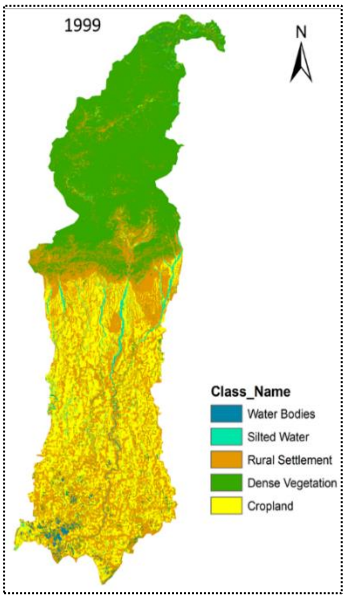


Figure 1 : The Puthimari Basin delineated from ASTER GDEM

In this study, LULC maps for the three different years i.e. 1999, 2009 and 2019 have been prepared as shown

in Figure 2 using supervised classification technique portraying the five different classes.



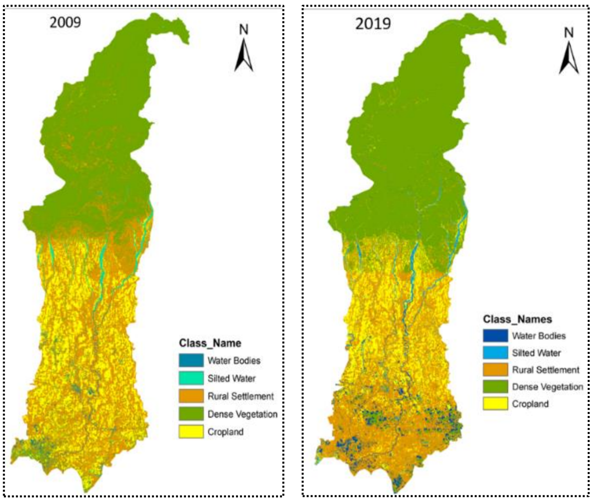


Figure 2 : LULC maps of three different years

Table I represents the areas covered by the five different LULC classes in different years. A change detection analysis

has then been carried out from the acquired data to understand the gains and losses of different classes in the basin.

TABLE1: AREA COVERED BY DIFFERENT LULC CLASSES FROM 1999 TO 2019

LULC Class	Area covered in Km^2		
	1999	2009	2019
Dense vegetation	1520.49	1458.96	1380.00
Water bodies	44.69	50.18	58.23
Crop land	752.09	659.74	540.74
Rural settlement	837.70	992.06	1195.37
Silted water	70.50	64.52	51.13

Throughout the study period that covers two decades from 1999 to 2019, compared to the other classes, dense vegetation has been observed to cover the maximum area that mainly occupies the northern part of the catchment that falls mostly in Bhutan and part of Assam state in India followed by rural settlement, crop land, silted water and water bodies. For all the three time periods i.e. 1999-2009, 2009-2019 and 1999-2019, decrease in area covered by dense vegetation, crop land and silted water and increase in area covered by rural settlement and water bodies can be witnessed graphically from Figure 3 and Figure 4. Based on the total catchment area, the percent of total basin area covered by each LULC class has been determined. Figure 3 shows the pie diagrams depicting the percent of total area covered by each LULC class. Figure 4 shows the Pie diagrams giving year wise percent of total area covered by each LULC class in Puthimari river basin from 1999 to 2019.

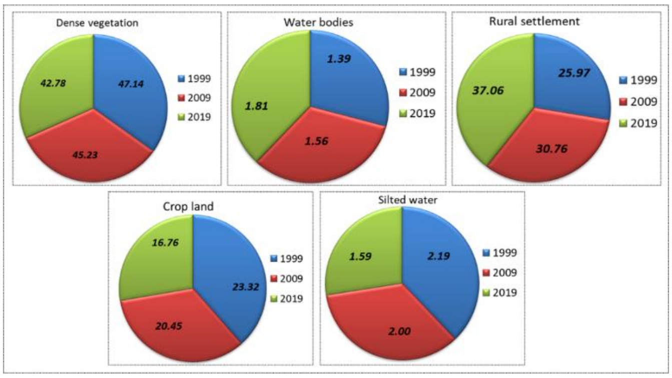


Figure 3 : Pie diagrams depicting the percent of total area covered by each LULC class

The percentages for dense vegetation, silted water and crop lands were found to be 47.14%, 2.19% and 23.32% respectively in the year 1999. After one decade i.e. in 2009, the area covered by these three classes decreased to 45.23%, 2.00% and 20.45%. A further decrease to 42.78%, 1.59% and 16.76% could be seen after one more decade i.e. in 2019.

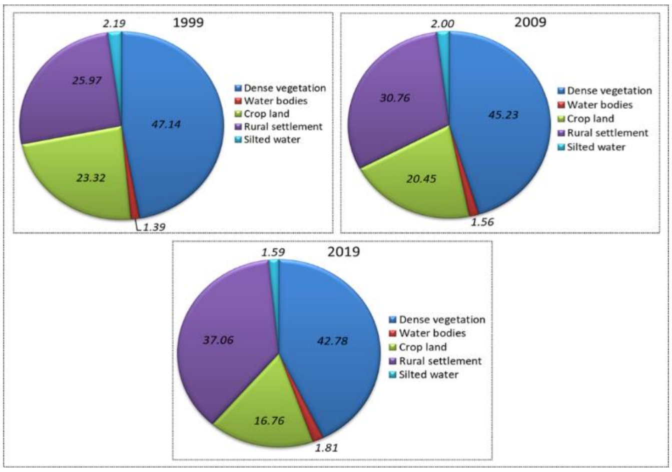


Figure 4 : Pie diagrams giving year wise percent of total area covered by each LULC class

A gradual decrease in area covered by these three classes is an evident that the decreased land has been occupied by some other land use classes. It is proved from both the Fig. 3 and 4 that the other two classes considered in the study i.e. rural settlement and water bodies have been increasing in terms of area from 1999 through 2009 to 2019. In 1999, 1.39% and 25.97% of total area respectively were covered by water bodies and rural settlement that increased to 1.56% and 30.76% in 2009. These then further increased to 1.81% and 37.06% in 2019. The percent changes in different classes during the time periods have been calculated as shown in Table II.

TABLE II : PERCENT CHANGES FOR DIFFERENT LULC CLASSES DURING DIFFERENT TIME PERIODS

Time period	**Percent change in LULC classes (%)**				
	Dense vegetation	**Water bodies**	**Crop land**	**Rural settlement**	**Silted water**
1999-2009	-4.05	12.29	-12.28	18.43	-8.47
2009-2019	-5.41	16.04	-18.04	20.49	-20.76
1999-2019	-9.24	30.31	-28.10	42.70	-27.47

These then are graphically represented as bar diagrams in Figure 5(a), (b) and (c) respectively for 1999-2009, 2009-2019 and 1999-2019. During the first decade from 1999 to 2009, rural settlement increased the maximum by 18.43% in contrast to maximum decrease in crop land by 12.28%. Also, dense vegetation and silted water decreased by 4.05% and 8.47% respectively and water bodies increased by 12.29%. Moving to the next decade from 2009 to 2019, again the rural settlement and water bodies increased by 20.49% and 16.04% respectively leading to 5.41%, 18.04% and 20.76% decrease in dense vegetation, crop land and silted water. Again, when the two-decade period has been considered altogether from 1999 to 2019, from Fig.7 it is clear that overall increase in rural settlement and water bodies in the basin are by 42.70% and 30.31% respectively. area covered by dense vegetation, crop land and silted water have been decreased by 9.14%, 28.10% and 27.47% respectively.

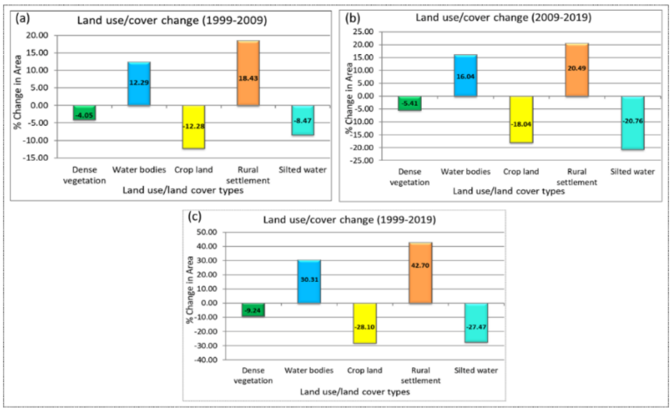


Figure 5 : Graphical representation of LULC changes during (a)1999-2009, (b) 2009-2019 and (c) 1999-2019

From the result, the continuos decrease in crop land and dense vegetation can be attributed to increase in rural settlement. Significant population growth and migration of people from nearby places to the basin is the reason behind decrease in vegetation cover. As much of the area started to be covered by human settlement, the area covered by agricultural crop land in turn started decreasing. Similar studies have been carried out by [31], in Islamabad, Pakistan from 1992 to 2012 and observed increase in are for agricultural land, settlement and water bodies while decreas in area for forest and barren land. The authors claimed that, climate change, economic development and population growth were the main resaons behind these changes. [32] carried out LULC study in Gudur area in Nellore district of Andhra Pradesh, India, and demonstrated that remote sensing and GIS is a powerfull tool to map LULC of an area. [33], analyzed the LULC changes in the Guangxi area of China from 1990 to 2017 using land use transition matrix, Markov chain model and Moran's I. They found an increase in built-up area and water bodies, and decrease in area covered by woodland, cropland and grassland during the 27 year period. Deforestation in the area has been considered as the main ecological issue.

Change in LULC can effect both environment and different components of the hydrologic cycle in the basin. Due to increase in settlement, surface air temperature will increase leading to change in both intensity and spatial pattern of precipitation [34]. Among all others, change in settlement is considered to be the most forceful one. Settlement will lead to decrease in infiltration by increasing the impervious area in the basin because of which runoff volume will ultimately increase. Puthimari is included among the major tributaries of mighty river Brahmaputra. As such, it has a substantial amount of contribution of runoff to the mainstream Brahmaputra at downstream leading to flood and erosion problem in the region. With these already existing natural calamatic problems, if LULC change also go on the pattern as obtained in the present study, there is a possibility that the increased surface runoff due to deforestation and rise in human settlement will lead to increase in peak discharges and flood magnitudes. Also, due to the LULC change, soil degradation may occur in the basin. Consequently the already sediment fueled river will develop more sediment at the downstream causing threat to the Brahmaputra in terms of increasing the braidedness of the river which is the main cause of bankiline erosion at the downstream. On the top of all these, being an important climate forcing, such pevasive LULC change will intensify both climate as well as environmental changes in the basin. For instance, in this study reduction in area covered by crop land is not negligible. This leads the farmers to use more pesticides and other fertilizers to increase the crop productivity. This can cause eutrophication when the excess nutrients get transported by surface runoff thereby polluting the water bodies. The possibility even increases if settlement area keeps on increasing the same rate by increasing surface runoff. Thus an accurate and timely analysis of LULC changes is important for proper management of any watershed. Based on the results of this study, policy makers and land use planners can plan proper management strategies which will further help in controlling flood and erosion problems in the downstream of Puthimari river. This also will help to some extent in reducing the contribution of sediment load of Puthimari river to the mainstream Brahmaputra thereby decreasing the braidedness of the river responsible for riverbank erosion. Also, future land use/land cover scenario of the basin can be developed based on these past analyses and thus long- term sustainable development can be achieved for the entire Puthimari basin.

IV. CONCLUSIONS

In this study, the land use/land cover change detection has been analyzed in the Puthimari river basin for five different classes i.e. dense vegetation, water bodies, silted water, crop land and rural settlement. It can be concluded that satellite remote sensing data plays an important role in understanding the nature of changes in LULC for a region in a particular period of time. Such information in turn is helpful for developing and preserving the natural resources and environment. Satellite remote sensing is a cost-effective approach which gives the necessary information accurately. The study conducted here in the Puthimari river basin indicates that to study the spatial and temporal variation of an area, preparation of LULC maps using multi temporal satellite data plays an important role while it becomes difficult using conventional mapping.

During the two decades periods, overall decrease in dense vegetation, silted water and crop land have been observed in the basin. This can be attributed to the fact that increasing population is putting pressure on the land use/land cover of the basins. This analysis will be beneficial for the local bodies, planners and policy makers for appropriate environmental planning and watershed management and subsequent economic development of the entire Puthimari basin.

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