Assessment of changing land use patterns in Morigaon district of Assam using unsupervised classification technique

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Abstract
Land use refers to the utilization of land resource by human beings for various purposes whereas land cover is the natural features present on the earth's surface. Land use and land cover are very dynamic properties of the earth and changes in them can be linked to various anthropogenic factors which further govern other earth processes. Studies on changing land use patterns have gained more importance recently due to its linkages with the observed changes in climate. The present study focuses on pattern of land use changes in a part of the dynamic flood plain region of the Brahmaputra river where presence of high population entirely dependent on agriculture for their sustenance is dominant. The region is also rich in plant and animal biodiversity. Land use changes are assessed with the help of remote sensing and GIS techniques which results in high accuracy. Seven different land use and land cover categories were differentiated within the study area. The classified images for 1996 and 2016 showed major changes in wetland and vegetation categories which are dominant land cover categories. Further studies can be done by using the results of this study as reference like impacts of changes in land use patterns on climate change, biodiversity, livelihood and income coupled with better field inputs. The outputs of the present study will be helpful for making better land management plans.

Keywords: *LULCC, Remote Sensing and GIS, Unsupervised Classification, Accuracy Assessment*

Introduction
Land use and land cover change (LULCC) refers to the modifications in the earth's surface coverage primarily due to human interventions. Land cover refers to natural features on the earth's surface which includes vegetation, water, bare soil, etc. and land use refers to the human alterations of the land surface such as agriculture, forestry, settlements and other artificial objects. Changes in land cover and land use is the second most important cause of climate change; it may be global, local or regional[1,2]. LULCC increases 0.35^{0}C mean surface warming per century[3]. Land use and land cover changes has modified the surface fluxes of heat and water vapour and resulted in affecting the atmospheric boundary layer[4]. Different land use change pattern can alter the soil carbon stock[5]. Land use change effect near surface specific humidity in winter, spring and summer[6]. Besides the impacts on climate and greenhouse gas emission, LULCC is also responsible for global biodiversity loss and pollution. By the year 2100, land use change will be the largest impact on biodiversity followed by climate change, nitrogen
deposition, species introduction and changes in CO_2 concentration[7]. Land use and land cover changes are linked to human population growth which in turn increases the demand for land resource. Land use and land cover change have major adverse impacts on biodiversity, soil degradation, ability of biological system to support human being and finally changes the earth system functioning[8].

Therefore, land use and land cover change is a major issue for global environment as well as climate change especially for the developing nations. Due to this reason, scientific research committees were set up for land use change study during Stockholm conference of human environment in 1972 and United Nations conference on environment and development (UNCED) in 1992. Due to this increased focus on climate alterations due land use and land cover dynamics all over the world, a renewed interest is seen in global land cover patterns and its change. The present work attempts to analyse the changing pattern of land use and land cover during the last 20 years using satellite remote sensing.

Remote sensing data is widely used in recent times in order to understand patterns on the earth's surface and their transitions in time due to its advantage in providing synoptic view and repetitive data acquisitions[9]. Earlier it was impossible to study land use and land cover change accurately because of unavailability of consistent, cost effective and historical data. But due to development and maintenance of consistent satellite sensors and data base with timely data delivery at reasonable prices, remote sensing data are very much useful in land use and land cover change study. Digital classification methods devised for automatic extraction of information from satellite images obtained by remote sensing is a convenient method for observing patterns in land use and land cover because manual digitization of land-use patches is extremely tedious as well as subjective[10]. Generally three types of digital classification methods are adopted by the researchers to study land use and land cover change using remote sensing data. These are unsupervised, supervised and hybrid classification. Many researchers have used supervised classification technique and found it to be a more reliable method then unsupervised classification[11,12]. Supervised classification is effective when detailed knowledge about the study area and good training data is available which is usually achieved in areas with homogeneous land use patches[13]. But in very heterogeneous area complex spectral variations in land cover makes it very difficult to collect sufficient training data. In such a case, unsupervised classification methods produce more accurate results compared to supervised classification[14].

The present study focuses on the changes in land use and land cover of a part of highly

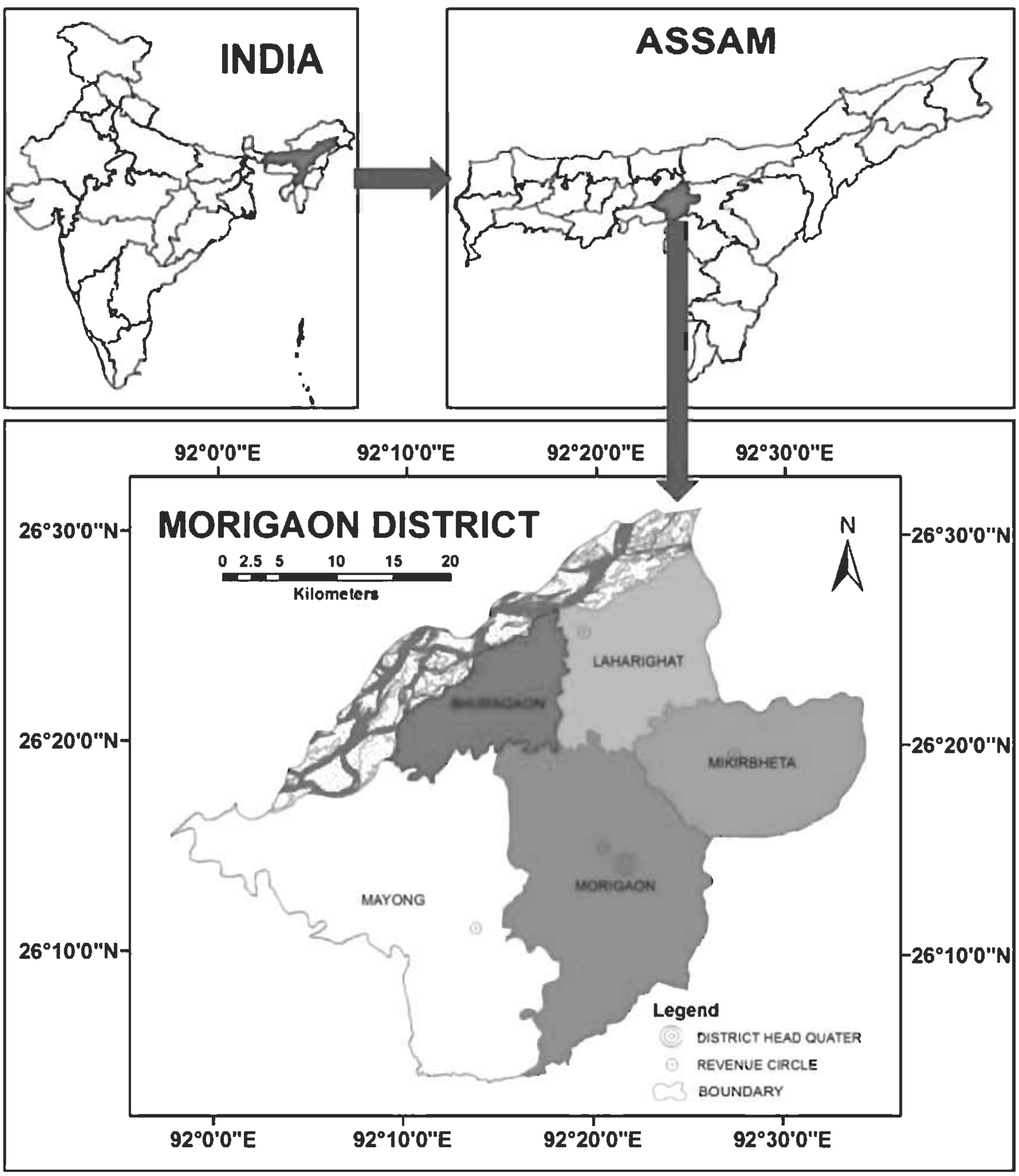

Fig 1: Location Map of the Study

dynamic flood plain region of the Brahmaputra river assessed with the help of unsupervised classification technique. The Brahmaputra river flows from west to east in Northeast India with low gradient and the floodplains are highly fertile lands with high population dependent entirely on agriculture. The study area comprises of Morigaon district in Assam which is located between latitudes 26°3′24″ - 26°31′12″ N and longitudes 91°25′56″- 92°34′40″ E with a total geographical area of approximately 1450 sq kms. The location map of the study area is shown in fig 1. The district comprises of 632 villages within 5 revenue circles with a total population of 9,57,853 as per 2011 census. The entire economy of this region is dependent on agriculture but huge losses are suffered every year due to the annual floods of the Brahmaputra river. Due to its close proximity to the river and its low elevation, the area is dotted with a number of wetlands locally known as *beels* which are also a source of income for the inhabitants of the region. Besides, the region has immense ecological importance with high biological diversity. Pobitora Wildlife Sanctuary is located within this district which has the highest density of the Great Indian One-Horned Rhinoceros besides being a home to various other animals, reptiles and birds. Timely monitoring and updation of data related to land use in this highly fragile, ecologically and economically important region is necessary for adopting proper land management measures. The objectives of the present study are:

1. To extract the pattern of land use and land cover in the study area during 1996 and 2016 using remote sensing and assess the accuracy of the outcomes.
2. To detect the changes in land use and land cover categories using GIS during the last 20 years.

Materials and Method

Data used

Remote sensing and GIS techniques have been extensively used across the globe for accurate study of land use and land cover change pattern. This work adopts the unsupervised classification technique using temporal satellite images to study land use and land cover change. Landsat images of two different time periods were utilized to detect changes in land use and land cover pattern. Details of the satellite images used for LULC analysis is given in table 1. Besides these, topographical maps of 1:250,000 acquired from US defense archives has been utilized for reference purpose. Ortho rectified images of the dry season were acquired to ensure that the images are completely cloud free. Erdas Imagine 2014 software was used for image processing, classification and accuracy assessment and ArcGIS 10.3 was used for assessment, change analysis and preparation of maps. Garmin Etrex handheld GPS was used for collecting field data.

Table 1: Dataset used

Satellite/ Sensor	Date of acquisition	Path/Row	Spatial Resolution	Source
Landsat-TM	2-2-1996	136/42	30m	USGS
Landsat- OLI	8-1-2016	136/42	30m	USGS

Image pre-processing

Satellite images of the study area were downloaded from the USGS GLOVIS website (http://glovis.usgs.gov/). The raw data which is in the form of individual band images in GEOTIFF format were processed to usable information by compositing the band images into a single image (layer-stacking) using Erdas Imagine image processing software . Landsat sensors (TM and OLI) collect images in the visible, infrared and thermal wavelengths of the electromagnetic spectrum. The area of interest, i.e. the Morigaon district was cropped out for future processing. The process is repeated for the two time periods and finally two images for 1996 and 2016 are obtained for the study area.

Digital image processing is a collection of techniques for manipulation of images and involves numerous procedures including formatting and correcting of data, digital enhancement to facilitate better visual interpretation. Two basic procedures for image enhancement is a pre-requisite for all analysis related to satellite images, especially change detection studies. These are: radiometric and geometric correction. Radiometric correction normally involves manipulation of image brightness values that may limit one's ability to interpret or quantitatively process and analyze digital remotely sensed images. In radiometric corrections, haze reduction, noise reduction and histogram equalization are performed for all the satellite images in the ERDAS Imagine software. Radiometric normalization is essential in land cover change detection studies which consist of multi-date and multi-sensor satellite data. Normalization reduces inconsistencies in the satellite images which are inherent in the images because of differences in acquisition conditions such as variation in sun zenith angles, shadow effect, sensors calibrations, and atmospheric condition etc[15,16]. Geometric correction involves changing the pixel locations of an image to fit that of a map projection or another reference image. Image to image registration is carried out to geometrically align both the images with each other to integrate or fuse corresponding pixels that represent the same objects.

Unsupervised classification

The part of floodplain region of Brahmaputra Valley in Morigaon district are classified into seven classes, viz. water body, urban settlement, plantation, sand, forest, grassland and agriculture using ERDAS imagine software. The classification scheme used for the present study has been modified from Hazarika et al.[17] and is given in table 2. These classes are representative of actual landscape of study area and can be easily determined by moderate resolution of Landsat imagery.

Unsupervised classification technique is a computer-automated process in which all pixels within an image is clustered into separate classes based on various statistical patterns that are inherent in the data[18]. These are simply clusters of pixels with similar spectral characteristics and have to be interpreted into meaningful classes of interest[19]. The ISODATA unsupervised classification algorithm was used to automatically classify the satellite images of the study area into 36 classes with similar spectral characteristics. These classes were then merged into the seven information classes based on the classification scheme adopted for the study. The final classified images were then filtered using a neighbourhood majority function with the help of a 3×3 matrix window which replaces the central pixel in the matrix with the most common data file value in the window. This is required for the removal of noise, reducing of salt and pepper effect and smoothening of classes in classified image. Recoding was performed for major misclassification of features with similar spectral characteristics such as water and shadow.

Table 2: Classification scheme adopted for the study

LULC Code	LULC Class	Description
1	Water body	Accumulation of water on the earth's surface such as rivers, lakes, ponds, etc.
2	Agricultural land	Land under cultivation
3	Wetland	Areas where the soil is saturated with water such as wet marshy and swampy areas
4	Vegetation	Areas covered with trees comprising of natural forests and plantations
5	Urban settlement	Area concentrated with settlement which constitute or is a part of urban area
6	Grassland	Areas where vegetation is dominated with grasses and shrubs
7	Sand	Sandbars and other sand deposition areas including both dry and wet sand areas

Accuracy Assessment

Accuracy assessment is important for automatically classified images to quantify the accuracy of the classified images. The accuracy of each classified image was assessed by a set of 70 random points based on the number of classes (10 points per class). These random points known as reference points were overlaid on the images and each point was assigned to one of the land-use classes which corresponds to the actual land use/ land cover category on the ground. Topographical maps, careful examination of satellite image, high resolution images and limited field verifications were used for assigning reference classes. For each map, a confusion matrix or error matrix was created with each row representing land-use classes in the classified map and each column representing the reference land-use classes. The overall accuracy and Kappa analysis were used to perform classification accuracy assessment based on error matrix analysis. The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels. Kappa analysis is a discrete multivariate technique of use in accuracy assessment[20]. It is the degree of correctness among classified map and reference map[21]. User's accuracy and producer's accuracy are also calculated. User's accuracy measures the proportion of each class which is correctly classified in the map as a particular class and producer's accuracy measures the proportion of land-use class which is correctly classified as the actual landscape present on the ground. Kappa co-efficient is measured by using following formula[21]:

$$K = \frac{N(Xii) - (Xi+) - (Xi+ \times X+i)}{N(Xi+) - (Xi+ \times X+i)}$$

where X_{ii} is the number of observations correctly classified for a particular category, X_{i+} and X_{+i} are the marginal totals for row i and column i associated with the category, and N is the total number of observations in the entire error matrix.

Change Detection

The final classified images were used to generate land use and land cover statistics for the entire study area during 1996 and 2016. The area statistics and change was analysed in Microsoft Excel.

Results and Discussion

After normalization of images with image pre-processing methods and radiometric corrections, the satellite images for 1996 and 2016 were classified using ISODATA unsupervised classification algorithm in Erdas Imagine software. The final classified images with the raw satellite images used for classification are shown in fig 2 and fig 3 for 1996 and 2016 respectively. These classified images were prepared after post-classification corrections like filtering and recoding.

The areas under each land use and land cover category was calculated from each classified image and the percentages of areas are shown in fig 4 (a) and (b) for 1996 and 2016 respectively using pie diagram.

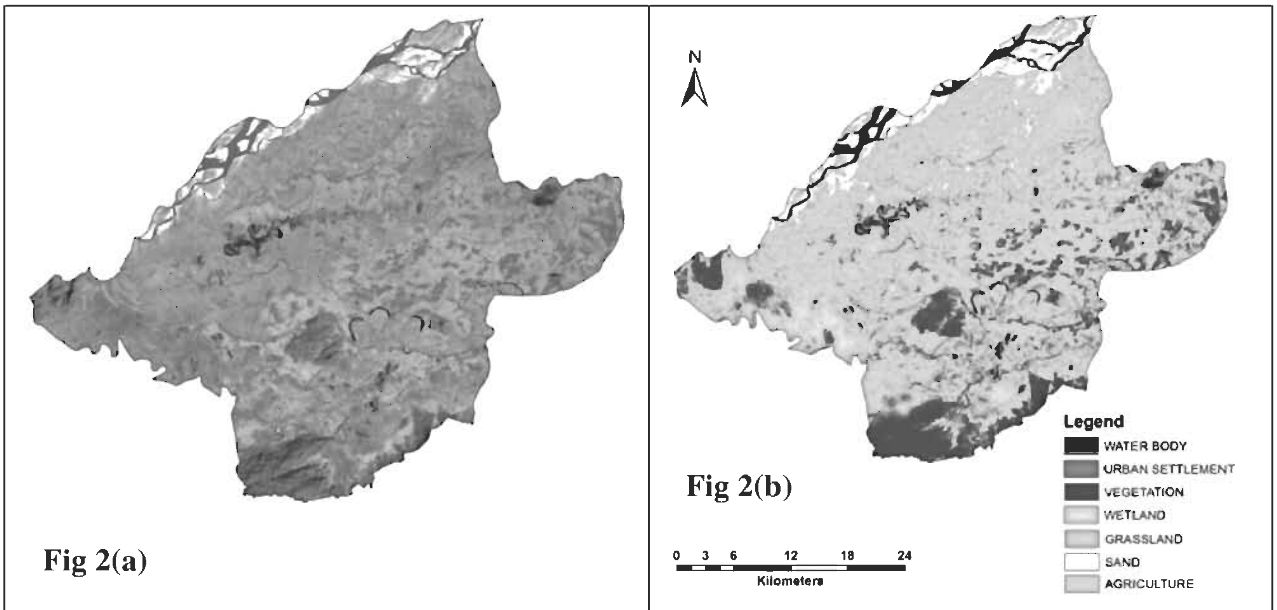

Fig 2(a) & (b): Raw satellite image and classified image for Morigaon district (1996)

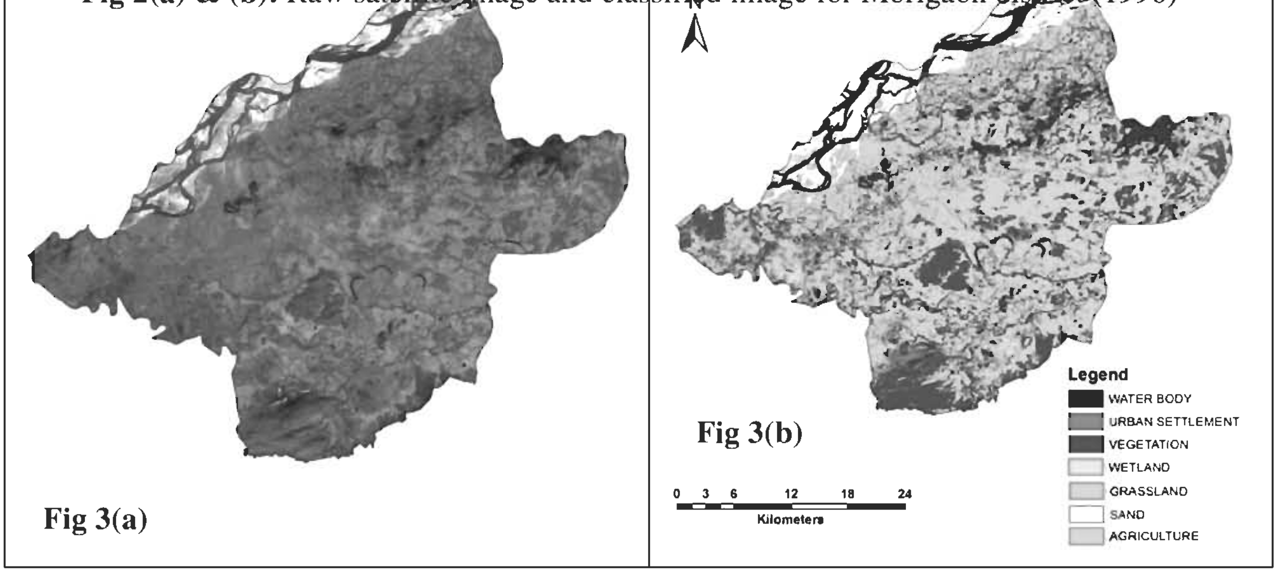

Fig 3(a) & (b): Raw satellite image and classified image for Morigaon district (2016)

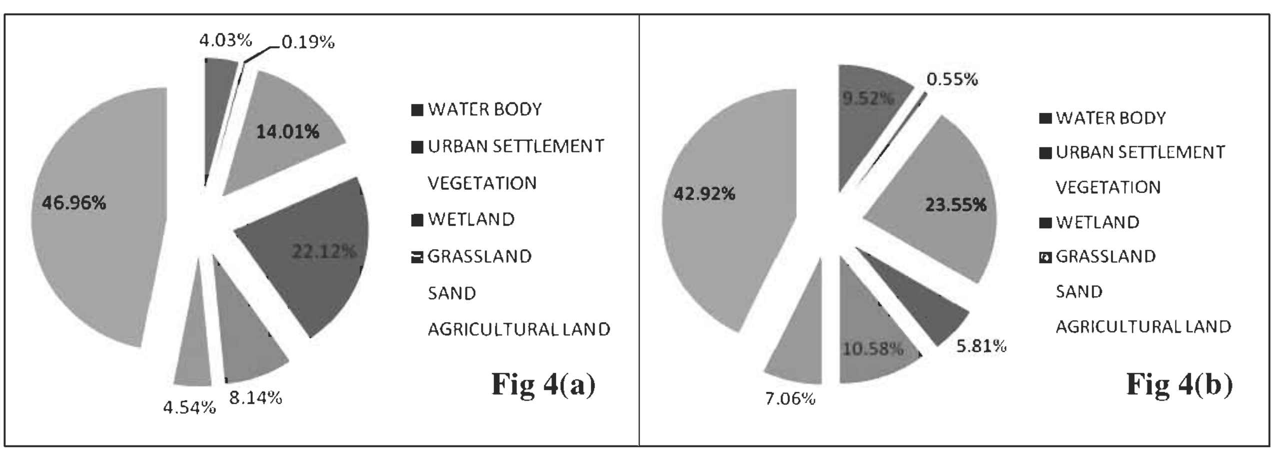

Fig 4 (a) & (b): Percentage of areas under different land use and land cover classes in 1996 and 2016 respectively

In order to check the accuracy of the classified images, 70 random points were generated on each image and ground truthing was carried out for a few locations based on accessibility. The ground control points overlaid on map of the study area with photographs of each location is shown in fig 5. The accuracy assessment was carried out in Erdas Imagine software by putting the reference values for the ground control points selected. Error matrices were generated for each classified image along with the overall accuracy and Kappa statistics. The error matrices are given in table 3 (a) and (b) for 1996 and 2016 respectively.

The error matrices generated show very high accuracies (more than 90%) for both the classified images. Therefore unsupervised classification method gives very good results in flood plain areas where classes are easily distinguishable from each other.

Table 3(a): Error matrix for unsupervised classification of Morigaon district (1996)

LULC classes	WATER BODY	VEGETATION	URBAN SETTLEMENT	WETLAND	GRASSLAND	AGRICULTURAL LAND	SAND	Row Total
WATER BODY	10	0	0	0	0	0	0	10
VEGETATION	0	10	0	0	0	0	0	10
URBAN SETTLEMENT	0	0	10	0	0	0	0	10
WETLAND	1	0	0	8	0	1	0	10
GRASSLAND	0	1	0	0	9	0	0	10
AGRICULTURAL LAND	0	0	0	0	0	10	0	10
SAND	0	0	0	0	0	0	10	10
Column Total	11	11	10	8	9	11	10	70
Overall classification accuracy		**95.71%**			**Kappa co-efficient**		**0.95**	

Table 3(b): Error matrix for unsupervised classification of Morigaon district (2016)

LULC classes	WATER BODY	VEGETATION	URBAN SETTLEMENT	WETLAND	GRASSLAND	AGRICULTURAL LAND	SAND	Row Total
WATER BODY	10	0	0	0	0	0	0	10
VEGETATION	0	10	0	0	0	0	0	10
URBAN SETTLEMENT	0	0	9	0	0	0	1	10
WETLAND	0	0	0	10	0	0	0	10
GRASSLAND	0	0	1	1	8	0	0	10
AGRICULTURAL LAND	1	0	0	0	0	9	0	10
SAND	0	0	0	0	0	0	10	10
Column Total	11	10	10	11	8	9	11	70
Overall classification accuracy		**94.29%**			**Kappa co-efficient**		**0.93**	

The areas under each LULC category for each year were compared to assess the changes in different land cover categories. The results are shown in table 4. The change in LULC classes in percentages are plotted in a bar diagram shown in fig 6. It can be clearly understood that in the study area during the span of last 20 years, wetlands have decreased drastically (more than 16%). This change can be attributed to the eutrophication of wetlands resulting in presence of aquatic vegetation over the surface of wetlands. Many wetlands have also being converted into natural grasslands, agricultural lands or settlement areas.

Agricultural areas have also decreased by around 4% due to the conversion of agricultural areas into sand or water body which is again attributed to the shifting of the Brahmaputra river towards the southern direction during the study period. This is also the reason for the increase in areas of water body (~5.5%) and sand (~2.5%). Moreover, due to heavy floods in the study area during the previous year, a number of wetlands in the region are covered with water. Vegetation areas have increased considerably in the study area and this is mainly due to the rural plantations and scrub areas in the previously wetland areas. Rural settlements in this region are surrounded by a number of trees like betel nut, mango, litchi etc. which are classified as vegetation areas in medium resolution satellite images. The region which has very minimal urban settlement area has also seen slight increase in urban areas of Jagiroad and Morigaon towns.

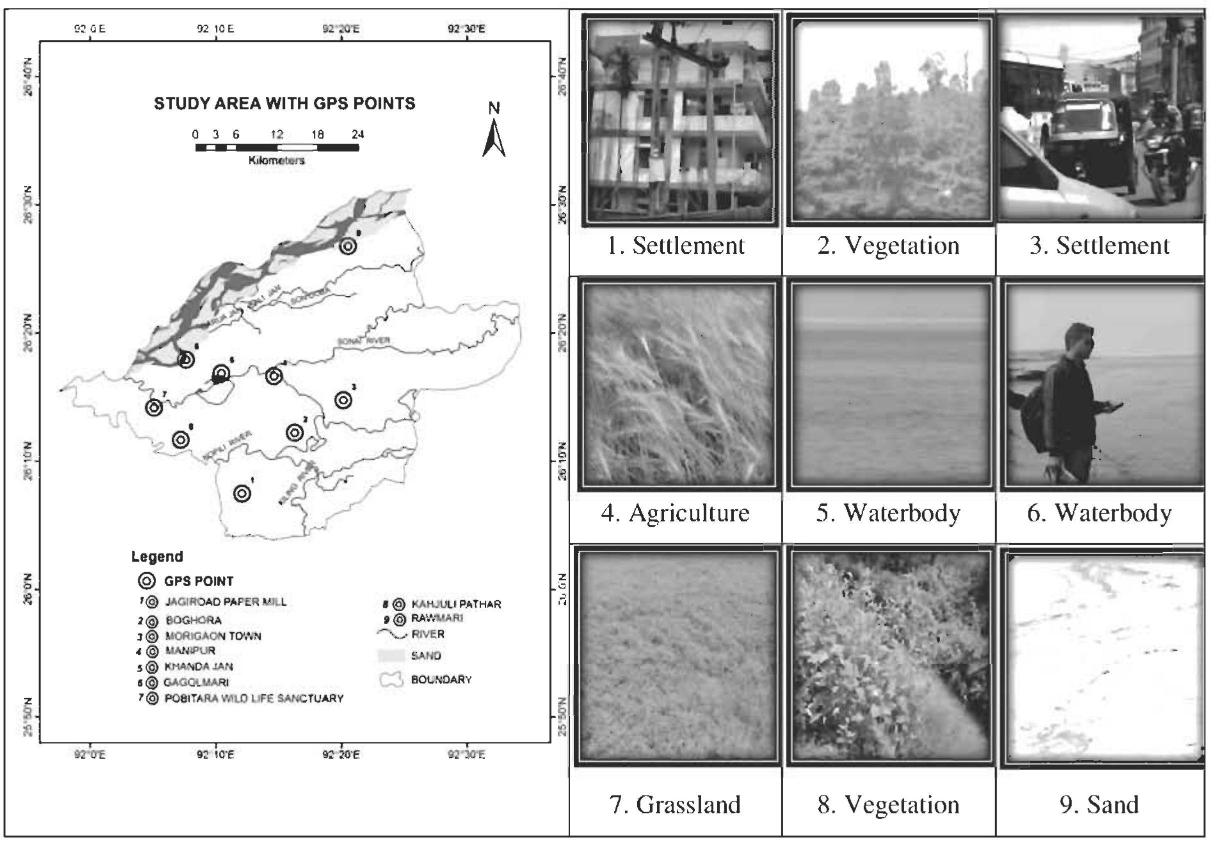

Fig 5: Field verification points with location on map and corresponding photographs

Table 4: Land use and land cover classes and their change in Morigaon district during 1996 to 2016

LULC classes	Area (ha)		Change	
	1996	2016	Area (Ha)	Percentage
Water body	6134.67	14499.90	8365.23	5.49
Urban Settlement	294.84	838.08	543.24	0.36
Vegetation	21336.60	35856.10	14519.50	9.54
Wetland	33674.10	8841.33	-24832.77	-16.31
Grassland	12401.10	16115.60	3714.50	2.44
Sand	6914.70	10755.10	3840.40	2.52
Agricultural land	71503.50	65356.60	-6146.90	-4.04

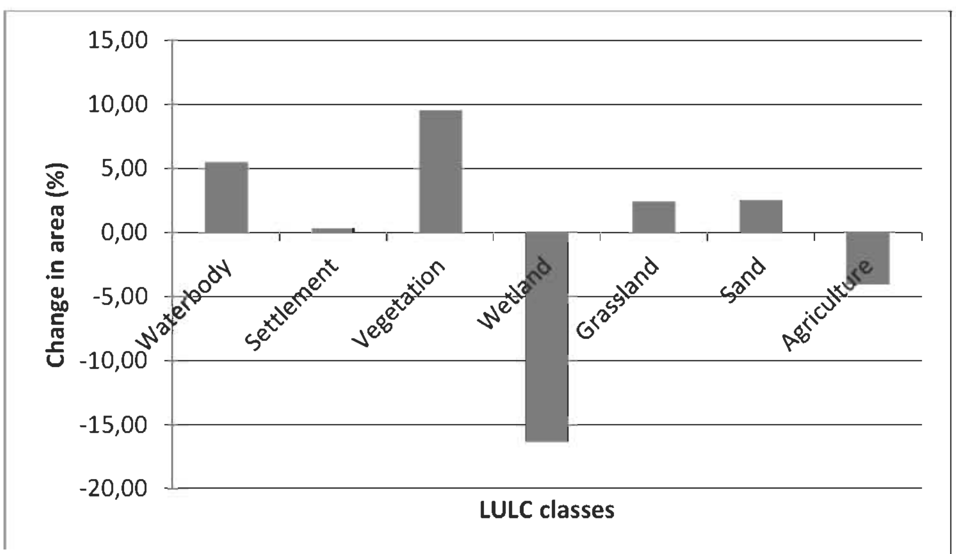

Fig 6: Percentage change in LULC classes in Morigaon district during 1996 to 2016

Conclusion

The present work assessed the land use and land cover in Morigaon district of Assam during the last 20 years using satellite remote sensing and Geographical Information System. The unsupervised classification technique was used for the purpose of the study and the classification resulted in high accuracies of 95% for 1996 and 94% for 2016 image. The study area is dominated by agriculture as almost half of the area is covered by cultivation areas. The second dominating LULC category was wetland in 1996 but it has changed into vegetation in 2016. The results show that the area is highly dynamic in nature and major changes are observed due to the shifting of the Brahmaputra river towards the south within the district. The highest change is observed in wetland areas which have decreased drastically along with slight decrease in agriculture areas. Vegetation and water bodies in the study area have increased along with slight increase in grassland, sand and urban settlement areas. A major lacuna in the study is the limited ground data collection due to time constrains and limitation in accessibility and a more comprehensive field survey will yield better understanding of land cover pattern and change. The results of the present study could eventually be a significant help in proper management of the land use pattern as well as biodiversity. Further studies in this area can also be implemented to analyse the climatic changes that might occur due to the observed land use and land cover change.

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