Land use Land cover Changes in Context to Floods: a Case Study of September 2010 - Flood Affected Villages of Delhi

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Abstract

Due to the increased population and the scarcity of lands, people are increasingly choosing the unsafe areas for settlements and authorities are choosing the areas for unsafe development of infrastructure and public utilities. Whenever the physical land use planning have underestimated the disaster risk in a hazard prone area, the overall risk has been increased. Delhi has experienced six major floods during the year 1924, 1947, 1976, 1978, 1988 and 1995, 2008 and recently in September 2010. The present study was carried out to understand the land use land cover changes and its implications on floods. Eight villages severely affected during the 2010 flood from the north and north-east districts of Delhi were selected for the study. Detailed analysis of all the eight villages was performed to understand the changes land use land cover. Satellite imageries for the year 1992, 1998, 2001, 2005, 2008 and 2010 were used for the study. Land use classification followed by deriving of spatial statistics to understand the changes for 5 land use classes viz, settlement, water body, open area, agriculture and natural was performed for all the villages. It was observed that all the selected villages have experienced substantial changes in the Land Use and Land Cover pattern. Increasing trend was observed in the built-up area in all the selected villages. On contrary a decrease in open area and water body was also observed till 2008. Post 2010 flood there was an increase in the water body and natural vegetation observed in many villages. Comparative analysis was also made between the Land use Land cover patterns derived from classified image of October 2010 of the study area with the proposed land use map of National Capital Region Master Plan 2021. In the NCR Master Plan 2021 consideration of the prevailing flood risk has been taken and the proposed land use for the flood plain ares is predominantly open areas, play grounds, natural vegetation etc. In the flood prone areas/river beds/banks, no construction activities proposed. On the contrary the comparison has shown that significant deviation has already been observed in the present landuse with the proposed land use of NCR 2021.

Key Words: Land use, land cover change, Floods, Image Classification, Settlement, Spatial Statistics

Introduction

The term flood is a general or temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters or from the unusual and rapid accumulation or runoff of surface waters from any source (Bhaskar & Moorthy,

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2003). Flood is one of the most frequent and most devastating disasters. Land use is a very meaningful indicator for the characterisation of urban structures and to know the ecological situation of the city. Changes in land use take place in two ways i.e. when natural areas such as water bodies, forest land are converted into habitation and for other purposes like industrial activities. On the other hand, agricultural areas are also converted for the township development and habitation. Urbanization in developing countries has been doubled from less than 25% in 1970 to more than 50% in 2006 (Gupta et al., 2011). Rapid and uncontrolled growth, bloom in number of vehicles, and financial constraints leading to diminishing investment on infrastructure, have worked together to make our city highly vulnerable to natural hazards. Overtime, continued urbanisation of natural floodplains has caused great annual losses of both wealth and human life. The most clinching evidence of floods having increased as a physical phenomenon comes from the increase in flood affected areas. The flood-affected area increased from an annual average of 6.48 mha in the 1950s to over 9 mha in 1980s and 1990s. This increase is definitely an indication of the country's growing flood proneness.

Table 1: Factors contributing to flooding

Metrological factors	Hydrological factors	Human factor aggravating natural flood hazards.
Rainfall	Soil moisture level	Land-use changes (e.g. surface sealing due to urbanization, deforestation) increase run-off and may be sedimentation.
Cyclonic storms	Groundwater level prior to storm	Occupation of the flood plain obstructing flows.
Small scale storms	Natural surface infiltration	Inefficiency or non-maintenance of infrastructure
temperature	Presence of impervious cover	Efficient drainage of upstream areas increases flood peaks.
Snowfall and snowmelt	Channel cross-sectional shape and roughness.	Climate change affects magnitude and frequency of precipitation and floods.
	Presence or absence of over bank flow, channel network	Urban microclimate may enforce precipitation events.
	Synchronization of runoffs from various parts of watershed.	
	High tide impeding drainage.	

Source: World Meteorological Organisation (2008), Urban Flood Risk Management – A Tool for Integrated Flood Management Version 1.0

Floods in Delhi

The Capital of India has suffered floods as back as in 1924, 1947, 1967, 1971, 1975, 1976, 1978, 1988, 1993, 1995, 1998 and 2010. The 1978 was the worst ever flood in Delhi when water level reached at 207.49 m (danger level is 204.83 m) with discharge 2.53 lakh cusec at old railway bridge (7.0 lakk cusec water released from Tajewala) resulted in submergence of 130 villages and 25 urban colonies in Delhi. As per the map of flood prone areas prepared by central water commission, Delhi has been classified into thirteen zones based on the flooding risk in relation to incremental rise in the water level of the Yamuna. Besides, the Delhi flood control order (2011) also divides the NCTD into four flood sectors, namely Shahdra, Wazirabad-Babrapur, Alipur and Nangloi-Najafgarg sectors. Eight severely flood affected villages from North Delhi viz. Burari, Badarpur, Baqia pad, Jagatpur, Pur, Sadatpur, Seelampur and Subhay pur village witnessed tremendous land use land cover changes over past two decades and the major cause of urban flood in these areas is due to uncontrolled development and land use changes.

Previous work

Flooding is a vigorous dynamic phenomenon where discharge is more than water carrying capacity of river resulting in over toppling of banks and inundation of areas which are otherwise dry (Apte, 2009). Heavy intensity rainfall is a principal cause of urban flooding and is further aggregated by human intervention. Urban areas i.e. cities and towns are growing uncontrollably resulting in drastic change in the land use pattern. This results in change of urban hydrology from gradual rising discharge to quicker and higher peak flows. Cities experiencing heavy precipitation due to their very nature of having large impervious areas, the rain flood water and wastewater do not infiltrate into the ground produce large run-off which the drainage network cannot accommodate, and are potentially exposed to floods (WMO, 2008). Under these circumstances the sustainable management of urban flood risk is becoming an increasingly challenging task for urban communities and the responsible authorities to address. Urban Flooding has become challenging problems in major cities like Delhi, Hyderabad and Calcutta. The un-even distribution of rain fall coupled with Mindless urbanization, encroaching upon and filling up natural drainage channels and urban lakes to use the high-value urban land for buildings are the cause of urban flooding (Pareva, ND). National Water Policy has been implemented over the years on regulating land use in the flood plains by scientifically demarcating areas under different degrees of risk from floods and limit. A case study has been performed on Flood plain zoning and management for Delhi (Rangachari, 2008). A detailed study on urban floods, its impacts and mitigation was carried out by NIDM with the support of IITs for 8 cities. A

case study of Delhi with special emphasis on the demographic and settlement pattern to know the land use changes and the vulnerability of floods in the city also carried out under this project (Gosain et.al, 2009). A detailed study of the land use land cover changes and its impact on urban ecology carried out by Gupta et al. (2011).

Aim

The study is aimed at understanding land use land cover changes and it's implication on flood scenario in selected villages of Delhi.

Objectives

1. To identify the villages affected by flood during Delhi floods, September 2010
2. To generate time series land use maps for the selected flood affected villages
3. To identify the land use changes for the flood affected villages for various land use categories (built-up area, water bodies, vegetation, agriculture and open area).
4. To compare the present land use scenario with the land use proposed in 2021 NCR Region Plan
5. Analyse the implications of land use land cover changes

Materials and Methodology

Flood inundated areas of 2010 floods were identified using the inundation maps developed using RADARSAT data (NRSC, 2010). Inundation map was overlaid on the village boundary map of the area and 8 most affected villages were identified for detailed analysis of land use land cover changes. The villages identified were Burari, Badarpur, Seelampur, Baqiapad, Subhaypur, Sadatpur, Jagatpur and Pur village.

Time series land-use land cover maps were prepared using Landsat ETM Orthorectified data and IRS LISS. Data preparation was initiated with layer stacking followed by Georeferencing & Sub-setting of image. Haze reduction and image enhancement was performed for the LISS III data of 2008 for better image interpretation. Visual interpretation of the time series satellite imageries (Landsat ETM and IRS data) of 1992, 1999, 2001, 2005, 2008 and 2010 was performed. Besides Google images were also used for verifying the analysis for the period 2000-2010. Subset images were prepared for all the 8 villages.

Unsupervised classification with five major classes were prepared and compared with Google images. Unsupervised scheme of classification was performed because it is not feasible to do field check for the historic data. The images used for the study were from multiple sources; hence it was not feasible to perform direct change detection using image processing techniques. Alternatively spatial statistics was computed for

all the classes from the classified imagery.

The following figure 1 shows the flow chart which explains the basic methodology followed in this study:-

Analysis and Results

Identification of Flood affected villages

Flood affected areas were identified using the RADARSAT data of September 2010 and also from the inundated area map obtained from National Remote Sensing Centre. Based on the visual interpretation and overlay analysis 8 affected villages were identified for detailed analysis. RADARSAT Image of 11 September 2010 and map showing flood affected villages of North and North East districts of Delhi are shown in Figure 2.

Interpretation of Land use changes

Visual interpretation of the time series satellite imageries (Landsat ETM and IRS data) of 1992, 1999, 2001, 2005, 2008 and 2010 depicts substantial changes in the Land use. In5all the selected villages, built area has increased and natural vegetation, agriculture and open area are reduced. (Figure 3 to 10). The outcome of the analytical study on different villages is presented in the following sections:-

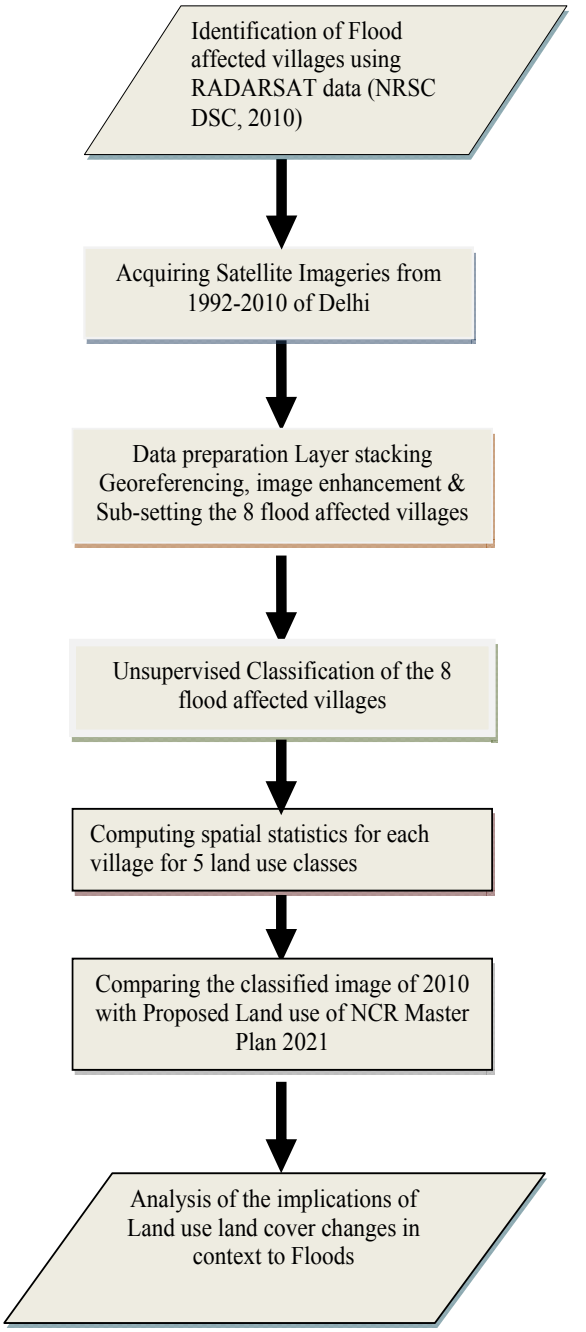


Figure 1: Methodology

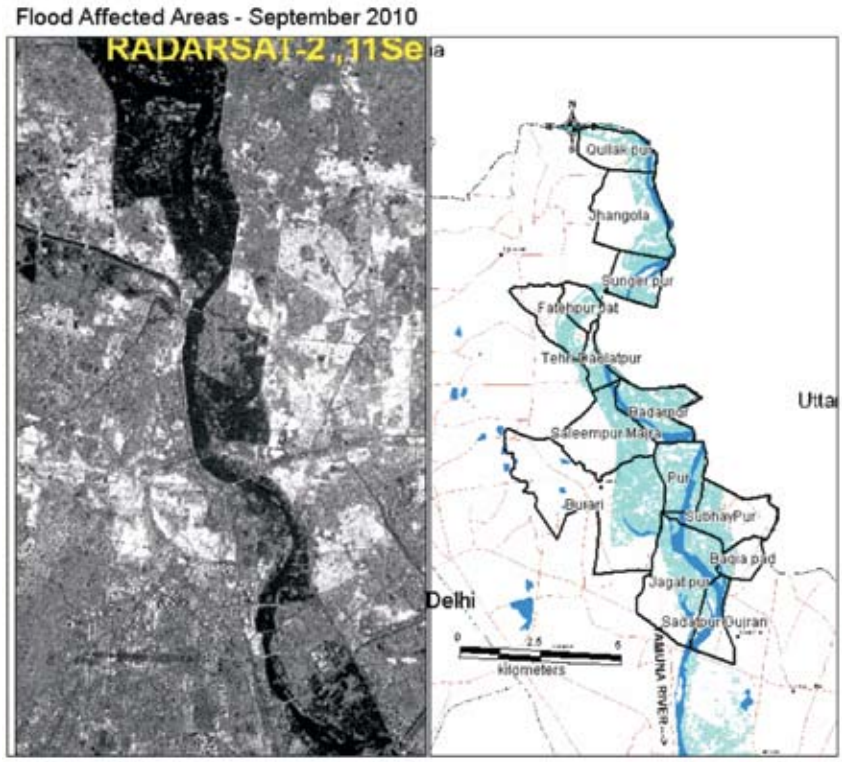


Figure 2: Map showing flood affected villages of North and North East districts of Delhi (*Source*: Decision Support Centre, National Remote Sensing centre, Hyderabad)

1. Burari village

Land use land cover mapping of Burari village depicts increase (more than 5 times) of built up area from 6.97 % in year 1992 to 35.43 % in year 2010. In 1992 satellite imagery Burari village shows an oxbow lake originated from Yamuna River but in 2001 the lake was disconnected from the river channel. The area of the lake was reduced later and in 2008 satellite imagery only a small water body left in south east area only about 2.26%. In the 2010 imagery, the lake area has shown increase due to 2010 floods. Also imagery shows very rich vegetation cover and agricultural land patches in 1992 and 1999 which were replaced by settlements in 2010 imagery. The landuse changes over the period 1992-2010 for the Burari village is shown in figure 3 and table 2.

Table 2: Land use changes in Burari village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	170.82	14.49	82.12	6.97	281.77	23.90	509.61	43.20	133.78	11.35
1998	161.55	13.71	237.04	20.12	228.78	18.16	450.28	38.22	117.54	9.33
2001	62.33	5.28	368.29	31.26	261.86	22.22	375.44	31.85	110.66	9.38
2005	61.87	6.94	365.19	30.99	182.64	15.50	480.65	42.83	84.78	7.53
2008	16.04	2.26	140.57	19..90	42.81	6.06	451.43	63.93	55.22	7.82
2010	154.89	13.14	417.42	35.43	133.74	11.35	346.23	30.30	128.32	10.89

For 2008 image was not available for the village

2. Badarpur village

Built up area increased from 4.06 % in the year 1992 to 21.36 % in the year 2010. On the other hand open area has been decreased to a greater extent The agriculture land percentage has remained the same during the analysis period. Change in the course of river channel is observed during period with in the Badarpur village area. Maximum change in the river morphology was observed in during 1992-1998 period. It was observed that the area under vegetation has decreased substantially i.e from 9.92 % in the year 1992 to 5.63 in the year 2005 and increased to 7.07 % after the 2010 flood event. The Land Use changes over the period 1992-2010 for the Badarpur village is shown in Figure 4 and table 3

Table 3: Land use changes in Badarpur village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	46.38	19.77	13.32	4.06	77.24	23.59	172.03	42.63	18.35	9.92
1998	86.58	30.67	11.07	3.37	42.12	12.80	174.87	40.57	14.31	3.36
2001	45.05	13.71	38.94	11.87	71.59	21.82	147.404	44.81	18.30	5.46
2005	64.81	19.90	42.88	13.06	63.76	19.20	141.81	42.57	18.36	5.63
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	50.13	15.39	69.57	21.36	43.74	13.45	142.29	43.29	23.22	7.07

** For 2008 image was not available for the village.

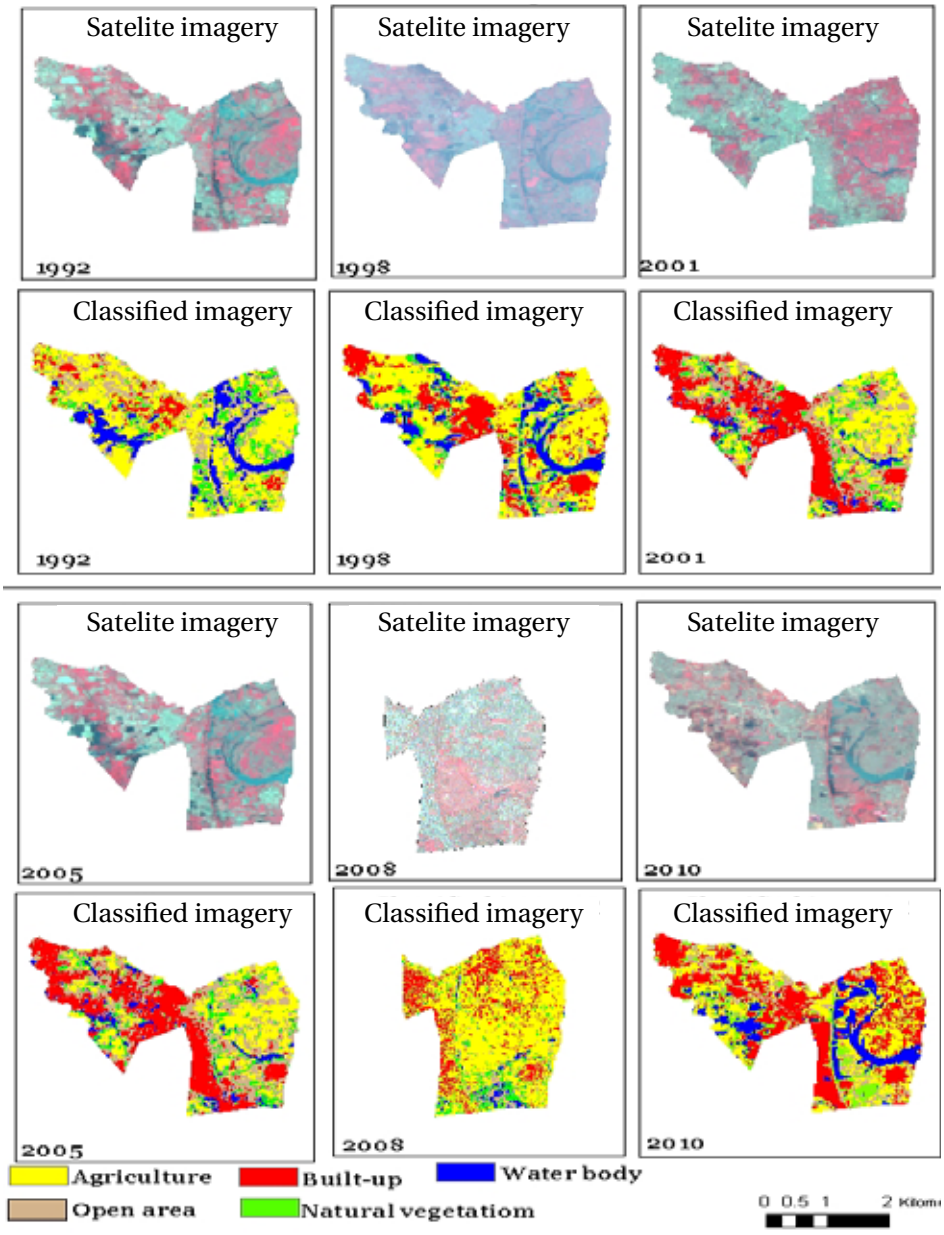


Figure 3: Time Series Satellite imagery and classified images of Burari Village

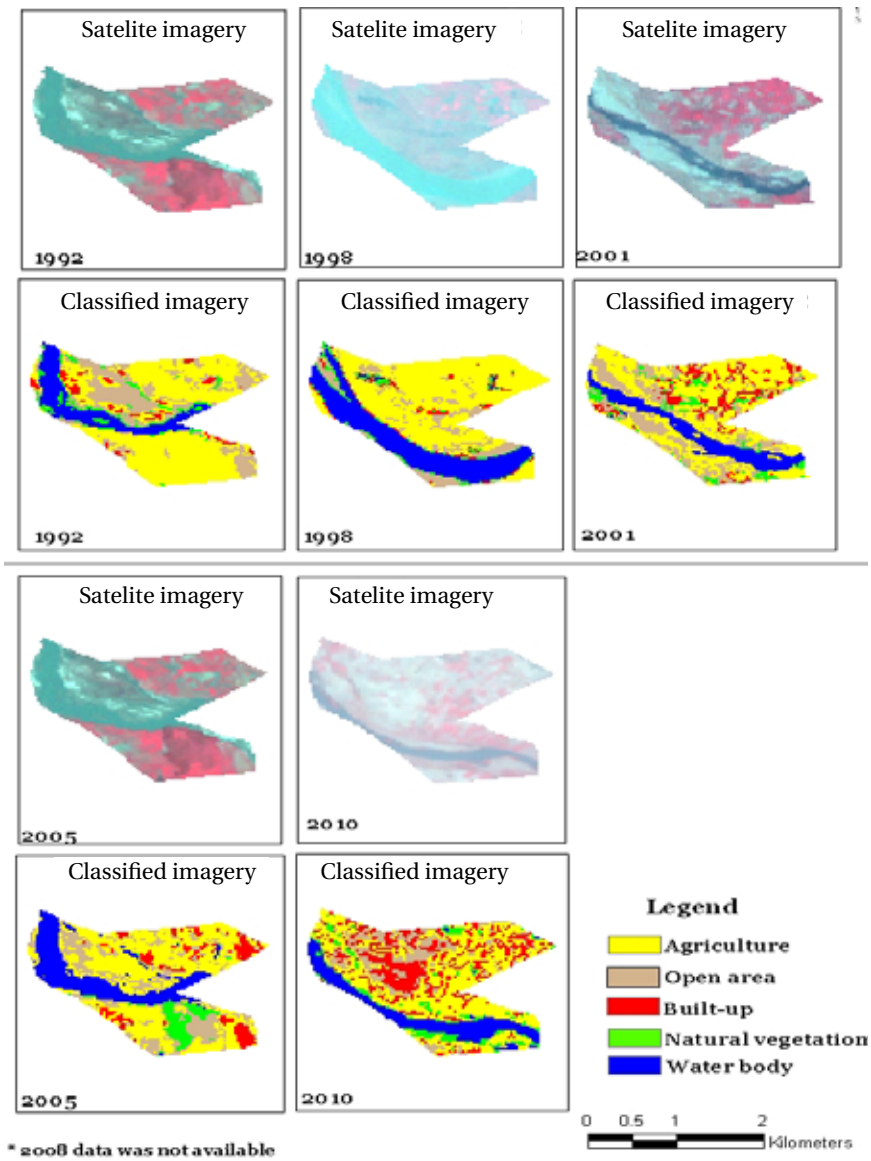


Figure 4: Time Series Satellite imagery and classified images of Badarpur Village

3. Seelampur village

An increasing trend of the built-up area has been observed for the Seelampur village. The increase is nearly two fold during the period 1992-2010 i.e. from 50.34 ha in year

1992 to 99 ha in year 2010. On the other hand decreasing trend was observed for the open area which has reduced by 50% from 115.451 ha in 1192 to 50.76 ha in year 2010. Agriculture area show marginal increase from 281.2 ha to 296.2 ha. The land use changes over the period 1992-2010 for the Seelampur village are shown in Figure 5 and Table 4.

Table 4: Land use changes in Seelampur village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	Ha	%
1992	23.39	4.63	50.35	10.08	115.45	23.18	281.20	56.69	25.42	5.12
1998	30.42	6.10	50.83	10.15	99.09	19.95	296.64	59.49	37.62	7.54
2001	4.95	1.813	51.18	9.28	69.84	23.99	281.54	56.99	39.80	8.05
2005	23.79	4.83	55.31	11.24	75.05	15.25	283.48	57.61	54.34	11.04
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	14.31	2.87	99	20.12	50.76	10.31	296.19	60.20	38.34	7.79

*** For 2008 image was not available.

4. Baqiapad village

Built-up area increased from 6.73 to 47.07 per cent (i.e. about 8 times). In Baqiapad village, small stretch of Yamuna River has shown eastward shift of about 200 meter during the period 1992-2001 and again westward shift during 2001-2010 period. Area of water body remained almost unchanged over the period although the water body was shrinked to 1.53 ha in the year 2008. The area of the water body increased to 3.15 ha after the 2010 floods. For the year 2008 the complete imagery of the Baqiapad village was not available. Natural vegetation is also showing a decreasing trend from 6.52 per cent in 1992 to 4.45 per cent in 2010.The land use changes over the period 1992-2010 for the Baqiapad village in figure 6 and table no 5

Table 5: Land use changes in Baqiapad village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	2.92	1.95	10.07	6.73	71.23	47.66	55.48	37.11	9.747	6.52
1998	4.30	3.16	31.23	23.00	55.04	40.53	29.31	21.58	15.89	11.70
2001	4.30	2.92	42.57	28.93	55.04	37.41	29.31	19.92	15.89	10.80
2005	2.92	1.96	45.23	31.03	60.35	40.46	29.97	20.09	9.47	6.35
2008	1.53	1.16	46.46	34.55	18.86	14.40	60.83	46.47	4.44	3.39
2010	3.15	2.10	70.38	47.07	30.7	20.53	38.7	25.88	6.66	4.45

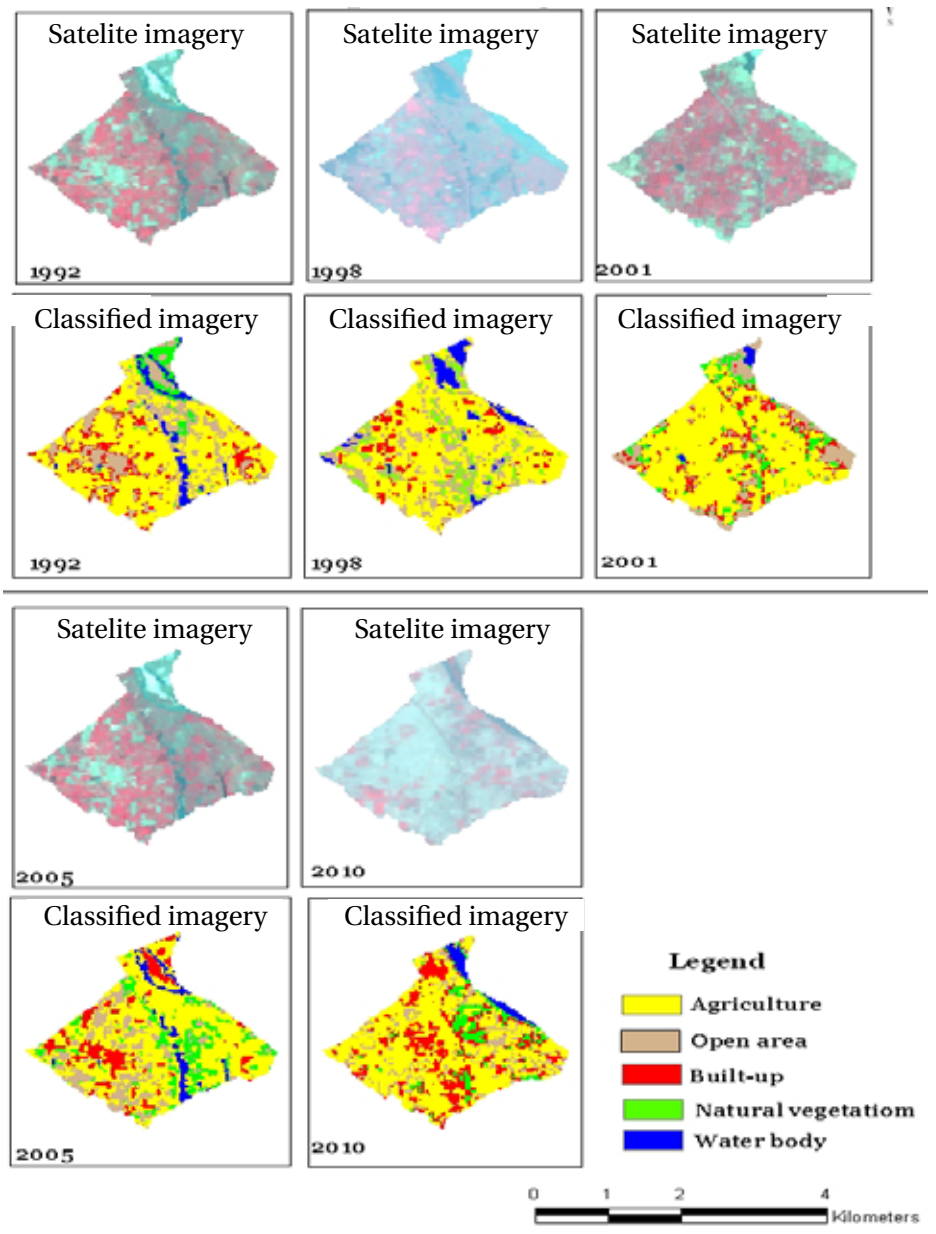


Figure 5: Time Series Satellite imagery and classified images of Seelampur Village

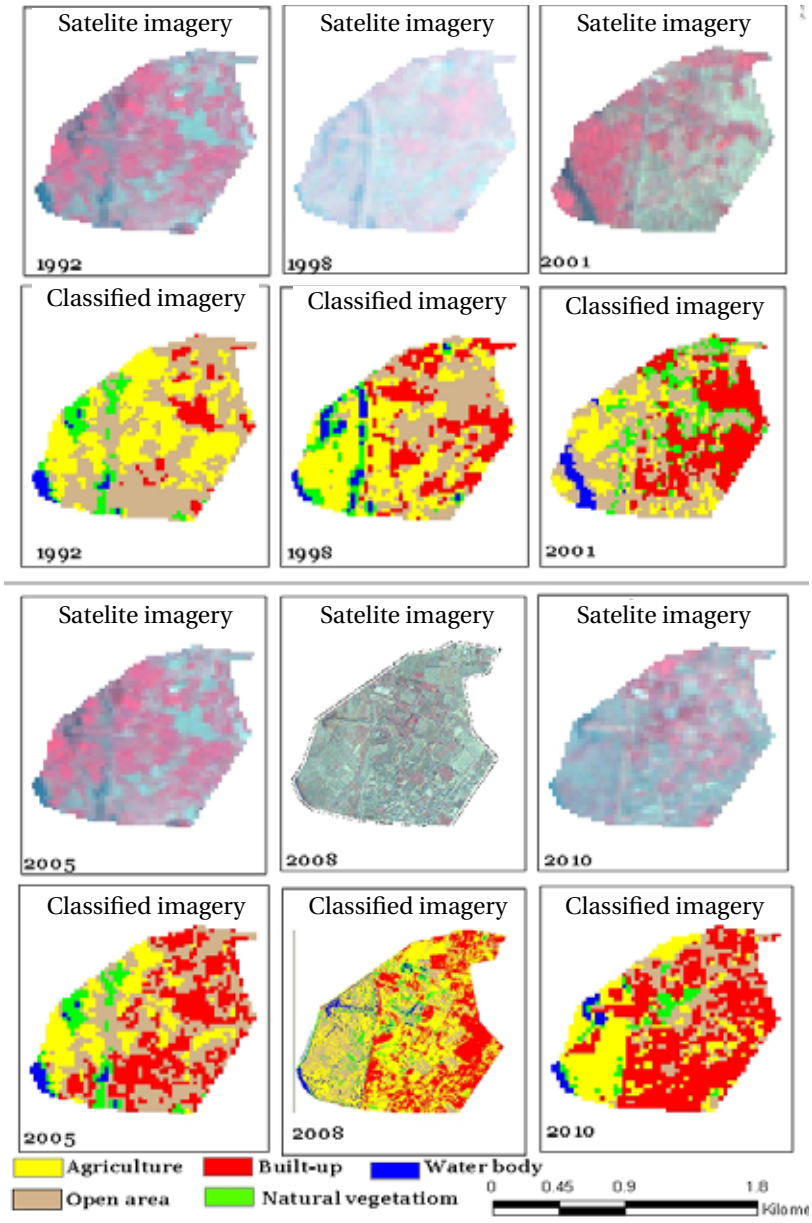


Figure 6: Time series satellite imagery and classified images of Baqiapad Village

5. Subhaypur village

The Land Use changes over the period 1992-2010 for the Subhaypur village is shown in figure 7 and table 6. Total area of Subhaypur village is 394.2 hectares out of which only 17.48 per cent of the total area was built-up (settlement) in 1992. The area has shown gradual increase from the 40.04 ha in 1992 to 100.53 ha in the year 2010. The percentage of land covered by open area has decreased from 26.98 per centrin the year 1992 to 15.33 per cent in the year 2010. For the agriculture land minor variations were observed from 46.57 per cent to 48.97 per cent during the analysis period. Area under the natural vegetation has also remained unchanged over the period.

Table 6: Land use changes in Subhaypur village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	23.39	4.63	50.36	10.08	115.45	23.18	281.20	56.69	25.42	5.12
1998	30.42	6.10	50.83	10.15	99.09	19.95	296.64	59.49	37.62	7.54
2001	4.95	1.81	51.18	9.28	69.84	23.99	281.54	56.99	39.80	8.05
2005	23.80	4.83	55.31	11.24	75.05	15.25	283.48	57.61	54.34	11.04
2008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	14.31	2.87	99.00	20.12	50.76	10.31	296.19	60.20	38.34	7.79

6. Sadatpur village

About 1/4th geographical area of Sadatpur village is covered by Yamuna river (year 2010). From year 1992 to 2010 there has been substantial increase in built up area from 8.11 per cent to 29.51 per cent. There has been increase in open area by 12.5 per cent to 29.9 per cent and there is decrease in agriculture land by 20.67 per cent. Natural vegetation also increased from 5.05 per cent in 1992 to 9.27 per cent in 2010. Water bodies including floodplains and smaller lakes are being converted into open areas. Agriculture area also decreased by 50 per cent. This strongly indicates that wetland and agricultural lands are converted into open areas for future non agricultural and non eco friendly purposes.

The Land Use changes over the period 1992-2010 for the Sadatpur village is shown in figure 8 and table7.

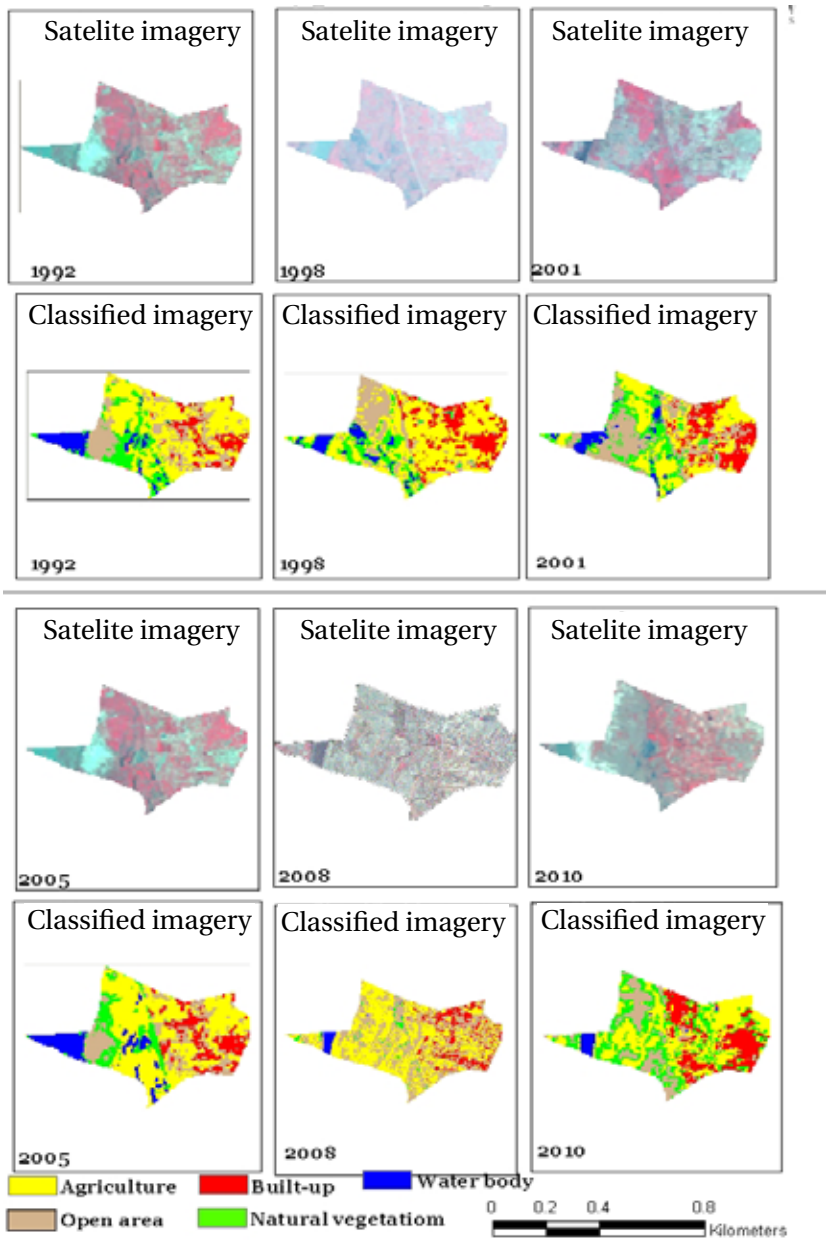


Figure 7: Time series satellite imagery and classified images of Subhaypur Village

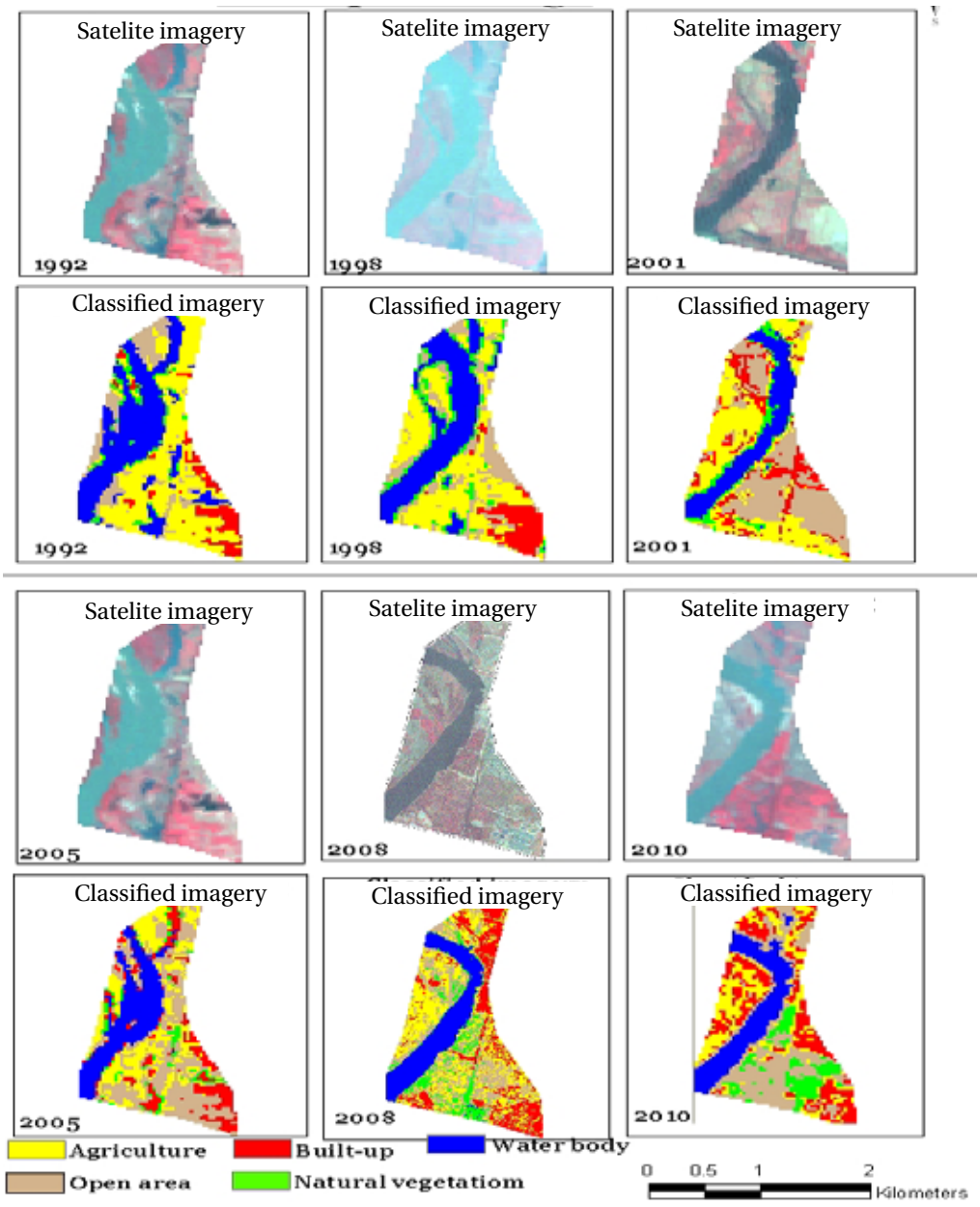


Figure 8: Time series satellite imagery and classified images of Sadatpur Village

Table 7: Land use changes in Sadatpur village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	76.60	33.54	18.52	8.11	28.59	12.52	93.08	40.76	11.53	5.05
1998	64.53	28.10	21.24	18.06	40.32	8.74	78.84	34.33	24.48	10.66
2001	39.07	18.45	30.07	19.37	69.98	11.31	71.59	44.79	13.92	6.10
2005	51.09	28.60	32.81	18.74	78.22	23.62	54.99	24.08	11.21	4.90
2008	42.64	18.70	44.27	19.41	57.90	25.39	63.33	27.77	18.90	8.29
2010	44.82	19.65	67.30	29.51	66.33	29.09	45.81	20.09	21.15	9.27

7. Jagatpur village

Built-up area has shown an increase of 7.41 per cent in the year 1992 to 34.84 per cent in year 2010. From the table listed it can be observed clearly that open area was under agriculture as seen in 1998 and 2001 imagery.

Table 8 : Land use changes in Jagatpur village

Land use / year	Water body		Settlement		Open area		Agriculture land		Natural Vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	112.17	16.35	50.85	7.41	143.69	20.94	320.76	46.76	58.40	8.51
1998	115.56	16.72	74.97	10.84	105.39	15.24	356.67	51.60	38.52	5.57
2001	121.09	17.61	148.57	21.61	78.88	11.47	268.49	39.06	70.30	10.22
2005	119.73	17.45	142.55	20.78	75.13	10.95	286.48	41.78	61.97	9.03
2008	59.72	8.71	199.90	29.18	50.43	7.36	312.34	45.59	59.09	8.62
2010	58.32	8.44	240.57	34.84	107.10	15.51	240.75	34.87	43.74	6.33

This may be due to the growing of seasonal crops like vegetables etc in the open area during winter season. This is also evident from land use map of 2001, 2005, and 2008. Water body in the Jagatpur village has shown a gradual decrease from 16.35 per cent in year 1992 to 8.44 per cent in year 2010. The Land Use changes over the period 1992-2010 for the Jagatpur village is shown in figure 9 and table8.

8. Pur village

In Pur village there is an increase in built-up area from 2.19 per cent to 25.34 per cent over the period 1992-2010. For the year 2008 satellite imagery for a part of the village is available and hence the spatial statistics is showing lower values for settlement. A

decrease in the percentage of agriculture area has been observed from 50.62 per cent in 1992 to 31.38 in the year 2010. Due to the growing population and urbanization most of the agriculture land has been converted to settlement. Area covered by natural vegetation is also showing a gradually decreasing trend till 2008. Further there is a minor increase in area under natural vegetation due to 2010 flood event similar to other villages.

The Land Use changes over the period 1992-2010 for the Pur village is shown in figure 10 and table9

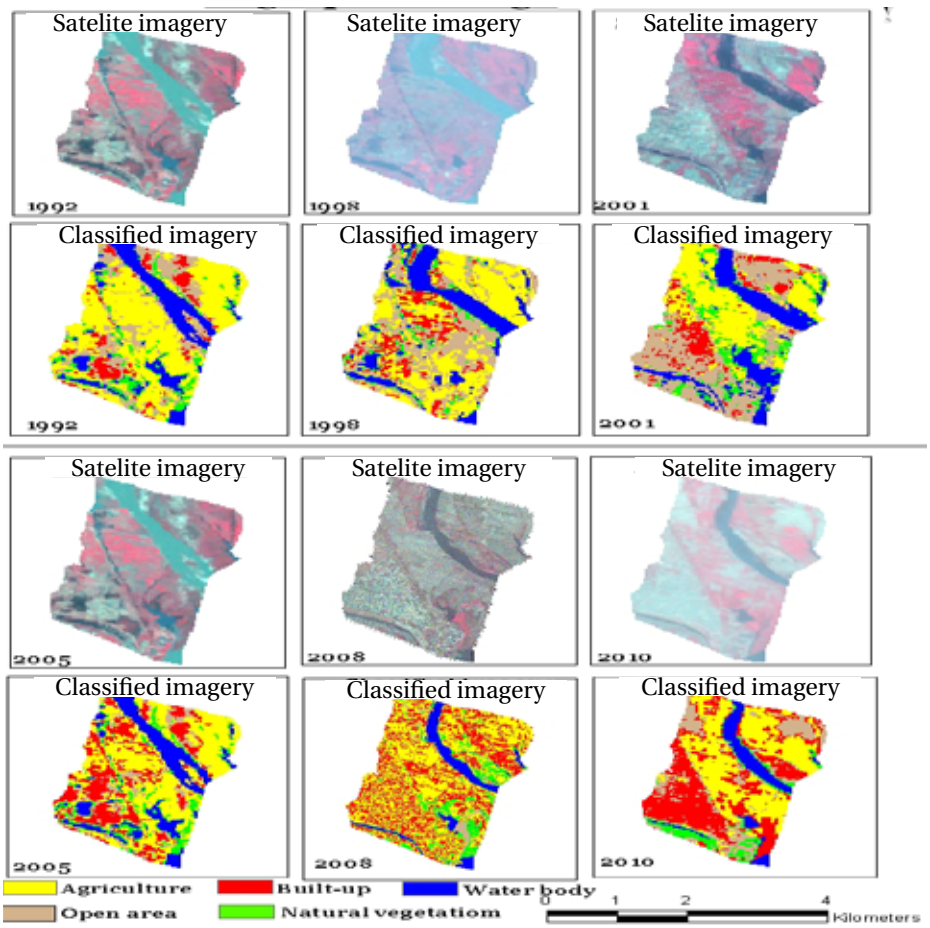


Figure 9: Time series satellite imagery and classified images of Jagatpur Village

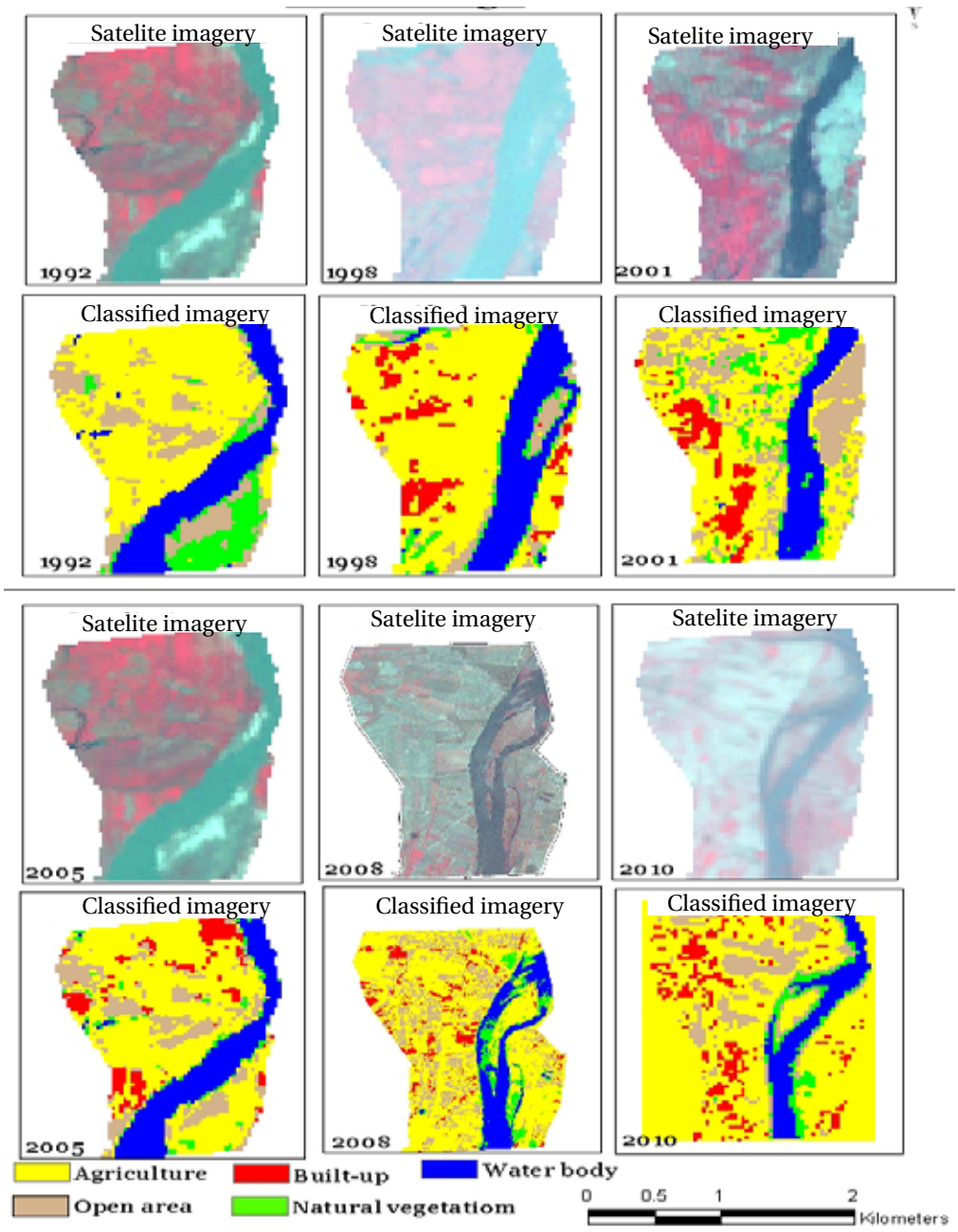


Figure 10: Time series satellite imagery and classified images of Pur Village

Table 9: The Land Use changes over the period 1992-2010 for the Pur village

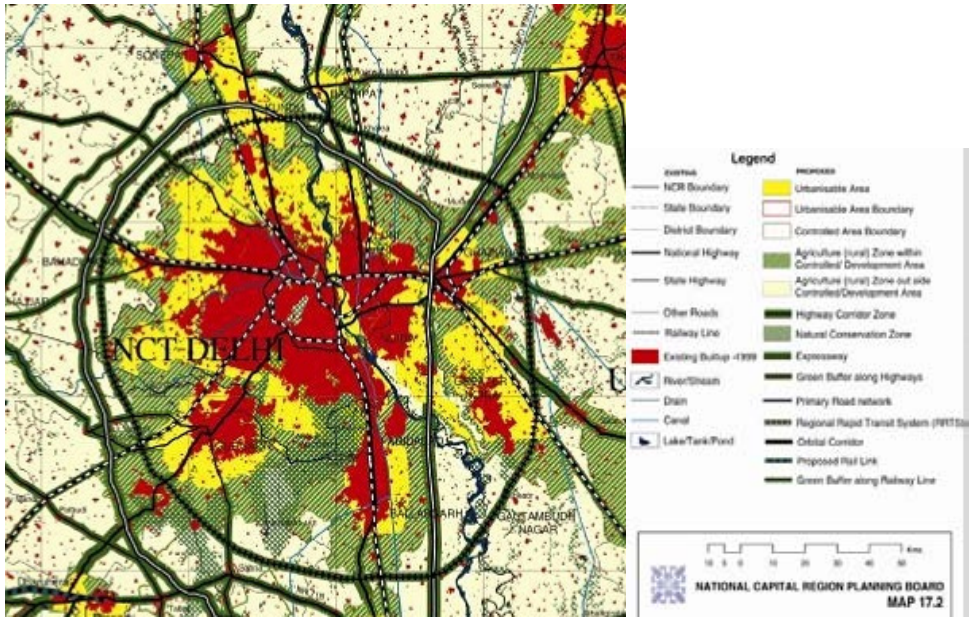
Land use / year	Water body		Settlement		Open area		Agriculture land		Natural vegetation	
	ha	%	ha	%	ha	%	ha	%	ha	%
1992	59.29	19.55	0.00	0.00	51.17	16.87	153.52	50.62	32.57	10.74
1998	65.16	21.39	6.66	2.19	66.51	21.63	156.96	51.53	15.93	5.23
2001	43.54	14.27	23.69	7.76	64.11	21.01	140.55	45.90	26.97	8.84
2005	55.63	18.29	24.61	12.12	50.44	12.89	162.45	53.47	9.67	3.83
2008	30.76	11.43	15.22	5.65	42.16	15.67	164.70	61.22	16.16	6.01
2010	38.79	12.75	33.57	25.34	44.64	24.33	168.12	31.38	20.25	6.66

Discussion and Conclusion

Urban areas are increasingly being reported to suffer with menace of urban flooding. The increasing trend of land-use shift towards built-up area also indicate permanent use of natural vegetation area or open area or conversion of agriculture land to non-agriculture purpose which is a irreversible change. **Study of land use land cover changes in the 8 flood affected villages of Delhi during 2010 September clearly depicts** significant changes in the land-use over the last two decades (1992 – 2010). The trends observed were not linear for all the land-use types. Prominent change of land-use was noted towards 'settlement' indicating increase of the built-up area in the villages – a common sign of urbanization impact and developmental aspiration.

Maximum increases in the settlements have been observed in Sadatpur village where the 48.79 per cent of land use under built-up area. Supporting to the observation on settlements, the open areas were reduced significantly in three of the villages, viz. Seelampur, Badarpur, Jagatpur. In the present study as well, certain villages, viz. Subhaypur, Sadatpur and Pur village has shown a marked reduction in area under active agriculture. These villages have also shown a decrease in the water-body. Gradual siltation of river course and thus making river-bed dry and hence susceptible for other land-use, i.e. for temporary settlements, agriculture or open areas.The images used for the present study are mainly post-monsoon data. Due to the floods in 2010, area under water bodies showed increase in 2010 image. In certain locations like that in village Burari, high floods have caused clearing of silt-loaded riverbed and thus allowing water to recede fast after a flood event.

A significant reduction in area under agriculture has been observed as a result of flood incidence in year 2010.Thus, there has been observed substantial loss of agriculture as result of flooding. On the other hand, flood risk and perception of likelihoods



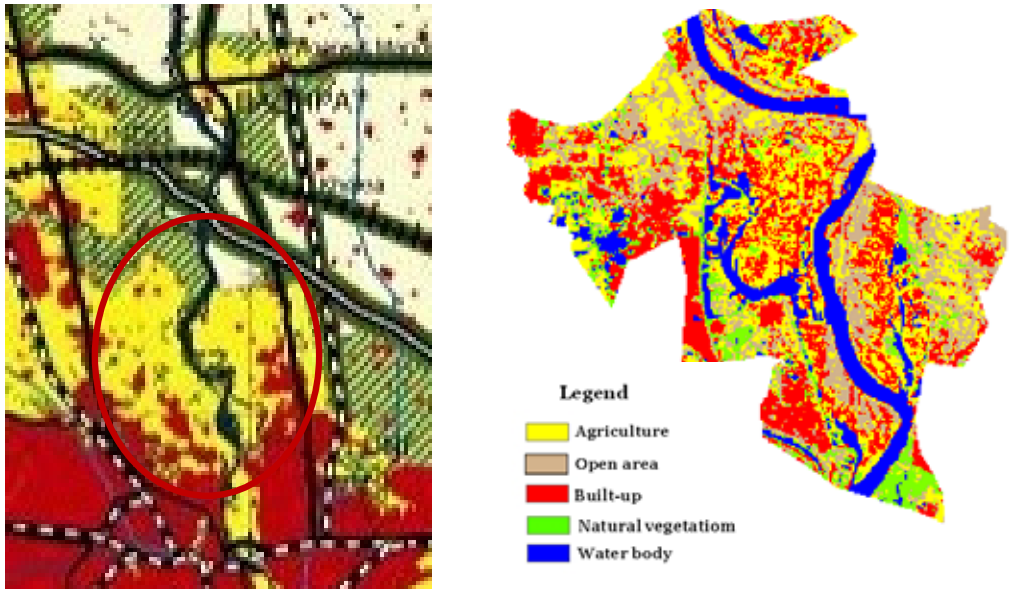


Figure 11: Proposed land use as per the NCR Plan 2021 and Classified land use map generated from landsat TM data of 2010

of floods have also triggered the motivation factor and choice of people towards increasing permanent settlements and as a cause of increased built-up area.

Four villages, viz. Burari, Pur, Sadatpur and Badarpur, show an increase in natural vegetation in the year 2010 after the floods. This has revealed the possibility that the area left fallow or un sown was encroached by weeds.

In general there has been slight but not much significant decrease in area under agriculture but the loss of natural or open area has been evident. People have probably chosen to build effective and better settlement to meet the challenges of some level of floods risk. People based on their experience or the inherited perception develops a notion of relative safety from floods by commissioning and occupying a pakka house or a permanent settlement rather than a kachcha house or temporary dwelling.

Present study has generated broad interpretations of increasing area under settlement and reduction of natural vegetation or open spaces. It is also important to mention that the natural or open spaces sometimes topographically low lying can serve as natural flood control sites as they can offer flood water collection and retention potentials. Loss of such natural areas on the turn also increase the risk of flood impacts on settlements and property including agriculture.

The present study has clearly found out the relationship between the human-induced land-use changes causing changes in the levels of flood risk, whereas increased understanding of the physical exposure of the land belonging to villagers have motivated the shifts to use of better construction materials and conversion of area non-under agriculture to settlement purposes.

Interestingly, the land use changes monitored through present study supersede the projected or envisaged land use for NCR planning for year 2021 (Figure 11). It presents a caution to the urban land use planners and environmental managers as the projections have been crossed even 10 years before the projected growth trend (2021). It has been indicated in NCR planning report that the region is prone to flooding in river Yamuna with return period of 5, 10, 25, 50 and 100 years, and need to be identified on map for land use zoning at regional, sub-regional levels. It is therefore recommended that regions from the NCR states should come up with detailed risk maps for their regions on a scale of 1:1, with marked areas under flood susceptibility.

In the absence of effective regulations of flood plain zoning and land-use controls in the peri-urban areas or villages adjacent to flood prone river channels and under control areas, the conversion of non-organ sable areas into urban uses especially into the settlements of built-up nature has continued unabated. This has caused significant loss of cultivable land as well besides aggravating the floods. The satellite

imageries have revealed that environmentally fragile and sensitive areas such as Yamuna riverbed or associated wetlands, ridge areas, forest areas are being subjected to developments authorized or un-authorized. Further detailed study to understand the trends and implications of flood risk on patterns of cropping, types of housing, and aspects on non-structural mitigation with development of vulnerability indicators is recommended as followup to this study.

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