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RESEARCH ARTICLE

MONITORING DYNAMICS OF LAND USE/ LAND COVER CHANGES OF THE RIVER YAMUNA IN UPPER STRETCH USING MULTI-TEMPORAL SATELLITE DATA

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ABSTRACT

This paper describes the methodology and results of classifications of multi-temporal Landsat 4-5 Thematic Mapper data of the River Yamuna in upper stretch, India for the years 1999 and 2011 respectively. Seven different land cover/use categories have been used, named built-up Area/settlement, forest, agricultural land, scrub land, wetlands, river/streams/drains and railways. The overall classification accuracies were 78.46% and 81.23% and Kappa as 0.7470 and 0.7795 for the year 1999 and 2011 respectively. One of the important results for the classifications is the decrease in agricultural land and forest areas and a considerable increase in built-up area as a result of anthropogenic activities in the study area. The classifications have provided an economical and accurate way to quantify, map and analyze changes over time in land cover.

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INTRODUCTION

Land-cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and and/or artificial structures. Land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. Land cover/land use is a composite term, which includes both categories of land cover and land use. Land cover/land use change information has an important role to play at local and regional as well as at macro level planning and management (Ioannis and Meliadis, 2011). The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Land cover and land use changes associated with urbanization are important drivers of local geological, hydrological, ecological, and climatic change (Stefanov *et al.,* 2001). One strategy to better understand urbanization has been to characterize and quantify land cover change, particularly rapid urban growth, through satellite remote sensing. Although historically aerial photography has been the basis for mapping land use/land cover in a region (Donnay *et al.,* 2001). The advantage of using satellite imagery is that data can be collected and analyzed at time intervals more frequently, and with less cost and less subjective interpretation than with aerial photographs due to the higher information content of multispectral data. Change detection as defined by Hoffer (1978) is temporal effects as variation in spectral response involves situations where the spectral characteristics of the vegetation or other cover type in a given location change over time. Singh (1989) described change detection as a process that observes the differences of an object or phenomenon at different times. Digital change detection is the process that helps in determining the changes associated with land use and land cover properties with reference to geo-registered multi-temporal remote sensing data (Papadopoulou and Tsakiri-Strati, 1993; Lu *et al.,* 2004). It helps in identifying changes between two or more than two dates of the area under

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study. Change detection is useful in many applications such as land cover / land use changes, rate of deforestation, rate and success of reforestation, habitat fragmentation, landscape evolution, through the synergetic use of the spatial and temporal analysis techniques of Geographic Information System (GIS) and Remote Sensing along with digital image processing techniques (Foody, 2002; Malinverni *et al.,* 2003). So, the remote sensing data at different time interval help in analyzing the rate of changes as well as the causal factors or drivers of changes. Hence it has a significant role in regional planning at different spatial and temporal scales.

Study area

The river Yamuna is of glacial origin and is the sub-basin of the Ganga river system. Yamuna is one of the most prominent and sacred rivers of India. A major tributary of the river Ganga, it originates from the Yamunotri glacier (Saptrishi Kund) near Bander punch peaks (38^0 59' N, 78 ^{0}27' E) in the Mussoorie range of the lower Himalayas at an elevation of about 6320 meter above mean sea level in Uttarkashi district of Uttarakhand. Due to significant variations in hydrological and ecological characteristics, the river Yamuna has been divided into five distinct segments (CPCB, 2001) i.e. The Himalayan segment, the Upper segment, the Delhi segment, the Eutrophicated segment and the Diluted segment. In the present study, a stretch of about 276 km of the Yamuna in upper stretch was surveyed during the year 2010 and 2011 respectively from Dakpathar upstream in the north to Palla in the south. In this stretch of the river ten sampling stations were selected. The details about elevation, latitude and longitude are given in Table 1.

Objectives

The objective of this study is to produce a land use land cover map of the River Yamuna in upper stretch at different epochs in order to detect the changes that have taken place.

MATERIALS AND METHODS

The main goal of this study is to reveal environmental changes using multi- temporal satellite data, in order to extract changes. In order to carry out land-use/land cover analysis, Landsat 4-5 Thematic Mapper data was used. The cloud free satellite data for the Year 1999 and 2011 respectively, for the study area was browsed from U.S. Geological Survey (USGS) official web-site: http://glovis.usgs.gov/ and downloaded. A high resolution multispectral sensor Landsat 4-5 TM data is freely downloadable in raw form and the entire study area is covered in four scenes which were processed. The details of data used is given in Table 2.Raw satellite data was processed using ERDAS IMAGINE 2011 Software and ArcMap 10 running on Microsoft Windows 7 operating system (Figure 1).

Development of a Classification Scheme

Based on the reconnaissance survey a classification scheme was developed for the study area (Table 3). The classification scheme developed gives a rather broad classification where the land use/cover was identified by a single unit. After classification, the accuracy assessment on each classified raster was conducted using the Google Earth imageries as reference points. 50 points for each class (except 25 in case of railways) were assessed in both imageries (1999 and 2011), after Congalton (1991). The classified category was then compared with the class identified in Google Earth and input into an accuracy matrix. Errors of omission and commission, overall accuracy, producers accuracy, users accuracy and Kappa of the maps were calculated.

RESULTS

In order to put any change into a proper perspective, it is important to establish the state of environment in the selected base year. The areal extent of each land use/ land cover class in the year 1999 and 2011 was analyzed in order to get an overview of changes in magnitude so as to justify the change analysis. (Map 2 and 3). Study area was restricted to a 5 km buffer on both sides of the river. The static land use/ land cover distribution for both the study years as derived from the maps are represented in the tables 4 and 5and figure 2 and 3 respectively. It was found that most of the area is under agricultural land use (66.18 – 68.78 %). Forest area(including all tree cover) covered about 12.27 % of the total area during 1999 mainly in the upper stretch. This has decreased to about 12.13 % in 2011. The settlement areas occupied a considerable portion and increased from 9.42 to 11.33%. The rivers/streams/drains ranged between 5.97 – 6.77 % and the scrub lands and wetlands were found quite less 1.98 – 2.06 % and 1.50 – 1.53% respectively. During the study period (1999 and 2011), there were changes in land cover and land uses. As a result of urbanization, a lot of agricultural area was converted into built-up area/settlements. The total agricultural area lost during the study period was 10408 ha which represented 46.76 % of the total area changed during the course of study. There has been a considerable increase (7876 ha) in built-up area representing 34.35 % of the total changed area. There was a gradual decrease of forest cover (540 ha) in all the forest types i.e. dense mixed forest, fairly dense mixed forest and open mixed forest in the descending order respectively. The sandbar and river areas have undergone an increase in area by 3240 ha and 64 ha respectively from 1999 to 2011 and the canals have decreased by 8 ha. Highland open scrubs, cut-off meander/ox-bow lakes, drains and railways have more or less remained unchanged.

Changes in different land use/ land cover categories from 1999 to 2011

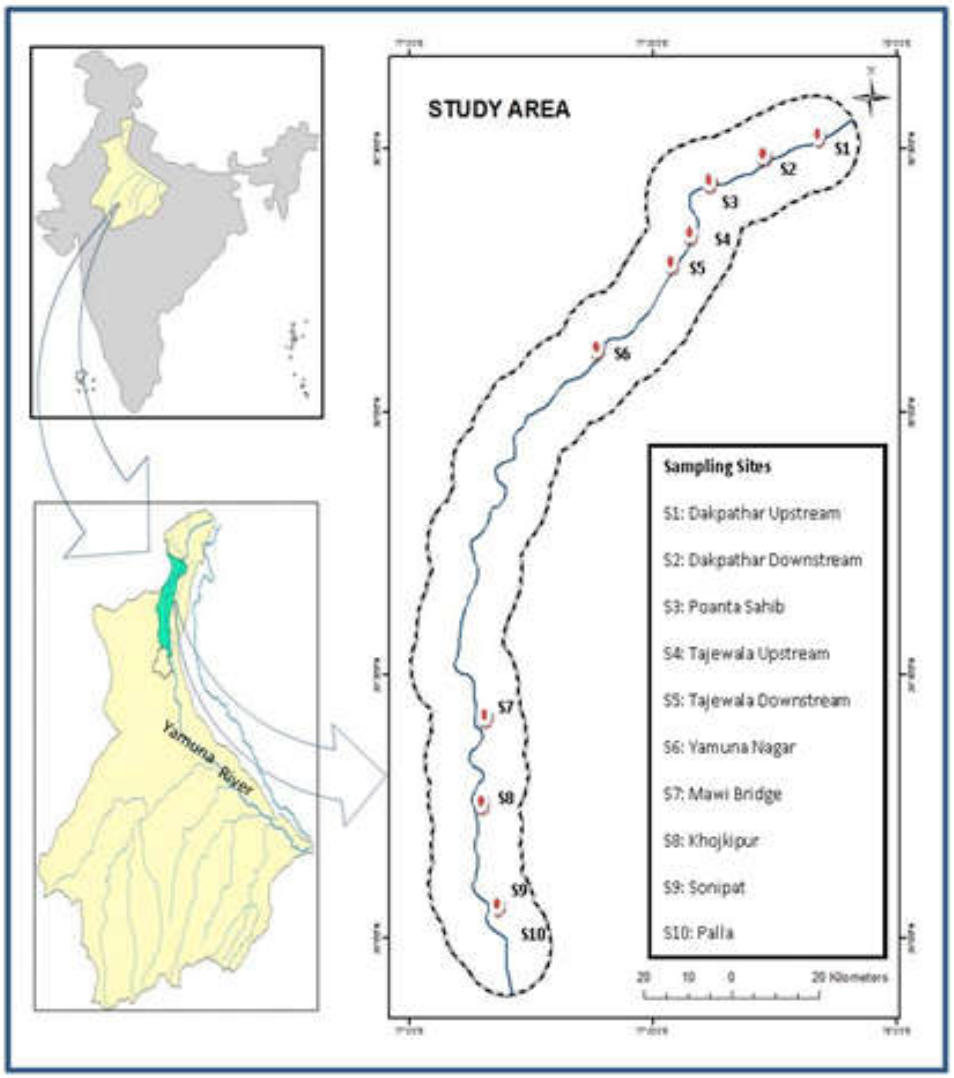
To understand the land use dynamics, the land cover change map of 1999 and 2011 for the upper, middle and lower reach of the river Yamuna has been prepared. In total forty seven classes of changes i.e., settlement to agricultural land; dense mixed forest to fairly dense mixed forest, agricultural land, open mixed forest, water-logged area and settlement; fairly dense mixed forest to highland open scrub, dense mixed forest, agricultural land, canal, open scrub and sandbar; open mixed forest to dense mixed forest, agricultural land and settlement; agricultural land to dense mixed forest, fairly dense mixed forest, settlement, river, canal, open scrub, sandbar and waterlogged area; highland open scrub to dense mixed forest, fairly dense mixed forest and river; open scrub to agricultural land, sandbar, settlement and river; cut-off meander/ ox-bow lake to agricultural land, water-logged area to agricultural land

and settlement; river to fairly dense mixed forest, agricultural land, open mixed forest, sandbar, open scrub, water-logged area and settlement; sandbar to river, agricultural land, open scrub, water-logged area and settlement; no change and other are considered. (Map 4)

Tables 6,7 and 8 give the overall changes in land use/ land cover dynamics during 1999 to 2011 in the upper, middle and lower reaches of the river Yamuna respectively. In these tables, the no change category has also been included to get an overview of overall scenario of the land use/land cover dynamics with respect to the entire land cover. It was found from the change analysis that maximum change was observed in the lower reach (9.49%) followed by middle reach (8.01%) and very little change was detected in the upper reach (0.52%). The differences in the changed area would not be equally appreciable had the unchanged area (no change category) been studied in the corresponding tables and graphs. So for better statistical and graphical representation of the data, only changes in the changed area (which is taken as 100% in total) are represented in tables 9, 10 and 11.In the upper reach of the river Yamuna, the maximum conversion was found in the rivers/streams/drains class followed by forests and agricultural land respectively. About 220 ha of the sandbar area which corresponds to 53.40% of the total changed area of the upper reach was converted into agricultural land (Map 5).

The land use land cover changes followed almost the same trend in both middle and lower reaches respectively with agricultural lands being mostly victimized followed by rivers/streams/drains class. About 10888 ha (57.28%) and 6036 ha (68.37%) of agricultural land in the middle and lower reach respectively were put into non-agricultural uses mainly built-up area/settlements and sandbar. (Map5). Similarly, 1872 ha (9.58%) and 484 ha (5.48%) of sandbar area in the middle and lower reaches respectively was converted into agricultural land and 1448 ha (7.62%) and 452 ha (5.12%) of the river area in the corresponding middle and lower reaches were converted into sandbars.

The accuracy assessments of classified maps indicated overall accuracies of 78.46% and 81.23% and Kappa as 0.7470 and 0.7795 for the year 1999 and 2011 respectively. The accuracy of the agricultural land was low compared to all other classes during both the years, with user accuracy values of 59% and 64% respectively in 1999 and 2011. For other classes it ranged from 78 – 100% in 1999 and 74 – 100% in 2011 with maximum user accuracy values being attributed to railway class during both the years. (Table 12)



Map 1. Map illustrating the stretch along the River Yamuna Studied

Table 1. The Sampling locations in Upper Stretch of the River Yamuna

S.No	Sampling Location	State	Elevation (m)	Latitude	Longitude
1	Dakpathar Upstream	Uttarakhand	492	30°30'42"N	77°49'57"E
2	Dakpathar Downstream	Uttarakhand	446	30°30'06"N	77°47'39"E
3	Poanta Sahib	Himachal Pradesh	370	30°26'03" N	77°37'26"E
4	Tajewala Upstream	Haryana	314	30°17'52"N	77°33'47"E
5	Tajewala Downstream	Haryana	302	30°17'46" N	77°33'42"E
6	Yamuna Nagar	Haryana	246	30°04'06"N	77°21'14"E
7	Mawi Bridge	Haryana	214	29°23'01"N	77°00'.59"E
8	Khojkipur	Haryana	220	29°15'56"N	77°07'38"E
9	Sonipat	Haryana	185	28°59'10"N	77°11'51"E
10	Palla	Delhi	157	28°59'13"N	77°12'30"E

Table 2. Details of Landsat 4-5 TM Data used

Year	Scene No.	Date	Path	Row
	1.	28/04/1999	147	039
	2.	21/04/1999	146	039
1999	3.	21/04/1999	147	040
	4.	28/04/1999	146	040
	1.	8/05/2011	147	039
	2.	22/04/2011	146	039
2011	3.	22/04/2011	147	040
	4.	8/05/2011	146	040

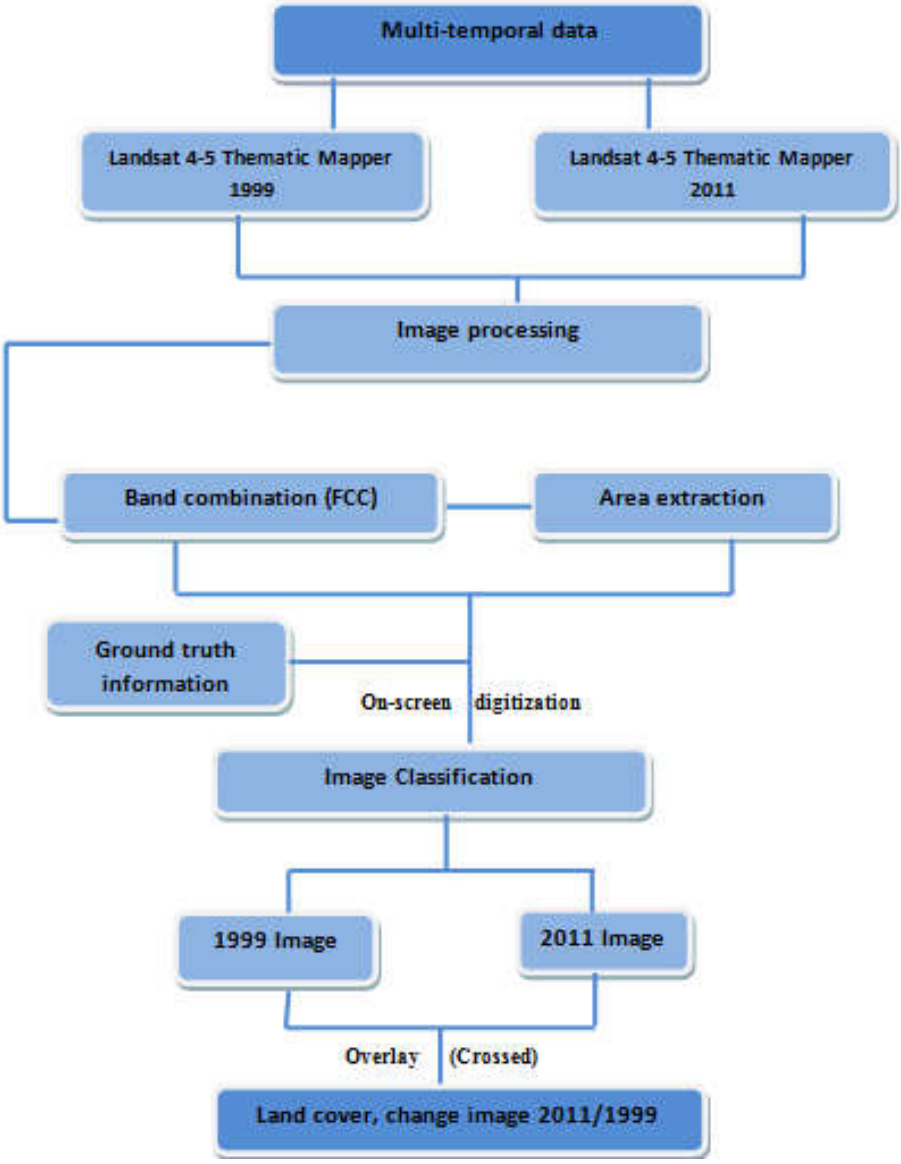
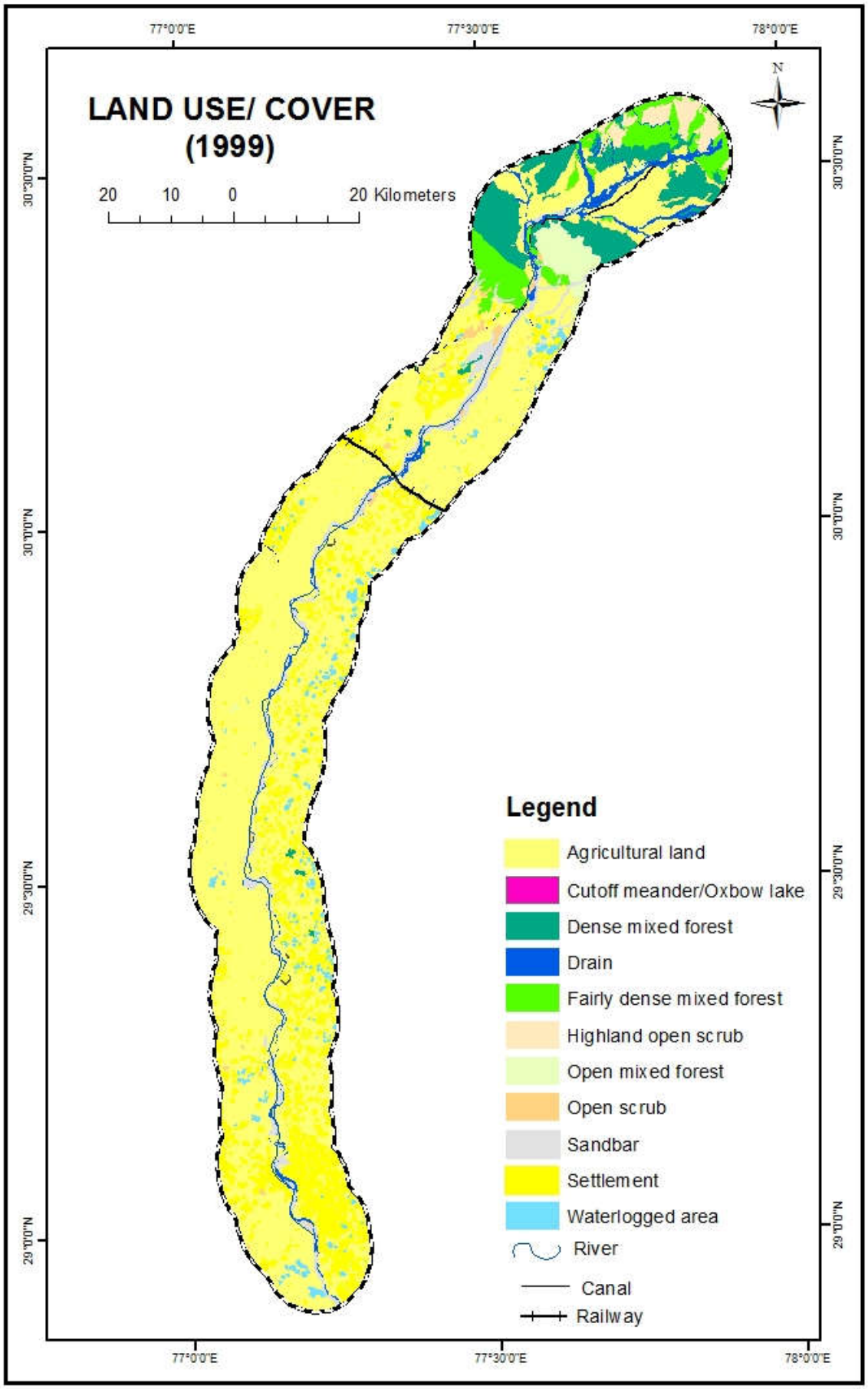
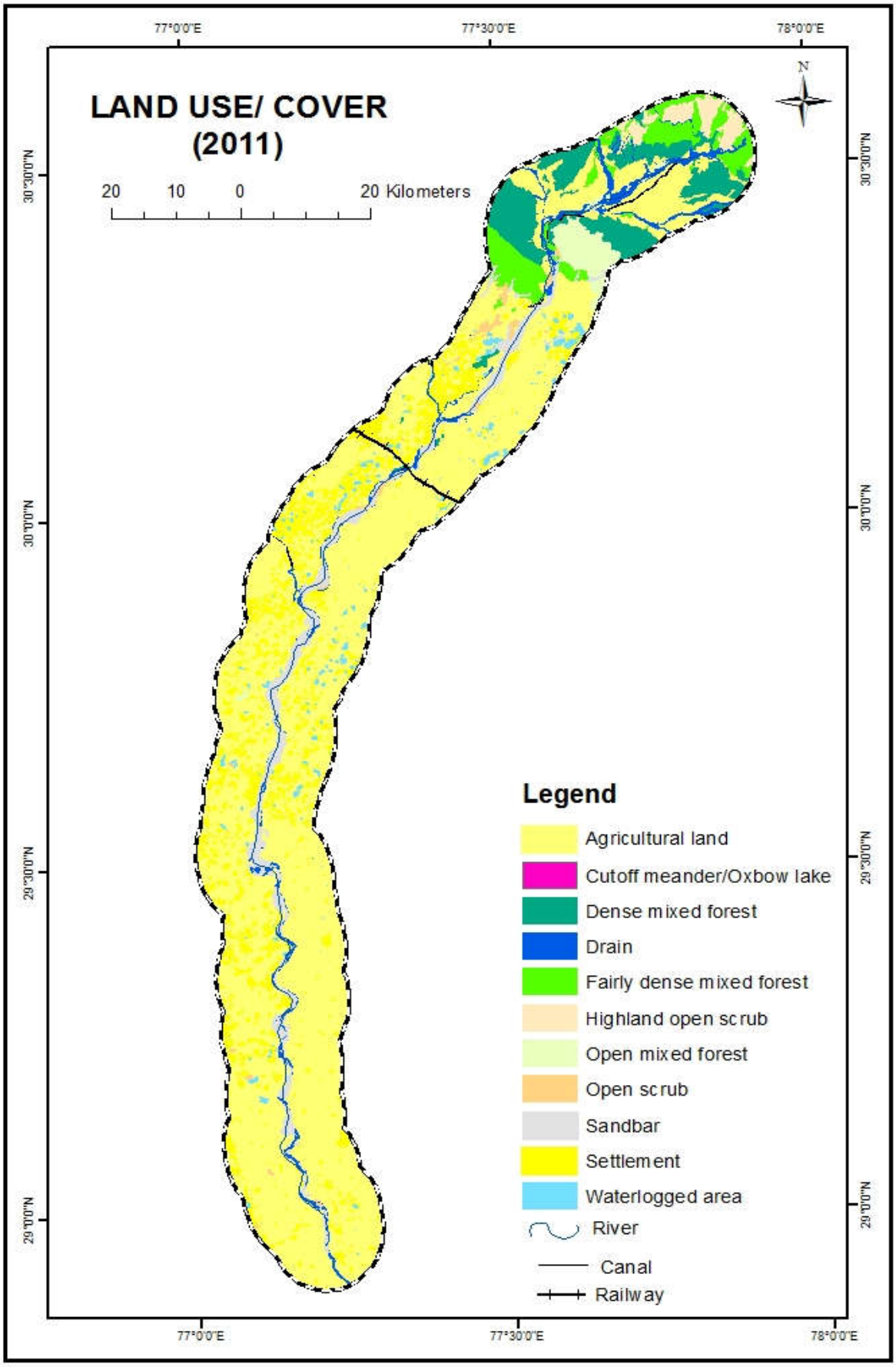


Figure 1. Flow chart for Land Use Land Cover Change Detection



Map 2. Land use/ land cover map of the river Yamuna in Upper stretch in 1999



Map 3. Land use/ land cover map of the river Yamuna in Upper stretch in 2011

Table 3. Land use land cover classification scheme

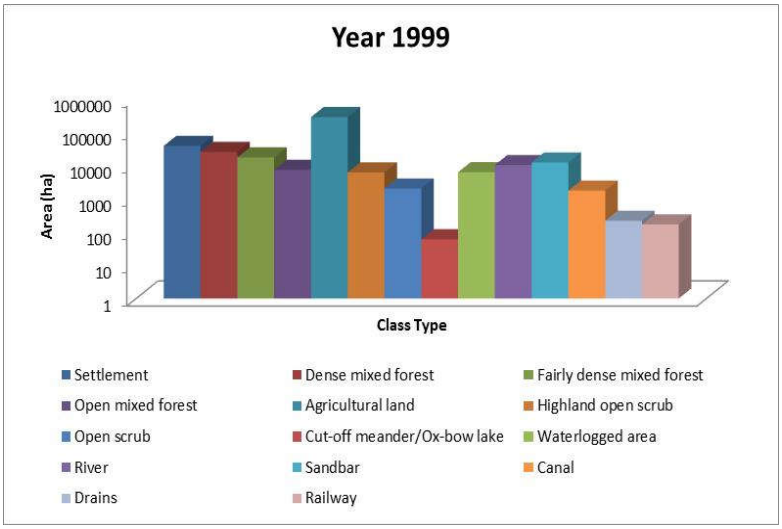
Land use /land cover classes	Class types
1.Built-up Area/Settlement	1.1 Settlement
2. Forest	2.1. Dense mixed forest
	2.2. Fairly dense mixed forest
	2.3. Open mixed forest
3. Agricultural land	3.1. Agricultural land
4.Scrub land	4.1.Highland open scrub
	4.2. Open scrub
5.Wetlands	5.1.Cut-off meander/ Ox-bow lake
	5.2.Waterlogged area
6.River/Streams/Drains	6.1. River 6.1.1 Sandbar
	6.2. Canal
	6.3.Drains
7.Railways	7.1.Railway

Table 4. Area (ha) and percentage of different land use/ land cover categories in the year 1999

Classes	Year 1999 Class Type	Area (ha)	Percentage (%)
Settlement	Settlement	38532	9.42
Forest	Dense mixed forest	25572	6.25
	Fairly dense mixed forest	17316	4.23
	Open mixed forest	7308	1.79
Agricultural land	Agricultural land	281416	68.78
Scrub land	Highland open scrub	6096	1.49
	Open scrub	2020	0.49
Wetlands	Cut-off meander/Ox-bow lake	60	0.01
	Waterlogged area	6228	1.52
River/Streams/Drains	River	10240	2.5
	Sandbar	12224	2.99
	Canal	1740	0.43
	Drains	216	0.05
Railways	Railway	168	0.04
Total		**409136**	**100**

Table 5. Area (ha) and percentage of different land use/ land cover categories in the year 2011

Classes	Year 2011 Class Type	Area (ha)	Percentage (%)
Settlement	Settlement	46408	11.33
Forest	Dense mixed forest	25312	6.18
	Fairly dense mixed forest	17072	4.17
	Open mixed forest	7272	1.78
Agricultural land	Agricultural land	271008	66.18
Scrub land	Highland open scrub	6088	1.49
	Open scrub	2340	0.57
Wetlands	Cut-off meander/ Ox-bow lake	28	0.01
	Waterlogged area	6116	1.49
River/Streams/Drains	River	10304	2.52
	Sandbar	15464	3.78
	Canal	1732	0.42
	Drains	216	0.05
Railways	Railway	160	0.04
Total		**409520**	**100**



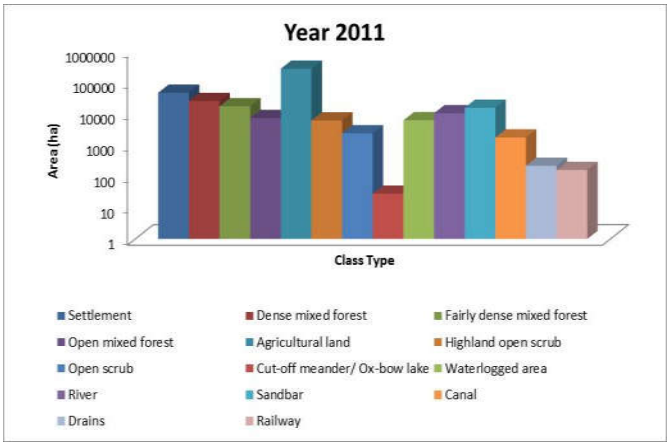


Figure 2. Area under different land use/ land cover categories in the year 1999 and 2011 respectively

Table 6. Overall changes in land use/ land cover categories in 1999 – 2011 in upper reach of the river Yamuna

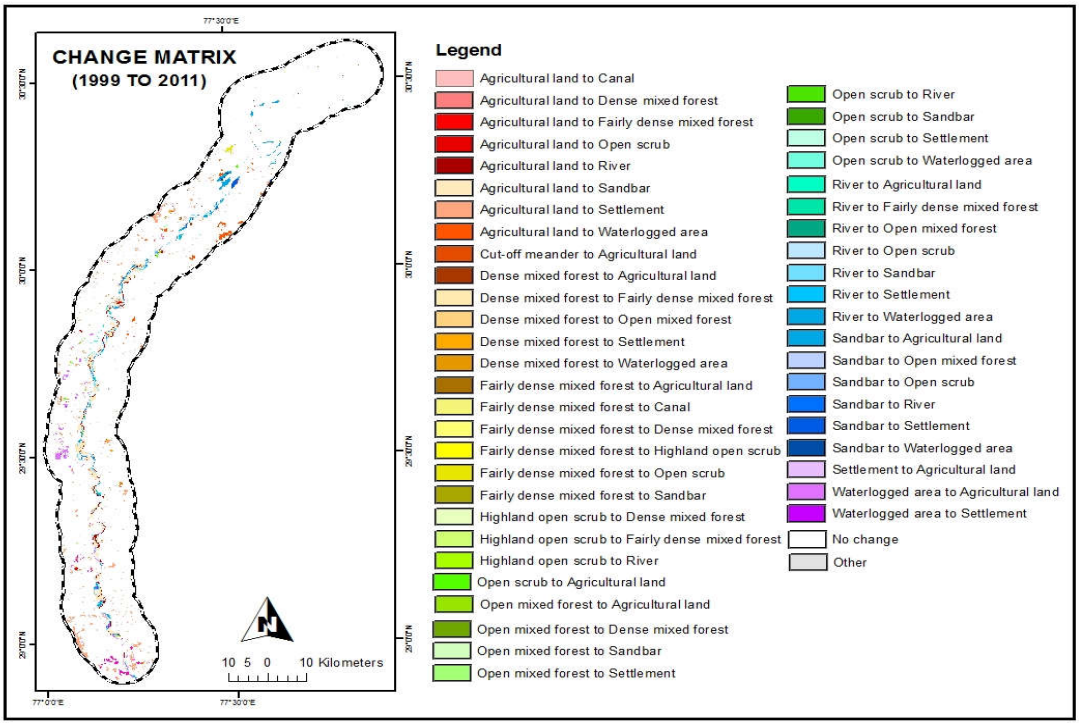
	Classes	Change Type	Area (ha)	Percentage (%)
UPPER REACH	**Forest**	Dense mixed forest to Fairly dense mixed forest	8	0.01
		Dense mixed forest to Agricultural land	16	0.02
		Dense mixed forest to Open mixed forest	12	0.02
		Fairly dense mixed forest to Highland open scrub	4	0.01
		Fairly dense mixed forest to Dense mixed forest	16	0.02
		Fairly dense mixed forest to Agricultural land	4	0.01
		Fairly dense mixed forest to Canal	4	0.01
		Open mixed forest to Dense mixed forest	4	0.01
	Agricultural land	Agricultural land to Fairly dense mixed forest	4	0.01
		Agricultural land to Dense mixed forest	20	0.03
		Agricultural land to River	36	0.05
	Scrub land	Highland open scrub to Fairly dense mixed forest	8	0.01
		Highland open scrub to Dense mixed forest	4	0.01
		Highland open scrub to River	4	0.01
	River/Streams/Drains	River to Fairly dense mixed forest	16	0.02
		River to Agricultural land	4	0.01
		River to Open mixed forest	4	0.01
		River to Sandbar	4	0.01
		Sandbar to Agricultural land	220	0.28
		Sandbar to River	4	0.01
	Other	Other	16	0.02
	No Change	No change	78184	99.48
	Total		**78596**	**100**

Table 7. Overall changes in land use/land cover categories in 1999 – 2011 in middle reach of the river Yamuna

	Classes	Change Type	Area(ha)	Percentage (%)
MIDDLE REACH	**Built-up Area/ Settlement**	Settlement to Agricultural land	452	0.19
	Forest	Dense mixed forest to Agricultural land	104	0.04
		Dense mixed forest to Waterlogged area	48	0.02
		Dense mixed forest to Settlement	128	0.05
		Fairly dense mixed forest to Open scrub	244	0.1
		Fairly dense mixed forest to Sandbar	12	0.01
		Open mixed forest to Agricultural land	16	0.01
		Open mixed forest to Settlement	32	0.01
	Agricultural land	Agricultural land to River	1148	0.48
		Agricultural land to Canal	20	0.01
		Agricultural land to Open scrub	208	0.09
		Agricultural land to Sandbar	4204	1.77
		Agricultural land to Waterlogged area	1628	0.69
		Agricultural land to Settlement	3680	1.55
	Scrub land	Open scrub to Agricultural land	216	0.09
		Open scrub to Sandbar	40	0.02
		Open scrub to Settlement	56	0.02
	Wetlands	Cut off meander/ Ox-bow lake to Agricultural land	36	0.02
		Waterlogged area to Agricultural land	1312	0.55
		Waterlogged area to Settlement	52	0.02
	River/Streams/Drains	River to Agricultural land	516	0.22
		River to Open scrub	40	0.02
		River to Sandbar	1448	0.61
		River to Waterlogged area	12	0.01
		River to Settlement	24	0.01
		Sandbar to Agricultural land	1872	0.79
		Sandbar to River	700	0.29
		Sandbar to Open scrub	96	0.04
		Sandbar to Waterlogged area	132	0.06
		Sandbar to Settlement	456	0.19
	Other	Other	76	0.03
	No change	No Change	218400	91.99
		Total	**237408**	**100**

Table 8. Overall changes in land use/land cover categories in 1999 – 2011 in lower reach of the river Yamuna

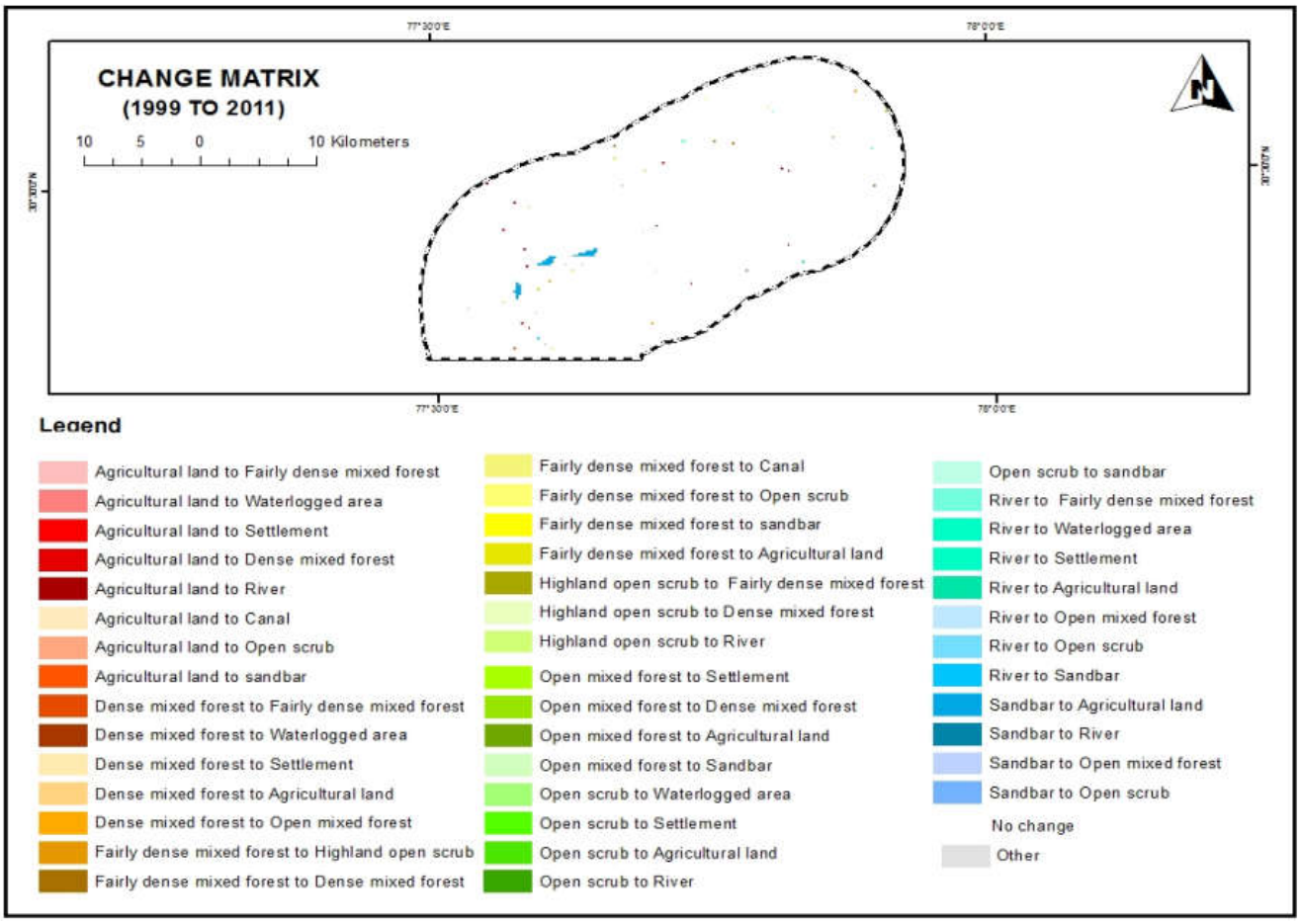
	Classes	Change Type	Area(ha)	Percentage (%)
LOWER REACH	**Built-up Area/ Settlement**	Settlement to Agricultural land	236	0.25
	Agricultural land	Agricultural land to River	616	0.66
		Agricultural land to Open scrub	64	0.07
		Agricultural land to Sandbar	1556	1.67
		Agricultural land to Waterlogged area	112	0.12
		Agricultural land to Settlement	3688	3.96
	Scrub area	Open scrub to Agricultural land	20	0.02
		Open scrub to River	20	0.02
	Wetlands	Waterlogged area to Agricultural land	584	0.63
		Waterlogged area to Settlement	112	0.12
	River/Streams/Drains	River to Agricultural land	304	0.33
		River to Open scrub	32	0.03
		River to Sandbar	452	0.49
		River to Settlement	52	0.06
		Sandbar to Agricultural land	484	0.52
		Sandbar to River	432	0.46
		Sandbar to Settlement	64	0.07
	No Change	No Change	84188	90.51
		TOTAL	**93016**	**100**

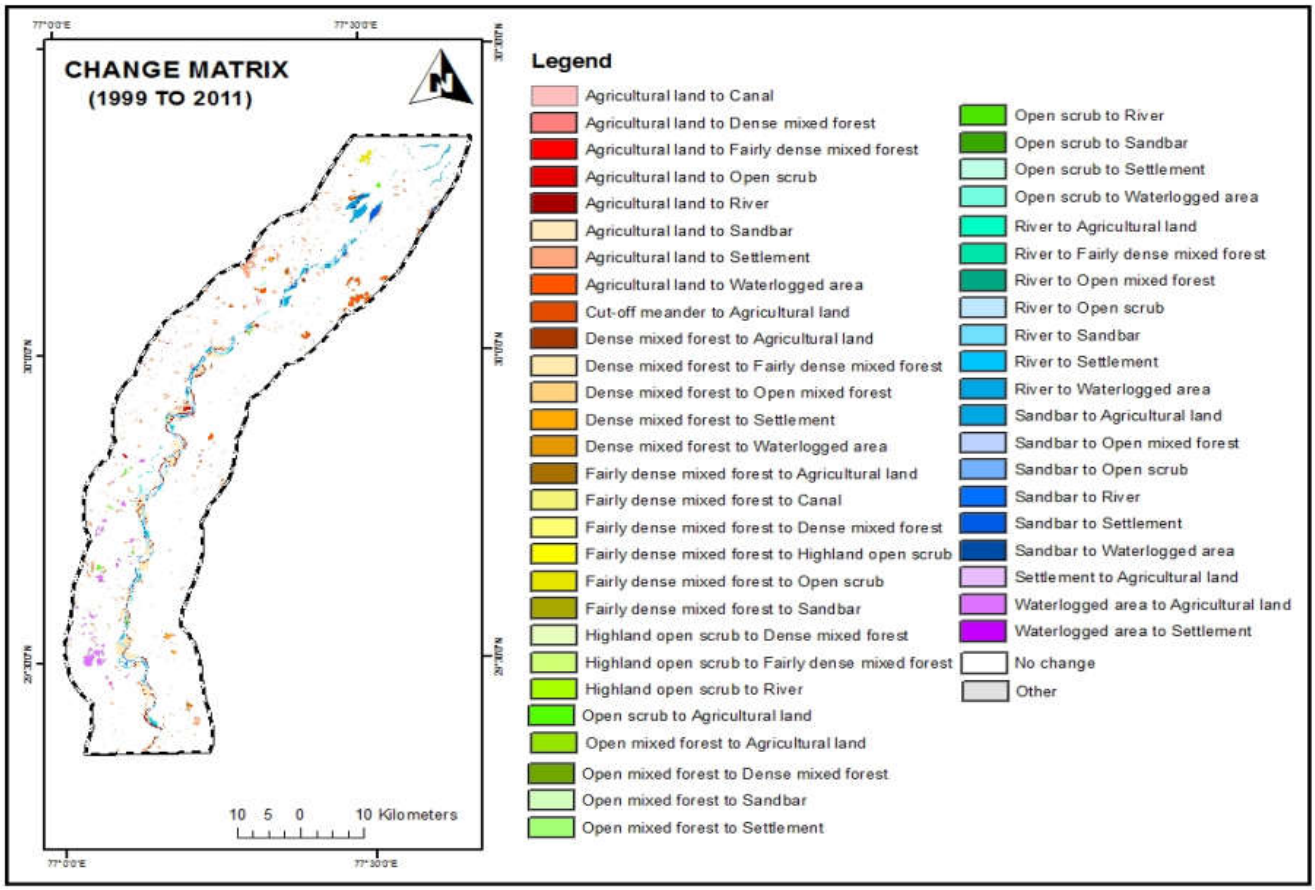


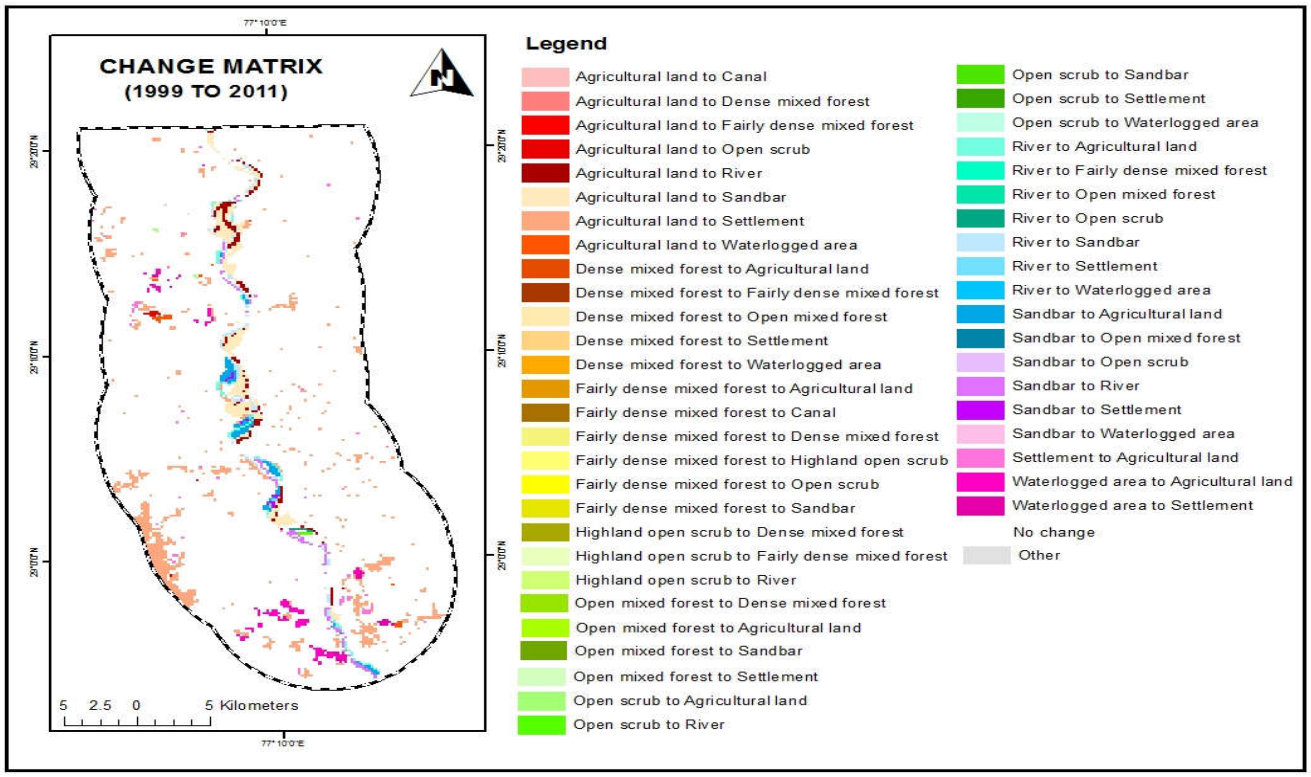
Map 4. Changes in different land use/land cover categories in the Upper Stretch of the river Yamuna from 1999 to 2011

Table 9. Changes in land use/ land cover categories in 1999 – 2011 in upper reach of the river Yamuna (excluding no change area)

	UPPER REACH		
Classes	**Change Type**	**Area(ha)**	**Percentage(%)**
Forest	Dense mixed forest to Fairly dense mixed forest	8	1.94
	Dense mixed forest to Agricultural land	16	3.88
	Dense mixed forest to Open mixed forest	12	2.91
	Fairly dense mixed forest to Highland open scrub	4	0.97
	Fairly dense mixed forest to Dense mixed forest	16	3.88
	Fairly dense mixed forest to Agricultural land	4	0.97
	Fairly dense mixed forest to Canal	4	0.97
	Open mixed forest to Dense mixed forest	4	0.97
	Total	**68**	**16.5**
Agricultural land	Agricultural land to Fairly dense mixed forest	4	0.97
	Agricultural land to Dense mixed forest	20	4.85
	Agricultural land to River	36	8.74
	Total	**60**	**14.56**
Scrub land	Highland open scrub to Fairly dense mixed forest	8	1.94
	Highland open scrub to Dense mixed forest	4	0.97
	Highland open scrub to River	4	0.97
	Total	**16**	**3.88**
River/Streams/Drains	River to Fairly dense mixed forest	16	3.88
	River to Agricultural land	4	0.97
	River to Open mixed forest	4	0.97
	River to Sandbar	4	0.97
	Sandbar to Agricultural land	220	53.4
	Sandbar to River	4	0.97
	Total	**252**	**61.17**
Other	Other	16	3.88
	Total	**16**	**3.88**


CHANGE MATRIX
(1999 TO 2011)
10 5 0 10 Kilometers
77°30'0"E
78°0'0"E
30°30'0"N
Legend
Agricultural land to Fairly dense mixed forest
Agricultural land to Waterlogged area
Agricultural land to Settlement
Agricultural land to Dense mixed forest
Agricultural land to River
Agricultural land to Canal
Agricultural land to Open scrub
Agricultural land to sandbar
Dense mixed forest to Fairly dense mixed forest
Dense mixed forest to Waterlogged area
Dense mixed forest to Settlement
Dense mixed forest to Agricultural land
Dense mixed forest to Open mixed forest
Fairly dense mixed forest to Highland open scrub
Fairly dense mixed forest to Dense mixed forest
Fairly dense mixed forest to Canal
Fairly dense mixed forest to Open scrub
Fairly dense mixed forest to sandbar
Fairly dense mixed forest to Agricultural land
Highland open scrub to Fairly dense mixed forest
Highland open scrub to Dense mixed forest
Highland open scrub to River
Open mixed forest to Settlement
Open mixed forest to Dense mixed forest
Open mixed forest to Agricultural land
Open mixed forest to Sandbar
Open scrub to Waterlogged area
Open scrub to Settlement
Open scrub to Agricultural land
Open scrub to River
Open scrub to sandbar
River to Fairly dense mixed forest
River to Waterlogged area
River to Settlement
River to Agricultural land
River to Open mixed forest
River to Open scrub
River to Sandbar
Sandbar to Agricultural land
Sandbar to River
Sandbar to Open mixed forest
Sandbar to Open scrub
No change
Other


CHANGE MATRIX
(1999 TO 2011)
10 5 0 10 Kilometers
77°0'0"E
77°30'0"E
30°30'0"N
Legend
Agricultural land to Canal
Agricultural land to Dense mixed forest
Agricultural land to Fairly dense mixed forest
Agricultural land to Open scrub
Agricultural land to River
Agricultural land to Sandbar
Agricultural land to Settlement
Agricultural land to Waterlogged area
Cut-off meander to Agricultural land
Dense mixed forest to Agricultural land
Dense mixed forest to Fairly dense mixed forest
Dense mixed forest to Open mixed forest
Dense mixed forest to Settlement
Dense mixed forest to Waterlogged area
Fairly dense mixed forest to Agricultural land
Fairly dense mixed forest to Canal
Fairly dense mixed forest to Dense mixed forest
Fairly dense mixed forest to Highland open scrub
Fairly dense mixed forest to Open scrub
Fairly dense mixed forest to Sandbar
Highland open scrub to Dense mixed forest
Highland open scrub to Fairly dense mixed forest
Highland open scrub to River
Open scrub to Agricultural land
Open mixed forest to Agricultural land
Open mixed forest to Dense mixed forest
Open mixed forest to Sandbar
Open mixed forest to Settlement
Open scrub to River
Open scrub to Sandbar
Open scrub to Settlement
Open scrub to Waterlogged area
River to Agricultural land
River to Fairly dense mixed forest
River to Open mixed forest
River to Open scrub
River to Sandbar
River to Settlement
River to Waterlogged area
Sandbar to Agricultural land
Sandbar to Open mixed forest
Sandbar to Open scrub
Sandbar to River
Sandbar to Settlement
Sandbar to Waterlogged area
Settlement to Agricultural land
Waterlogged area to Agricultural land
Waterlogged area to Settlement
No change
Other



Map 5. Changes in different land use/land cover categories in the upper, middle and lower reaches of the river Yamuna from 1999 to 2011

Table 10. Changes in land use/ land cover categories in 1999 – 2011 in middle reach of the river Yamuna (excluding no change area)

MIDDLE REACH			
Classes	**Change Type**	**Area(ha)**	**Percentage (%)**
Built-up Area/ Settlement	Settlement to Agricultural land	452	2.38
	Total	**452**	**2.38**
Forest	Dense mixed forest to Agricultural land	104	0.55
	Dense mixed forest to Waterlogged area	48	0.25
	Dense mixed forest to Settlement	128	0.67
	Fairly dense mixed forest to Open scrub	244	1.28
	Fairly dense mixed forest to Sandbar	12	0.06
	Open mixed forest to Agricultural land	16	0.08
	Open mixed forest to Settlement	32	0.17
	Total	**584**	**3.06**
Agricultural land	Agricultural land to River	1148	6.04
	Agricultural land to Canal	20	0.11
	Agricultural land to Open scrub	208	1.09
	Agricultural land to Sandbar	4204	22.12
	Agricultural land to Waterlogged area	1628	8.56
	Agricultural land to Settlement	3680	19.36
	Total	**10888**	**57.28**
Scrub land	Open scrub to Agricultural land	216	1.14
	Open scrub to Sandbar	40	0.21
	Open scrub to Settlement	56	0.29
	Total	**312**	**1.64**
Wetlands	Cut off meander/ Ox-bow lake to Agricultural land	36	0.19
	Waterlogged area to Agricultural land	1312	6.9
	Waterlogged area to Settlement	52	0.27
	Total	**1400**	**7.36**
River/Streams/Drains	River to Agricultural land	516	2.71
	River to Open scrub	40	0.21
	River to Sandbar	1448	7.62
	River to Waterlogged area	12	0.06
	River to Settlement	24	0.13
	Sandbar to Agricultural land	1872	9.85
	Sandbar to River	700	3.68
	Sandbar to Open scrub	96	0.51
	Sandbar to Waterlogged area	132	0.69
	Sandbar to Settlement	456	2.4
	Total	**5296**	**27.86**
Other	Other	76	0.4
	Total	**76**	**0.4**

Table 11. Changes in land use/ land cover categories in 1999 – 2011 in lower reach of the river Yamuna (excluding no change area)

LOWER REACH			
Classes	**Change type**	**Area(ha)**	**Percentage (%)**
Built-up Area/ Settlement	Settlement to Agricultural land	236	2.67
	Total	**236**	**2.67**
Agricultural land	Agricultural land to River	616	6.98
	Agricultural land to Open scrub	64	0.72
	Agricultural land to Sandbar	1556	17.63
	Agricultural land to Waterlogged area	112	1.27
	Agricultural land to Settlement	3688	41.78
	Total	**6036**	**68.37**
Scrub area	Open scrub to Agricultural land	20	0.23
	Open scrub to River	20	0.23
	Total	**40**	**0.45**
Wetlands	Waterlogged area to Agricultural land	584	6.62
	Waterlogged area to Settlement	112	1.27
	Total	**696**	**7.88**
River/Streams/Drains	River to Agricultural land	304	3.44
	River to Open scrub	32	0.36
	River to Sandbar	452	5.12
	River to Settlement	52	0.59
	Sandbar to Agricultural land	484	5.48
	Sandbar to River	432	4.89
	Sandbar to Settlement	64	0.72
	Total	**1820**	**20.62**

Table 12. Error matrix accuracy totals for the classified images of the year 1999 and 2011

	Classified Image of 1999								Percentage	
Reference data (Google Earth)	Settlement/Built-up Area	Forest	Agricultural land	Scrub land	Wetlands	River/Streams/ Drains	Railways	**Row total**	**Producer Accuracy**	**Error of Omission**
Settlement/Built-up Area	41	2	5	0	0	2	0	50	82	18
Forest	0	35	5	8	0	2	0	50	70	30
Agricultural land	7	0	36	2	0	5	0	50	72	28
Scrub land	0	8	1	39	2	0	0	50	78	22
Wetlands	3	0	9	0	38	0	0	50	76	24
River/Streams/Drains	0	0	2	0	4	44	0	50	88	12
Railways	0	0	3	0	0	0	22	25	88	12
Column Total	51	45	61	49	44	53	22	**325**		
Use Accuracy (%)	80	78	59	80	86	83	100	**Overall accuracy = 78.46%**		
Error of Commission	20	22	41	20	14	17	0	**Kappa = 0.7470**		

	Classified Image of 2011								Percentage	
Reference data (Google Earth)	Settlement/ Built-up Area	Forest	Agricultural land	Scrub land	Wetlands	River/Streams/ Drains	Railways	**Row total**	**Producer Accuracy**	**Error of Omission**
Settlement/Built-up Area	42	3	5	0	0	0	0	50	84	16
Forest	0	41	2	6	1	0	0	50	82	18
Agricultural land	2	0	39	1	7	1	0	50	78	22
Scrub land	0	6	4	37	3	0	0	50	74	26
Wetlands	4	0	4	0	40	2	0	50	80	20
River/Streams/Drains	0	0	5	0	3	42	0	50	84	16
Railways	0	0	2	0	0	0	23	25	92	8
Column Total	48	50	61	44	54	45	23	**325**		
Use Accuracy (%)	87	82	64	84	74	93	100	**Overall accuracy = 81.23%**		
Error of Commission	13	18	36	16	26	7	0	**Kappa = 0.7795**		

DISCUSSION

A multi-temporal Lands at TM data of the study area for the years 1999 and 2011 was used for preparation of LULC maps of both years and for change detection analysis. Seven different land cover/use classes were used including settlements, forest, agricultural land, scrub land, wetlands, river /stream /drains and railways. It was found that during both the years, the maximum area was covered by agricultural land (66.18 – 68.78%) followed by forest (12.13 – 12.27%) and settlement (9.42 – 11.33%). In order to monitor land-use land-cover dynamics, change detection map for the entire study area as well as upper, middle and lower reaches separately were also prepared. It was found from the change analysis that maximum change was observed in the lower reach (9.49%) followed by middle reach (8.01%) and very little change was detected in the upper reach (0.52%). In the upper reach of the river Yamuna, the maximum conversion was found in the rivers/streams/drains class followed by forests and agricultural land respectively. About 220 ha of the sandbar area which corresponds to 53.40% of the total changed area of the upper reach was converted into agricultural land. The land use land cover changes followed almost the same trend in both middle and lower reaches respectively with agricultural lands being mostly converted followed by rivers/streams/drains class. About 10888 ha (57.28%) and 6036 ha (68.37%) of agricultural land in the middle and lower reach respectively were put into non-agricultural uses mainly built-up area/settlements and sandbar. Similarly, 1872 ha (9.58%) and 484 ha (5.48%) of sandbar area in the middle and lower reaches respectively was converted into agricultural land and 1448 ha (7.62%) and 452 ha (5.12%) of the river area in the corresponding middle and lower reaches were converted into sandbars.

Conclusion

The study has indicated the potential use of remote sensing data in studying land cover/ land use change. Information from satellite remote sensing can play a useful role in understanding the nature of changes in land cover/use, where they are occurring, and projecting possible or likely future changes. In this study Lands at images were used satisfactorily for the identification of the seven categories. It's observed that some categories in the area under study changed during 1999- 2011 remarkably. Decrease in agricultural land and forest areas and a considerable increase in built-up area has been as a result of anthropogenic activities in the study area.

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