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Soil Science

Land use/land cover change dynamics of a district with one of the highest population growth rate in India: A geo-spatial approach

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Abstract

Nadia district of West Bengal, India has very special characteristics in land use/ land cover dynamics due to its long international boundary with Bangladesh and proximity to Kolkata city. In this study, satellite remote sensing and GIS technology has been used to measure the curves and shifts of land use/ land cover change in Nadia district over a time period of more than three decades. Landsat MSS data of year 1972, TM data of 1989 and ETM+ data of 2006 have been used for this purpose. Four prime land use classes have been adopted for supervised classification following maximum likelihood classification technique of images. Results revealed a huge increase of settlement during 1972 to 2006 and subsequent decrease of natural vegetation cover mainly due to high illegal immigration from Bangladesh. Increase in numbers of people working at Kolkata but living in Nadia district with much cheaper lifestyle is the other factor. In comparison to settlement growth, only minor initial increase and then decrease of land under agricultural practice indicates a high rate of urbanization.

Keywords: Change detection, Land cover, Land use, Human geography

Land is one of the most important natural resources for all flora and fauna. Agriculture to habitations, mineral resources to forests depend on land and its behaviour. Land use/ land cover (LULC) change is a dynamic process controlled by several natural phenomena like rainfall, flood, drought and anthropogenic activities like population density, agriculture, settlement. With the rapid increase of human population over last few centuries, the utilization of land changed in several ways. Transformation of natural vegetation area to agricultural lands for more food supply and then urbanization and industrialization in agricultural lands changed the total dynamics of LULC. Most of these LULC changes have a long-term negative effect on environment as well as on other natural resources as they happened and still happening without any proper planning. An optimum knowledge about LULC information is essential for proper management, planning and monitoring of natural resources as well as to develop a sustainable land use plan, which could play an important role for the well being of the global environment[4].

Satellite remote sensing is an important tool to measure the changes of LULC for large coverage area over a time period and also justifies the accuracy of estimated LULC. On the other hand, GIS is an important technology used to provide spatial data integration and tool for urban planning and natural resource management [5]. The combining geospatial technology of remote sensing and GIS holds the potential for timely and cost-effective assessment of LULC and their change pattern. Detection of LULC change using digital image processing technique with multitemporal satellite data has been one of the first and most critical applications of remote sensing. There are two change detection technique categories, viz. 'from to' change (image classification) and binary change and non change information (image differencing, image rationing, vegetation index differencing, fractals etc.).

India is the country with world's seventh largest land holding and second highest human population. Population density of this country is 382 per sq. km . West Bengal is a state of India situated in eastern part. Due to highly fertile soil of Ganges, Hoogly and other river plains and several other reasons, population density of West Bengal is much more i.e. 1029 per sq. km. Nadia is a district of West Bengal, situated approximately between 22°52'253 to 24°06'033 North latitude and 88°08'113 to 88°48'083 East longitude. The Tropic of Cancer divides the district in two parts. It is situated at the fertile plains of Hoogly river and approximately 14 m above mean sea level. The LULC change dynamics of Nadia district is a matter of prime concern due to steep increase in population in last few decades. Total area under Nadia district is about 3927 sq. km and population density is 1316 per sq. km , which is even higher than average of the state. There is an increase of 12.24 % in the population in 2011 compared to population as per 2001. However, in comparison to the earlier decennial population growth of Nadia viz. 19.54 % and 29.95 % in 1991-2001 and 1981-1991 times span, respectively, the decrease in growth rate is distinct. Nadia has Bangladesh at its east and surrounded by other districts of West Bengal on other sides. Figure 1 shows the exact location of study district.

Beside fertile soil, one more important determining factor for gradual inflation in population is the high number of illegal immigrants from Bangladesh since 1947 for better life and sometimes also for religious reason. After independence of Bangladesh in 1971 and thereafter incident like Zia-ur-Rahman's coming to power in Bangladesh results increased influx of refugees (mainly Hindus) due to fear of communal violence in Bangladesh. As per record, during 1972-1993, a total number of approximate 4125576 people infiltrated in India from Bangladesh as illegal immigrants. Out of that a total 836524 overstayed (difference between immigrants and emigrants figure). Of them 538501 are Hindus (who were minority in Bangladesh). With time passed, the betterment and stability of communal situation in Bangladesh might be the factor of gradual decrease of seepage of refugees in Nadia in last two decades. Another reason of high population density of this area is vicinity from Kolkata city. Kolkata was the former capital and one of the megacities of India. A huge numbers of office

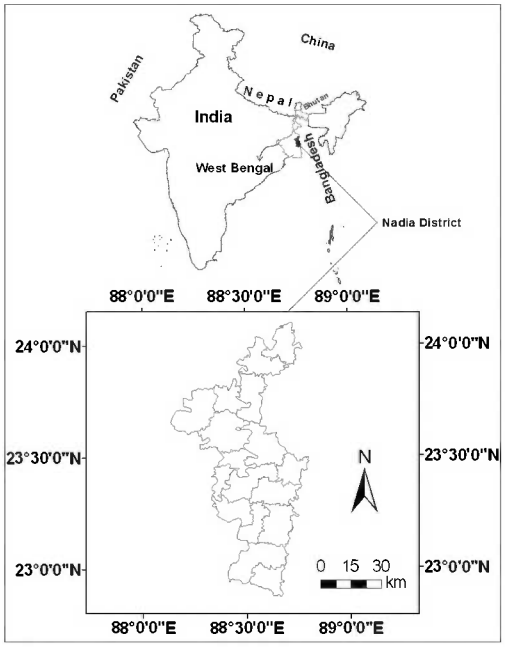

Figure 1: Location map of the study area

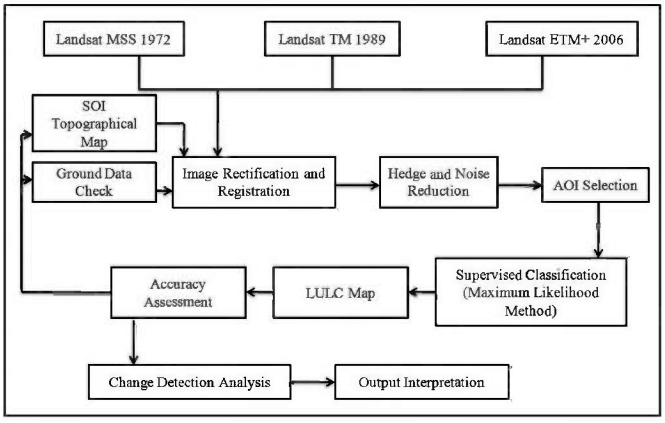

Figure 2: Flowchart of methodology followed in the present study

Table 1: Description of acquired satellite images

Year	Satellite and Sensor	Date of Acquisition	Spatial Resolution (m)	Path and Row
1972	Landsat Multispectral Scanner (MSS)	21st October	56×79	Path 151, Row 45
		7th November		Path 150, Row 43
		7th November		Path 150, Row 44
		17th January		Path 149, Row 45
1989	Landsat Thematic Mapper (TM)	11th November	30	Path 138, Row 43
		14th November		Path 138, Row 44
2006	Landsat Enhanced Thematic Mapper Plus (ETM+)	17th November	30	Path 139, Row 43
		17th November		Path 139, Row 44

workers, farmers, and businesspersons of Nadia district are dependent on Kolkata for their livelihood but live in Nadia with much cheaper lifestyle than a metropolitan city.

The basic objective of the study was to examine the LULC pattern and its change dynamics of Nadia district over three decades (1972-2006). For this purpose we used remote sensing and GIS technique for comprehensive understanding.

Materials and Methods

Data sources

Three multi-temporal Landsat satellite images of year 1972, 1989 and 2006 of Nadia district were downloaded from website of United States Geological Survey. All the images were chosen of almost same season to reduce the misclassification related to spectral analysis of different LULC. The descriptions of ortho-rectified acquired images are presented in Table 1.

For geo-registration, Survey of India (SOI) toposheets (78 D and 72 A, B) was used having scale of 1: 250000. Ground truth verification was conducted by field-survey with 500 ground control points (GCPs) using a GARMIN handheld GPS. Total 100 plots of different LULC classes were taken in field study and after applied for accuracy assessment.

Image processing

This study aims to detect LULC changes with supervised classification. ERDAS IMAGINE 9.1 and ArcGIS 9.3 softwares have been used for the purpose. False colour composite (FCC) of all images of four years were produced by stacking of all four bands of MSS, band 1 to 5 for TM and band 1 to 5 for ETM+ image. Nearest neighbourhood algorithm was applied to these datasets for resampling to assign all pixels in the image into one of the four signature classes using the best band subsets [13]. Area of interest (AOI) was selected after hedge reduction.

Image classification and change detection

Training data extraction is a critical step in supervised image classification process. Based on the ground truth observations, training signature sets for all the images and LULC classes were identified. For supervised classification of each of the images, maximum likelihood classification (MLC) method was chosen as classification technique because of its ready availability and the fact that it did not require an extended training process [15]. MLC method is based on the principle that the pixels of unknown class membership are allocated to those classes with which they have the highest likelihood of membership. Four prime LULC classes were adopted for image classification based on digital values of pixels and ground survey of the study area. These LULC classes are agricultural land, settlement, natural vegetation and water body.

Following the classification, accuracy assessment has been performed by error matrices for all the images which had different measures of accuracy like producer's accuracy, user's accuracy and kappa coefficient. Kappa coefficient is a discrete multivariate technique which incorporates the off-diagonal elements of an error matrix and corresponds to the amount of agreement obtained after eliminating the proportion of agreement that could be expected to occur only by chance.

$$\hat{k} = \left[N\sum x_{i+} - \sum (x_{i+}x_{+i}) \right] / \left[N^2 - \sum (x_{i+}x_{+i}) \right]$$

In the post classification stage, change-detection has been carried out to produce transition/ change area matrices of subsequent pairs of the classified LULC images. Figure 2 clearly depicts the detail methodology followed for image processing classification and change detection in this study.

Results and Discussion

Assessment of LULC and their change

The digital analysis of satellite images over three decades highlights dynamics of the change of LULC of Nadia district. To detect the changes over time, supervised classification of each image have been performed. Figure 3 shows the supervised classified images of all individual years with prime classes while figure 4 describes year wise comparative distribution of

Table 2: Areas under different land use/ land cover categories for 1972, 1989 and 2006

LULC Classes	1972		1989		2006				
	Area (sq km)	%	Area (sq km)	%	Area (sq km)	%	Change (%) (1972-1989)	Change (%) (1989-2006)	Change (%) (1972-2006)
Agricultural Land	2431.98	61.93	2445.24	62.26	2362.05	60.15	0.33	-2.11	-1.78
Natural Vegetation	1303.17	33.18	813.88	20.72	401.62	10.22	-12.46	-10.50	-22.96
Settlement	110.48	2.81	587.03	14.95	1056.48	26.9	12.14	11.95	24.09
Water body	81.54	2.08	81.02	2.07	107.02	2.73	-0.01	0.66	0.65
Total	3927.17	100.00	3927.17	100.00	3927.17	100.00	-	-	-

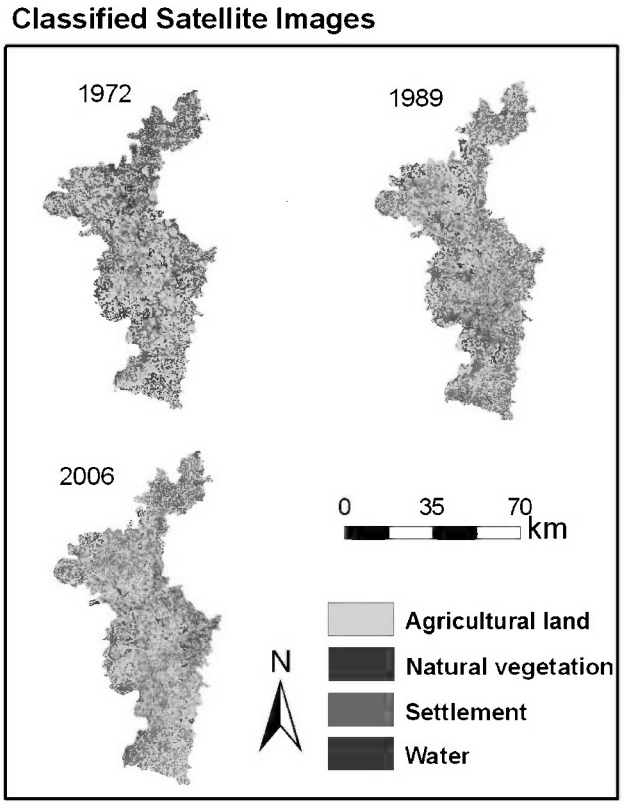

Figure 3: Supervised classificafied images of Nadia district of 1972, 1989 and 2006

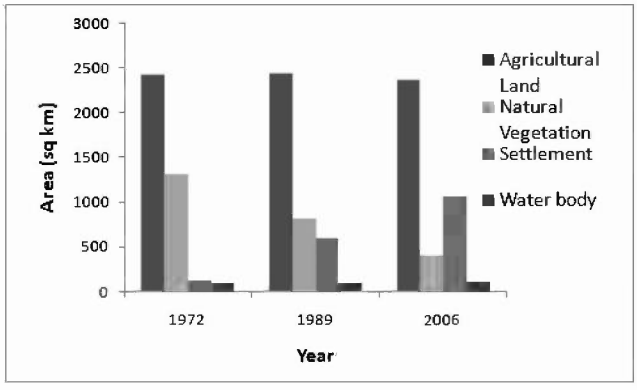

Figure 4: Amount of land under different LULC classes in 1972, 1989 and 2006

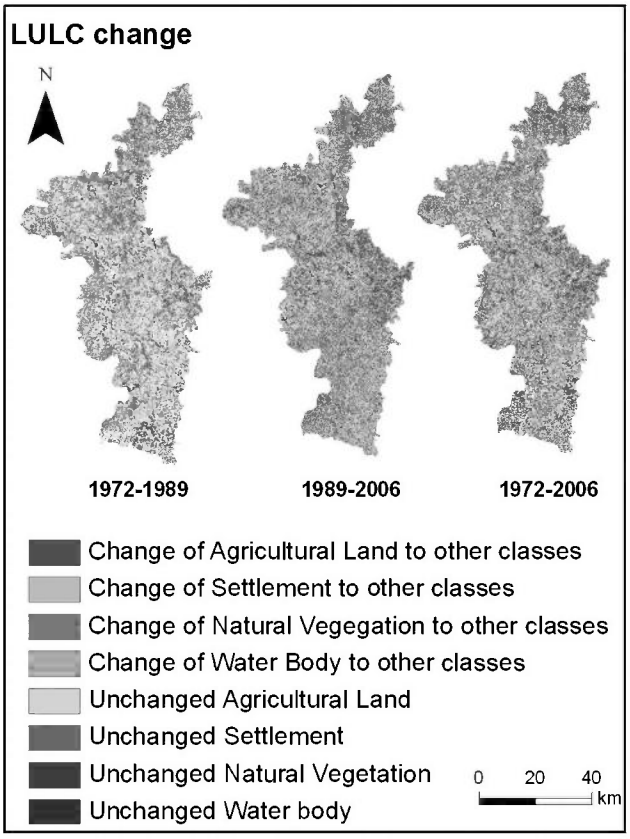

Figure 5: Changes in LULC during 1972-1989, 1989-2006 and 1972-2006

prime LULC classes. Statistical analyses of the prime classes are given in table 2.

From the analysis of figures and table, it is clear that agricultural practices increased a little bit from 1972 to 1989 (0.33 %). After that, it followed a decreasing trend in the time span from 1989 to 2006. In case of natural vegetation, from 1972 to 1989 and again from 1989 to 2006, there was a decrease (12.46 and 10.50 %, respectively) in an alarming rate which results area under natural vegetation 33.18 % in 1972 to only a little more than 10 % in 2006. On the other hand, land under settlement increased massively during the time span. It was just 2.81 % of total land area in 1972 while in 2006, it become 26.9 % of the geographical area of Nadia. The area under water bodies remained more or less unchanged during 1972-1989 time span. However, in 2006, the area under water body class increases to 2.73 %.

Analysis of LULC change pattern

For better understanding of the LULC classes of the area and their conversion dynamics to other classes, LULC transition/ transformational/ change matrix of the study area have been

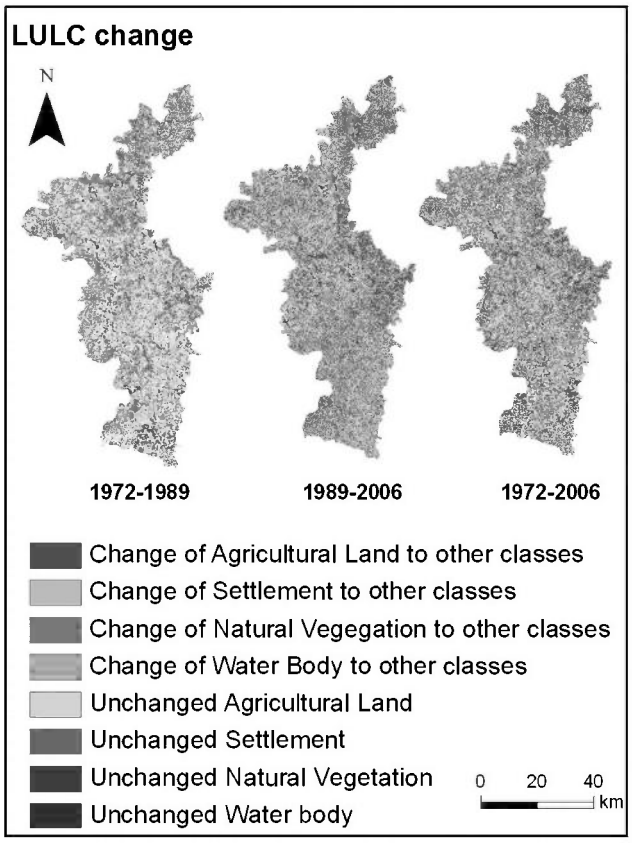

Figure 6: Changes in LULC during 1972-1989, 1989-2006 and 1972-2006

analysed for different temporal span. Table 3, 4 and 5 represent the LULC transition matrix of year 1972-1989, 1989-2006 and 1972-2006, respectively. Figure 5 have been prepared by subtracting images from one another shows the trend of change of LULC.

During 1972-1989, there was a huge conversion of area under natural vegetation to settlement and also some amount to agricultural lands. There was also a mentionable amount of land cover change from agricultural land to settlement. The transition of LULC from agriculture to water body class may be due to misclassification of submerged rice fields as water body in satellite images. Least transformation occurred of settlement class. In the 1989-2006 time span also, high amount of area under natural vegetation and agricultural land was shifted to settlement class. Like the earlier, least change of LULC was from settlement class. However, in contrary to 1972 to 1989 duration, in 1989-2006 there was a remarkable change from all other LULC classes (mainly from natural vegetation) to water bodies. In the whole time span (1972-2006), shifts indicate the fast growth rate of population as well as urbanization. Some amount of LULC change from settlement to natural vegetation and agriculture instead of huge increase of total settlement probably indicated shift of people from rural to urban areas. On the other hand, shift lands under water body class to settlement class were an indicator of development of human habitat by damping water bodies.

Accuracy assessment and field verification

For accuracy assessment of the supervised images, producer's,

Table 3: LULC transition matrix of the study area from 1972 to 1989 (in ha)

LULC classes (1972)	LULC classes (1989)			
	Agricultural Land	Natural Vegetation	Settlement	Water body
Agricultural Land	226684.40	380.74	15892.25	240.22
Natural Vegetation	17371.19	80452.07	32176.47	317.71
Settlement	440.47	114.32	10305.42	188.38
Water body	28.04	441.50	328.65	7355.13

Table 4: LULC transition matrix of the study area from 1989 to 2000 (in ha)

LULC classes (1989)	LULC classes (2006)			
	Agricultural Land	Natural Vegetation	Settlement	Water body
Agricultural Land	217605.02	372.68	26403.07	143.25
Natural Vegetation	18526.70	39540.34	20848.81	2472.25
Settlement	19.53	168.05	58283.29	232.45
Water body	54.16	80.94	113.21	7854.00

Table 5: LULC transition matrix of the study area from 1972 to 2006 (in ha)

LULC classes (1972)	LULC classes (2000)			
	Agricultural Land	Natural Vegetation	Settlement	Water body
Agricultural Land	199765.30	753.42	42295.32	383.47
Natural Vegetation	35897.89	38603.77	53025.28	2789.96
Settlement	460.00	282.37	9885.55	420.83
Water body	82.20	522.44	441.86	7107.75

user's and overall accuracy have been calculated along with kappa statistics in a stratified random sampling design following [13]. For supervised images of different years a range of 314 to 331 pixels were randomly selected and checked with reference ground data. The overall accuracy of the LULC images of the year 1972, 1989 and 2006 are 85.31, 86.70 and 87.23 %, respectively. On the other hand, kappa co-efficient of these supervised images are 0.80, 0.82 and 0.83, respectively. Field visiting of the district confirmed image prime LULC classes match their positions in the real-world.

Analysis of LULC dynamics

From the analysis of LULC classes of all the years and change/ transition matrix, it can be said that there was a huge increase in population and settlement during the whole time line. The predicted main reason behind this was high numbers of illegal immigrants from Bangladesh. Migration of people from other parts of the state and country to the neighbouring areas of Kolkata city was another main factor for these increasing habitations. As an unavoidable effect of new settlement development, decrease of natural vegetation was there for this time span. However, only initial little increase and then decrease of agricultural land with contrast to increase in population pressure clearly indicates the increase of population was not directly related to farming, i.e. urbanization. Precipitation data from India Meteorological Department (IMD) and its distribution analysis over Nadia district for all these three years showed that precipitation over Nadia district was more than 1200 mm in the year 2006 which was much more in comparison to other years of study (Figure 6). This excessive rainfall may be the reason of more land cover under water in analysis of LULC of 2006 satellite image as well as in transition matrix as the heavy rain caused water stagnation in many low lying areas.

Conclusion

This study describes the change dynamics of LULC of Nadia district over a long period of 1972-2006 with the help of satellite remote sensing and GIS technology along with field truth. Results show how the nature of LULC gradually changed in the whole district during this time span. This study intends to offer a proper view of LULC and its change in Nadia district which was never observed thoroughly earlier. It is expected,

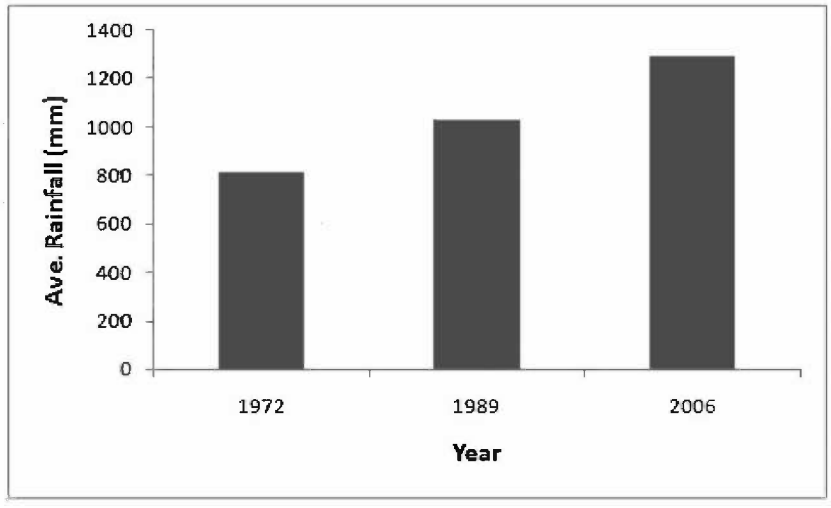

Figure 7: Average rainfall of Nadia district in 1972, 1989 and 2006

Table 6: LULC categories, description and average digital number in each band (B) of different sensors

LULC Classes	Description	Land sat MSS (1972)				Land sat TM (1989)					Land sat ETM+ (2006)				
		B1	B2	B3	B4	B1	B2	B3	B4	B5	B1	B2	B3	B4	B5
Agricultural Land	Irrigated and non-irrigated cultivation lands	17.8	22.9	33.5	29.0	75.1	35.0	37.2	56.0	62.2	77.2	36.3	37.8	64.9	76.5
Natural Vegetation	Continuous and discrete, dense and open tree cover	15.5	17.6	31.3	30.8	68.8	27.3	26.7	54.7	57.2	70.7	30.0	26.3	66.4	54.8
Settlement	Households, villages, sub-urban and urban area	15.7	19.7	21.4	14.7	68.0	26.8	25.1	52.1	47.6	72.2	31.1	29.6	62.6	55.7
Water body	River, river lets, ponds and lake	17.4	19.4	13.7	4.9	72.3	31.4	31.3	12.3	4.3	78.5	34.5	32.4	24.6	17.2

Table 7: Accuracy assessment for supervised classification of Landsat MSS image (1972)

LULC Classes	Agricultural land	Settlement	Natural Vegetation	Water body	Total	User's accuracy (%)
Agricultural land	81	4	7	2	94	86.17
Settlement	7	65	4	2	78	83.33
Natural Vegetation	8	5	71	3	87	81.61
Water body	2	2	1	56	61	91.80
Total	98	76	83	63	320	Kappa = 0.80
Producer's accuracy (%)	82.65	85.53	85.54	88.89	Overall accuracy	= 85.31 %

Table 8: Accuracy assessment for supervised classification of Landsat TM image (1989)

LULC Classes	Agricultural land	Settlement	Natural Vegetation	Water body	Total	User's accuracy (%)
Agricultural land	76	5	6	2	89	85.39
Settlement	4	74	3	3	84	88.10
Natural Vegetation	9	3	77	2	91	84.62
Water body	3	1	3	60	67	89.55
Total	92	83	89	67	331	Kappa = 0.82
Producer's accuracy (%)	82.61	89.16	86.52	89.55	Overall accuracy	= 86.70 %

Table 9: Accuracy assessment for supervised classification of Landsat ETM+ image (2006)

LULC Classes	Agricultural land	Settlement	Natural Vegetation	Water body	Total	User's accuracy (%)
Agricultural land	86	2	8	3	99	86.87
Settlement	5	66	6	1	78	84.62
Natural Vegetation	7	2	75	1	85	88.24
Water body	3	2	2	60	67	89.55
Total	101	72	91	65	329	Kappa = 0.83
Producer's accuracy (%)	85.15	91.67	82.42	92.31	Overall accuracy	= 87.23 %

this paper will act as a model for LULC analysis of other districts of India and future decision making about different aspects like sustainable development, urbanization, transport, marketing, agriculture etc. of Nadia district.

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