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Land Transformation and Urban Planning Case of Sonipat City, Haryana, India

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Abstract

Up to date information of land use/land cover is very important for city planning at micro level. The present study is based on satellite imagery of LANDSAT TM (1989), town directory map 1991 and Google Earth image 2002 and 2011. Study reveals that the agriculture based surrounding rural landscape is turned into an urban landscape due to residential, industrial and infrastructure development. Results shows that the rapid growth of city is at the cost of fertile productive agricultural land. The planned area has been marked in the east and west part of the city by Haryana Urban Development Authority (HUDA). The study area has a significant increase in unplanned residential area which provides housing to stay in the city's rapidly growing population in all direction but it was least increased in eastern side due to planned development by HUDA. There has been a very big increase in unplanned residential area. This indicates haphazard expansion, without good planning. Effective city planning and management is needed for maintaining the urban expansion of the city. It will release the burden from the city in term of population growth and loss of agricultural land.

Introduction

Land use change is one of the most important fields of human induced environmental transformation, with an extensive history dating back to antiquity (Wolman and Fournier, 1987). Urbanization, a cause of land use changes, is a gift to the human society if it is controlled, coordinated and planned. It makes impulsive and long lasting changes on the landscape. In 2008 more than half of the world's population were urban dwellers and the urban population is expected to reach 81 per cent by 2030 (UNPF, 2007). The conversion of rural areas into urban areas through development is currently occurring at an unprecedented rate in recent human history and is having a marked effect on the natural functioning of ecosystems (Turner, 1994). Ecosystems of urban areas are strongly influenced by anthropogenic activities; considerably more attention is currently being directed towards monitoring changes in urban land use/ land cover (Stow and Chen, 2002). Regular and up-to-date information on urban change is required for urban planning, land use management and for appropriate allocation of services and infrastructure within the urban areas (Barnsley and Barr, 1996). In this context, accurate information on the current extent of urban areas is needed for documenting growth, making policy decisions and improving land use planning (Gross and Schott 1998, Bullard and Johnson 1999 and Jacobson, 2001) is a required parameter for predictive urban modelling (Epstein *et al.*, 2002).

Recent decades, changes in land use/land cover, especially in developing countries, has involved a decrease in the area of rural land use and an increase in the area of urban land use through urbanization (Dewan and Yamaguchi, 2009).Sonipat is one of the important cities in NCR region of Haryana where land conversion took place strongly during 1991-2011.

Study Area

Sonipat is one of the important cities of the state of Haryana located in northern part of India. It is also called 'educational city'. Sonipat city is the headquarter of Sonipat district which lies in the national capital region (Fig.1). As per 2011 census, the total population of the city is 2, 89,333 persons and the literacy rate is 75.24%

whereas sex ratio is 875 females/ '000 males. It is close to National Capital Territory. Easy and fast accessibility to it through N.H. 1 has lead to urbanization of the city. The impact of the urbanization is reflected in the high literacy rate, easy access to technology, and a better quality of life. The Haryana Government has drawn up a master plan for the development of Sonipat city as a satellite town of the National Capital Region (NCR) and proposed as many as 38 sectors for accommodating the increase in population in the industrial and commercial areas.

Objectives

The major objectives of this study are —

1. To analyze the spatial expansion in Sonipat city during the period of 1991 to 2011.
2. To examine the land use/ land cover changes and land transformation during 1991 to 2011.

Data Sources and Methodology

The present study is secondary data obtained from different sources. Following data sources have been used for present work —

1. Topographic Sheet No. H43Q16, H43R4, H43W13 and H43X1 at scale of 1:50,000 (Survey of India, Dehradun) 1968 and 2005-2006.
2. Landsat-TM (Thematic Mapper) Image with path/row 147/40 dated October 9, 1989.
3. Google Earth Pro image February 2, 2002.
4. Geoeye satellite Image downloaded from Google earth pro October 14, 2011.
5. Census data published by Census of India.
6. Municipal Committee office and Department of Town and Country Planning, Haryana.

Satellite data of the study area for 1989 has been downloaded from the www.glovis.usgs.gov/ site, 2002 and 2011 satellite Image was downloaded from Google Earth Pro. Topographic Sheet No. H43Q16, H43R4, H43W13 and H43X1 on 1:50,000 are used for the geo-referencing of M.C. map of study area in different time periods. The changes in land use pattern have also been assessed and mapped with the help of Arc GIS 9.3. Field verification was performed throughout the study area using GPS and obtained correct setting for each land use class incorporated in the categorization format. The study is based on supervised classification and visual interpretation of different time satellite imagery. The 1991 and 2002 land use pattern could not be checked against the ground truth but, the available historical data for the study area was used to confirm the interpretation made. However, in 2011 data was directly checked against ground truth all the way through the study area.

Landuse/Land Cover Analysis

Analyzing of land use/land cover changes is one of the important ways to understand the existing ecological status of a region and continuing changes. An important aspect of it is to determine what is actually changing and to what i.e. which land use class is changing to the other. The information on land use change reveals both the desirable and undesirable changes and classes that are "relatively" stable overtime. This information serves as an essential tool in management decisions and policy formulation (Zubair, 2006; Singh and Kumar, 2012).The land use/land cover maps of three points of time, that is, 1991 and 2011 have been extracted from town directory and satellite image based on visual interpretation.

Sonipat City: Landuse/Land Cover in 1991

According to MC office record of Sonipat, the city had 14.60 sq. km area to its existing boundary. Table 2 reflects that in 1991, agriculture land emerged as the leading land use class in study area. It covers an area of 48242203.99 m^2 i.e. 80.26% of the study area followed by unplanned residential area, waste/scrub land and public and semi-public i.e. 11.70%, 2.18% and 1.97% respectively. Public and semi-public area includes place of work, education institutions, religious places, administrative offices, railway station, bus stand, water works, mini sect orate, police line, medical and social-cultural centre. Sonipat being a district headquarter in 1972 from the Rohtak District, also needs and accommodates a lot of public and semi-public offices and educational institutions.

The central part of the city which represents the establishment of the city has high density area and is used for the residential purpose with narrow streets. A huge part of the city is covered by the public and semi-public area on the north western part of the city. It represents the police line and mini secretariat. Some public and semi-public area located along within railway line, are the education institutions such as S.M. Hindu Sr. Sec. School, Sambhu Dayal Sr. Sec. School, Hindu College, Chhotu Ram Arya College, Vivekananda School and Tika Ram Girls College etc. Industrial area covers 215008.86 m^2 i.e. 0.36% of total study area. A number of small scale industries are located in south and south eastern part of the study area. They build bicycles parts, do the assembling of complete bicycles, hand tools, barbed wire, sewing machine parts, bolts and nuts, steel re-rolling, glass and ceramics, rubber goods, food processing and cotton textiles. Some industrial areas are found in the northern part of the city. They are sugar mills Commercial areas covers 447947.13 m^2 i.e. 0.75% of the study area. Commercial areas are those which are used mostly for the sale of products and services.

These are located in the central part of the city within residential area and public and semi-public areas. It is also located along within the road network till built up areas (Fig.2). In 1991, recreational areas (include parks, gardens and play grounds) have been recorded 70139.33 m^2 which was 0.12% of the study area. It is the prime need of any city as the healthy

environment. It was noticed that maximum recreational area was located in Modal town which was the well planned area of the city. Planned residential area has been noticed between the commercial and industrial area in the form of Modal town. It was the first planned residential area in the city. It was recorded 795722.01m^2 i.e. was 1.32 %. It has a uniform size and spacing. Water bodies occupied an area of 28989.15% i.e. 0.36% of the study area followed by the waste/scrub and forest i.e. 2.18 and 0.11 % respectively (Table - 2).

Sonipat City: Landuse/Land Cover (2002)

Table - 3 shows that in 2002, the agricultural land remained a dominant land use category within 37312938.53 m^2 which was 61.64% of the study area but it has been reduced 10929265.46 m^2 i.e. 18.62 % of total area. After 1991, new economic reform gave a way to urban development of Sonipat city with industrialization on the cost of fertile agriculture land. In 2002, Industrial area was increased on the south and south eastern part of the city along with Bhalgarh road and Narela Road on the cost of fertile farming land.

Industrial area reached 1766813.90 m^2 from the 1169211.93 m^2. It was increased 597601.97 sq. meters. In 2002, 11407138.14 m^2 land was recorded under unplanned residential area which was 18.84%of the study area. It has been increased 4373184.96 m^2. It has taken place on the peripheral, areas noticeably, at the(all direction of)boundaries of the city and along (with) the transport network (Fig. 3). Planned residential area covers 795722.01 m^2 in 1991 which (was) reached 2029901.08 m^2 in 2002. It was increased 1234179.07 m^2 i.e. 2.03% of total area. It was the impact of HUDA (Haryana Urban Development Authority) which provides well planned and well-organized sectors of industrial/ commercial/residential purposes. It was noticed that planned area has increased between Murthal and Bhalgarh road. Some planned area was recorded on the south-western part of the city. It is Sector 23 planned by HUDA.

Public and semi-public area reached 2093315.71 m^2 whereas it was 1182305.18 m^2 in 1991. It was increased 911010.53 m^2 i.e. 1.49 % of the total study area. It was the impact of population pressure which provides a way to manufactured new school and colleges for educational purpose, water works for drinking water and other government and semi-government building for other purposes. Water bodies were 410091 m^2 of the total area in 2002; it was 218989.15 m^2 in 1991. It was increased 191102.06 m^2 during this period due to development of water works for providing drinking facilities within population growth. Plotted area is the area which is delineated and marked for future residential or other purposes.

The plotted area was recorded in the outer side of the city within 3666351.68 m^2, i.e. 6.06% of total study area but maximum area was located south western, north eastern and south eastern part of the city. It (was) includes land marked for sectors and other purposes by Haryana Urban Development Authority (HUDA) and private builders. In 2002, commercial area was reached 605990.28 m^2 whereas it was 447947.13 m^2 in 1991. It has been increased near about 158043.15 m^2 during this period. The commercial area increased within road network and central part of the city also shifted in commercial area. It was observed that waste/scrub land has been reduced 629317.69 m^2 whereas it was 1309552.34 m^2 in 1991 and reached 680234.64 m^2 in 2002. It was shifted in agricultural land by the farmers. Recreational area also increased during this period and reached 492421.57 m^2 in 2002 from 70139.33 m^2 in 1991. It was increased in newly planned residential area while some patches were also recorded in unplanned residential area. Open/vacant land was recorded in peripheral parts of the city within unplanned residential areas and plotted land. Forest area was reached 63516.77 m^2 in 2002 whereas it was 66168.21 m^2 in 1991. It was reduced 2651.44 m^2 during these eleven years (Fig. 2 and 3).

Sonipat City: Landuse/Land Cover (2011)

It has been represented in Table 4 that in 2011, agricultural land has been recorded as dominant land use in study area i.e. 32185681.82 m^2. It represents 53.17% of total area (Fig. 4).

Unplanned residential area has recorded 15782447.61 m^2 followed by planned residential area, plotted area and industrial area i.e. 3748058.85m^2, 2421002.58 m^2 and 1834704.28 m^2 respectively. Industrial areas have been found in the northern and south- eastern part of the city. In northern side, it is represented by the sugar mills which are located on the Jatwara and Jhowarhi village land. On the other hand in south and south-eastern part there are a knot of small scale industries such as bicycles parts, assembling of complete bicycles, hand tools, barbed wire, sewing machine parts, bolts and nuts, steel re-rolling, glass and ceramics, rubber goods, bulb and tube light etc (Fig. 4). Industrial growth gives a way to urban development of city and attracts people from adjoining areas. Water bodies cover an area of 280722 m^2, i.e. 0.41% of the total area. It is represented by water works and ponds in adjoining villages while there is absence of lake and river in study area. Commercial area has recorded 832628.79 m^2 which is 1.38 %. It is noticeable in the central part of the city and along the transport network in all direction. Recreational area has been recorded 653045.82 m^2 in the form of small patches located in planned residential area. It is garden, playgrounds and parks. Open / vacant land covers an area of 221603.69 m^2followed by waste / scrub land and forest i.e. 130445.85 and 83460.60 m^2.

Landuse / Land Cover Change (1991 - 2011)

Study shows the shift of landuse/land cover category of Sonipat City during 1991, 2002 and 2011. It expresses that during this time period, the area of public and semi-public and industrial sector has increased to a slight extent. The area of first category was 1.97 % in 1991, 3.46 % in 2002 and 3.90% in 2011. In the same way, the industrial sector has a cover of 1.95, 2.92 and 3.03 % in 1991, 2002 and 2011 respectively. The planned residential area has not significant change. It was 1.32

% in 1991 and 6.19 % in 2011. On the other hand, a remarkable change has been noticed in unplanned residential area. It has increased from 11.70 % in 1991 to 18.84 % in 2002 and 26.07 % in 2011. This was the result of unintended urban growth which became the cause of slum and unauthorized development in the city. The highest but negative change has been faced by agriculture sector. In 1991, the agricultural land had an area of 80.26 % of total area of the city. This cover decreased to 61.64 % in 2002 and remains only 53.17 % in 2011. Due to increasing demand of land, the area of waste/scrub land category has reduced and remains 0.22 % in 2011 as compared to 2.18 % in 1991 and 1.12 % in 2002. The area of open/vacant and plotted land also has been seen in 2011 (0.01% and 4.00% respectively). The land use category of commercial and recreational area has also increased but not so significant where as the forest area has got decreased.

Land Transformation (1991-2011)

The land transformation requires a comprehensive understanding and monitoring of all the factors which was responsible for this land transformation. During(the) 1991 to 2002, Sonipat city not only prolonged in size but there was also a significant interchange of land between land use categories (Fig.5). Table 6 demonstrates what kinds of land use changes were responsible for land transformation from one class to another during the study period. The public and semipublic area increased from 1182305.18 m^2 to 2093315.71 m^2, gaining land from agriculture (902597.83 m^2) and water bodies (10208.42 m^2) while 1795.72 m^2 area also shifted in commercial category. The industrial area increased from 1169211.93 m^2 to 1766813.90 m^2, gaining land from agriculture 597601.97 m^2. It has captured land mainly from land because this progress is mostly away from the city centre. The commercial area increased from 447947.13 m^2 to 605990.28 m^2, gaining land from unplanned public semipublic (1795.72 m^2), unplanned residential area (138732.66 m^2), agricultural land (17511.86 m^2), and forest (2.9 m^2) of the total area. The water bodies increased from 218989.15 m^2 to 410091.21 m^2, capturing land from agriculture (232379.95 m^2) and waste/scrub land (11073.66 m^2) whereas water bodies also shifted in public semipublic 10208.42 m^2 followed by unplanned residential area and agricultural land i.e. 325.76 and 41817.37 m^2 respectively.

Unplanned residential area recorded a massive increase, from 7033953.18 m^2 in 1991 to 11407138.14 m^2 in 2002, gaining land from water bodies (325.76 m^2), agriculture (4508243.19 m^2), waste/scrub land (603.21 sq. meters), and forest land (2745.46 m^2) while losing mainly due to commercial activities i.e. 138732.66 m^2. Planned residential area reached, from 795722.01 m^2 in 1991 to 2029901.08 m^2 in 2002, gaining land from agriculture (1234179.07 m^2) from peripheral part of the city due to Haryana Urban Development Authority. Recreational area reached, from 70139.33 m^2 to 492421.57 m^2 during this period, gaining land from agriculture 422282.24 m^2. Waste/scrub land recorded a massive decline, from 1309552.34 m^2 in 1991 to 680234 m^2 in 2002, shifted from agriculture 673812.92 m^2, unplanned residential area 603.21 m^2, water bodies 11073.66 m^2, open vacant land 7478.94 m^2 and plotted land 4054.52 m^2. It was the impact of human involvement while 67705.55 m^2 land also shifted in m^2) in the appearance of playgrounds and parks. Waste/scrub land has declined, from 680234 m^2 to 130445 m^2 from 2002 to 2011 (Fig. 6). It was shifted to public semipublic 274.63 m^2, unplanned residential area 212876.74 m^2, agriculture 274820.67 m^2, open land 25264.49 sq. meters and plotted land 67595.60 m^2 while 31043.34 m^2 land also shifted in waste/scrub category from agriculture land.

Forest area increased from 63516.21 m^2 to 83460.60 sq. meters during this period, gaining land from agriculture (31043.34 m^2) while it was shifted in 370.39 m^2 in public semipublic area, 21512.19 m^2 in unplanned residential area and 11675.36 m^2 in commercial land. Agriculture land also recorded a huge declined, from 37312938.53 sq. meters to 32185681.82 $m^2$from 2002 to 2011, shifted to public semipublic (222687.56 m^2), industries (66486.53 m^2), planned residential area (205320.65 m^2), unplanned residential area (2692625 m^2), water bodies (52907.24 m^2), open land (188860.26 sq. meters), plotted land (1799983.88 m^2), commercial (8390.83 sq. meters), recreational area (111849.71 sq. meters), waste/scrub land (31043.34 m^2) and forest land (43383.90 m^2). It was also shifted from water bodies (21461.54 m^2) and waste/scrub land (274820.67 m^2) to agricultural land.

Conclusion

The study demonstrated the efficiency of satellite data and GIS as a tool in the study of land use /land cover changes. Particularly in the absence of required data from the local authorities, it gives a good understanding of land use information and changes for a period of three decades, which in turn will be very helpful for local administrative bodies. Thus, this technology has the capability to provide the necessary input and intelligence for preparation of base maps, formulation of Planning proposals and act as a monitoring tool during the implementation phase. Some of the main findings of the present study are as follows —

1. The study (has been)analyzed that the rapid growthof city over comes on the cost of fertile productive agricultural land.
2. The planned area has marked to the east and west part of the city by Haryana Urban Development Authority (HUDA).
3. The study area has a significant increase in unplanned residential area which provide housing to stay in the city's rapidly growing population in all direction but it was least increased in eastern side due to planned development by HUDA.
4. There has been a very large increase in unplanned residential area. This indicates haphazard expansion, without good planning. It is also an issue of concern for the society.

5. The city planner should use satellite data for city planning for accurate and up to date land use information of the city and identification of suitable lands sites for establishment of new residential colonies, industrialized sectors and educational institutions without harming productive agricultural land.
6. The city planners can use satellite data and GIS tools to develop road planning, bye pass routes and necessity of flyovers for solution of jamming problems in the city.
7. The city administration authorities responsible to provide basic facilities such as drinking water, education, good sewerage system and street light facilities. They should prepare a complete record for the city, so that they may know the status of the facilities accessible in different parts of the city. It would help in identifying the areas where the facilities are lacking or needs immediate measures.
8. There has been an increase in the area under forest land due to planned development as a form of green belt and along within Gohana road.
9. The urban expansion of the study area in the form of built-up and non-built-up has smashed productive agriculture land. The Ganda Nala which is used to dispose the waste water now has been encroached by residence of slum population and also used for the disposal of garbage and wastes.
10. The 23943477.83 m^2 of fertile productive agricultural land has been vanished from 1991 to 2011 in study area.
11. Sonipat city expanded towards north, west and southern part of the city in an uncontrolled manner, engulfing used productive farming land.

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Table – 1: Landuse Classification of Sonipat Municipal Corporation

Sr. No.	Level I	Level II	Sr. No.	Level I	Level II
1	Built-up Area	Unplanned Residential Area	2	Non Built-up Area	Open/Vacant Land
		Planned Residential Area			Plantation Area
		Public & Semi-Public Area			Agricultural Land
		Recreational Area			Waste/Scrub land
		Commercial Area			Water Body
		Industrial Area			
		Plotted Area			

Source: Modified from NUIS Manual, 2008

Table – 2: Landuse/Land Cover of Sonipat City (1991)

Sr. No.	Landuse Categories	Area (sq. m)	Area (%)
1	Public and Semi Public Area	1182305.18	1.97
2	Industrial Area	1169211.93	1.95
3	Planned Residence Area	795722.01	1.32
4	Un Planned Residence Area	7033953.18	11.70
5	Water bodies	218989.15	0.36
6	Agricultural Land	48242203.99	80.26
7	Open/Vacant Land	-	-
8	Plotted Land	-	-
9	Commercial Area	447947.13	0.75
10	Recreational area	70139.33	0.12
11	Waste/Scrub Land	1309552.34	2.18
12	Forest	66168.21	0.11
	Total	60536192.44	100.00

Source: *Calculated from Town Directory, 1991 and TM Image 1989*

Table – 3: Landuse/Land Cover of Sonipat City (2002)

Sr. No.	Landuse Categories	Area (sq. m)	Area (%)
1	Public and Semi Public Area	2093315.71	3.46
2	Industrial Area	1766813.90	2.92
3	Planned Residence Area	2029901.08	3.35
4	Un Planned Residence Area	11407138.14	18.84
5	Water bodies	410091.21	0.68
6	Agricultural Land	37312938.53	61.64
7	Open/Vacant Land	7478.94	0.01
8	Plotted Land	3666351.68	6.06
9	Commercial Area	605990.28	1.00
10	Recreational area	492421.57	0.81
11	Waste/Scrub Land	680234.64	1.12
12	Forest	63516.77	0.10
	Total	60536192.44	100.00

Source: Calculated from Google Earth Image 2002

Table – 4: Area under Landuse/ Land Cover of Sonipat City (2011)

Sr. No.	Landuse Categories	Area (sq. m)	Area (%)
1	Public and Semi Public Area	2362390.01	3.90
2	Industrial Area	1834704.28	3.03
3	Planned Residence Area	3748058.85	6.19
4	Un Planned Residence Area	15782447.61	26.07
5	Water bodies	280722.40	0.46
6	Agricultural Land	32185681.82	53.17
7	Open/Vacant Land	221603.69	0.37
8	Plotted Land	2421002.58	4.00
9	Commercial Area	832628.79	1.38
10	Recreational area	653045.82	1.08
11	Waste/Scrub Land	130445.85	0.22
12	Forest	83460.60	0.14
	Total	60536192.44	100.00

Source: Calculated from GeoEye Image 2011

Table – 5: Landuse/ Land Cover Change of Sonipat City, (1991-2011)

Sr. No.	Landuse Categories	Area Change (sq. m)		Percent Point Change	
		1991-2002	2002-2011	1991-2002	2002-2011
1	Public and Semi Public Area	911010.53	269074.30	1.49	0.44
2	Industrial Area	597601.97	67890.38	0.97	0.11
3	Planned Residence Area	1234179.07	1718157.77	2.03	2.84
4	Un Planned Residence Area	4373184.96	4375309.47	7.14	7.23
5	Water bodies	191102.06	-129368.81	0.31	-0.21
6	Agricultural Land	-10929265.46	-5127256.71	-18.62	-8.47
7	Open/Vacant Land	-	214124.75	-	0.35
8	Plotted Land	-	-1245349.10	-	-2.06
9	Commercial Area	158043.15	226638.51	0.26	0.37
10	Recreational area	422282.24	160624.25	0.70	0.27
11	Waste/Scrub Land	-629317.69	-549788.79	-1.05	-0.91
12	Forest	-2651.44	19943.83	-0.01	0.03

Source: Calculated from Town Directory Map, 1991 and TM Image 1989, Google earth 2002 and GeoEye Image 2011

Table – 6: Land Transformation in Sonipat City, (1991-2002)

Land use Categories	P/S	Indus	P R Area	U R Area	Water	Agri	Com	Recre	W/S	Forest	2002 (sq.m.)
P/S	1182305.1				10208.4	902597.8					2093315.7
Indus		1169211.9				597601.9					1766813.9
P R Area			795722.0			1234179.0					2029901.0
U R Area				7033953.1	325.7	4508243.1			603.21	2745.4	11407138.1
Water					218989.1	232379.9			11073.6		410091.2
Agri					41817.3	48242203.9			673812.9	30053.7	37312938.5
O/V									7478.9		7478.9
Plott						3662297.16			4054.5		3666351.6
Com	1795.7			138732.6		17511.86	447947.1			2.9	605990.2
Recre						422282.24		70139.3			492421.5
W/S						67705.55			1309552.3		680234.6
Forest						30150.68				66168.2	63516.7

Source: *Calculated from the Town Directory Map Sonipat City, 1991 and TM Image 1989 and Google Earth Image 2002*
Note: Figures in Red (diagonally) are area under that particular land use in 1991, while the figures in the same column represent the shift in area to other landuses.

Table – 7: Land Transformation in Sonipat City, (2002-2011)

Landuse Categories	P/S	Indus	P R Area	U R Area	Water	Agri	Com	Recre	W/S	Forest	2011 (sq.m.)
P/S	2093315.1				3060.5	222687.5		56670.7			274.6
Indus		1766813.9				66486.5		1403.8			
P R Area			2029901.08		22417.8	205320.6		1490419.2			
U R Area				11407138.1	141395.1	2692625.0		1488555.8			212876.7
Water					410091.2	52907.2		7693.6			
Agri					21461.5	37312938.5					274820.6
O/V						188860.2	7478.94				25264.4
Plott					5.8	1799983.8		3666351.6			67595.6
Com	13989.5			181655.5	12.7	8390.8		10914.5	605990.2		
Recre					1615.8	111849.7		47158.6		492421.5	
W/S						31043.3					680234.6
Forest					0.01	43383.9		10117.8			

Source: Calculated from the Google Earth Image 2002 and GeoEye Image 2011
Note: Figures in Red (diagonally) are area under that particular land use in 2002, while the figures in the same column represent the shift in area to other land uses.

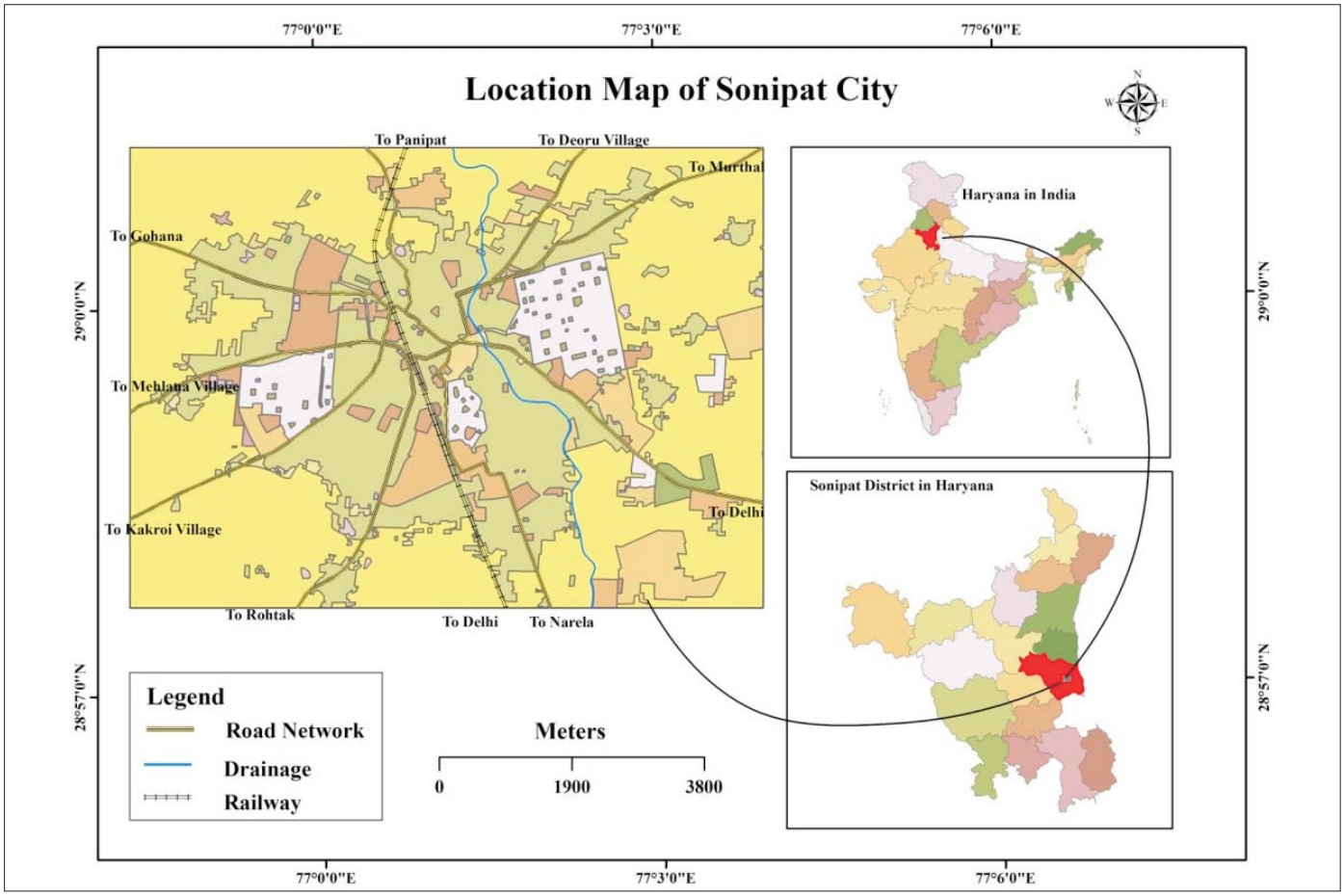

Fig. 1: Location of the Study Area

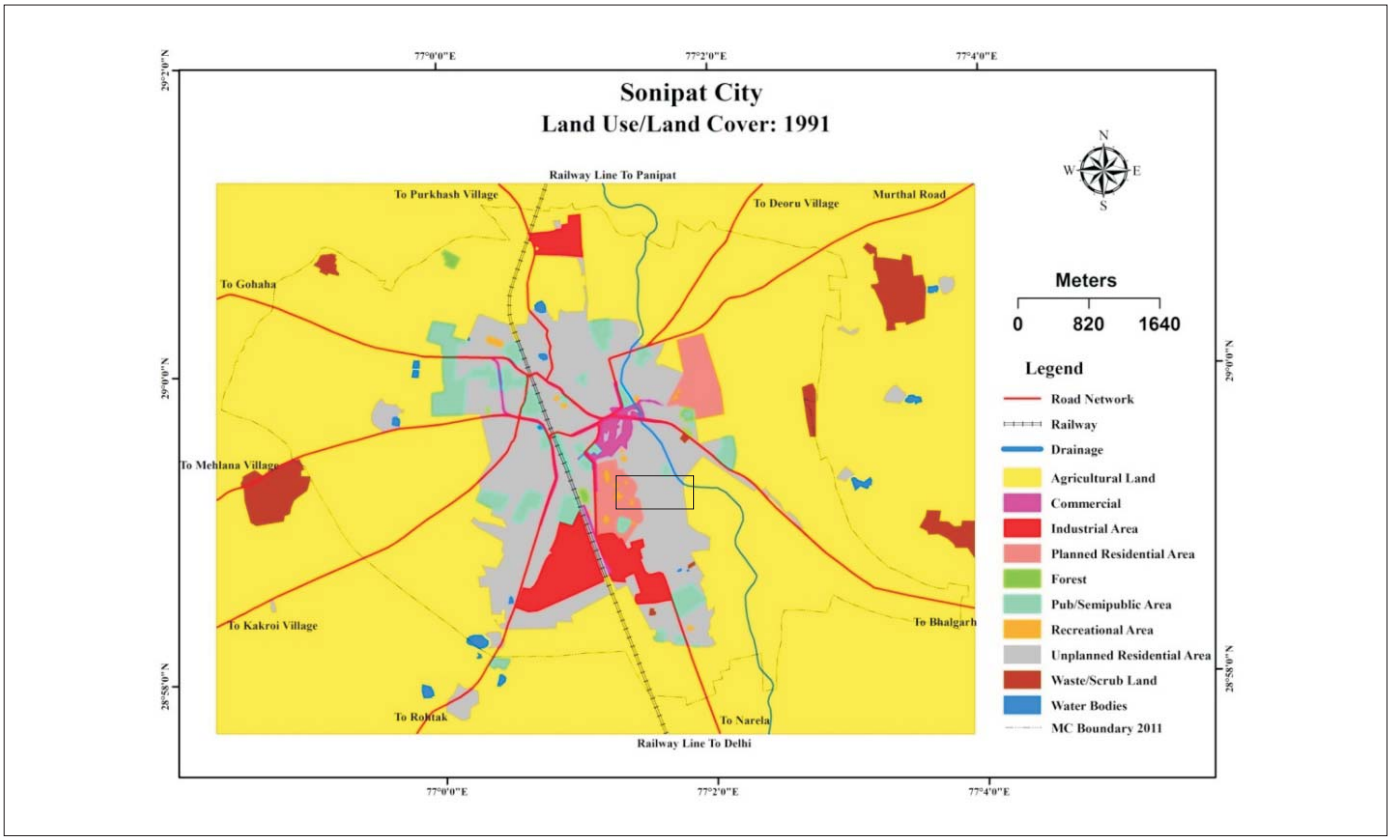

Fig. 2: Landuse / Land Cover Map of Sonipat City, 1991

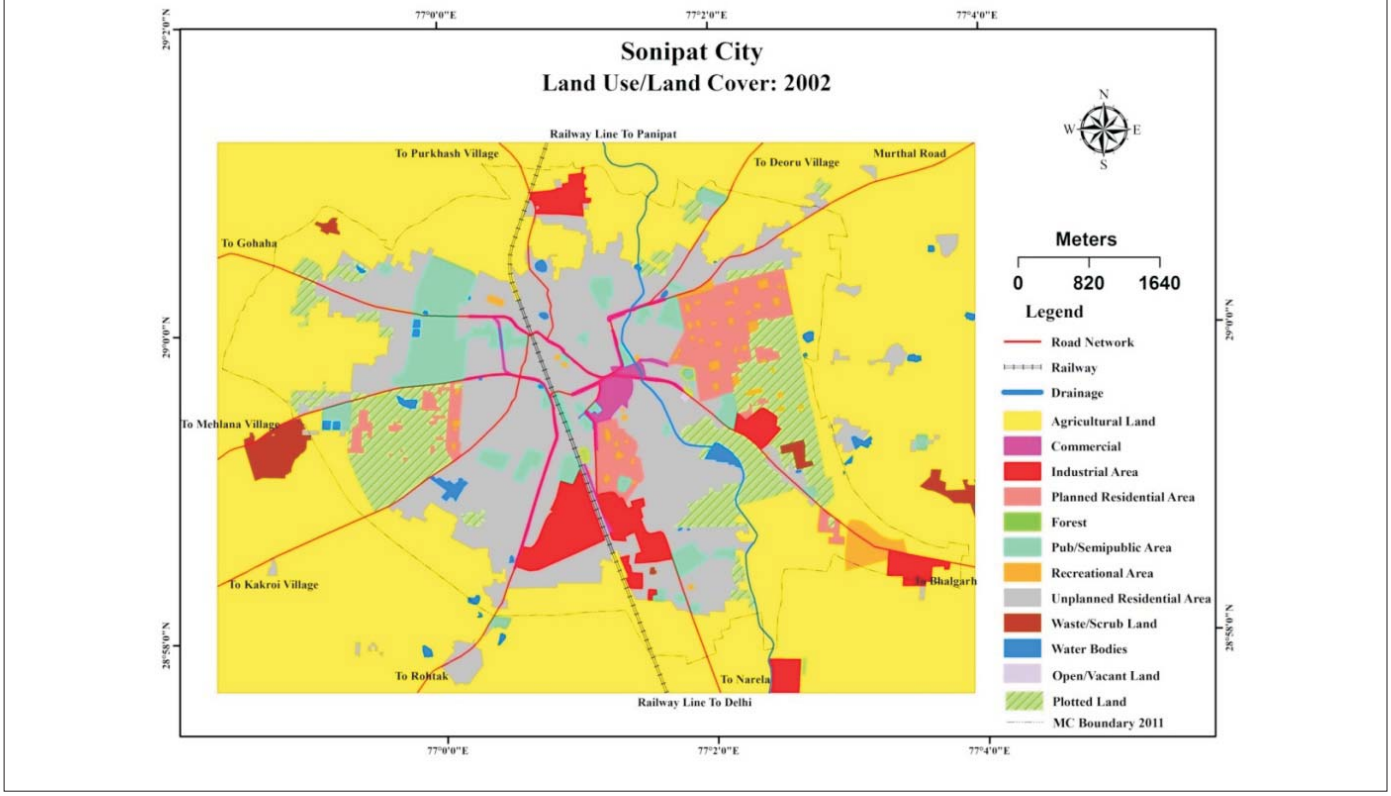

Fig. 3: Landuse / Land Cover Map of Sonipat City, 2002

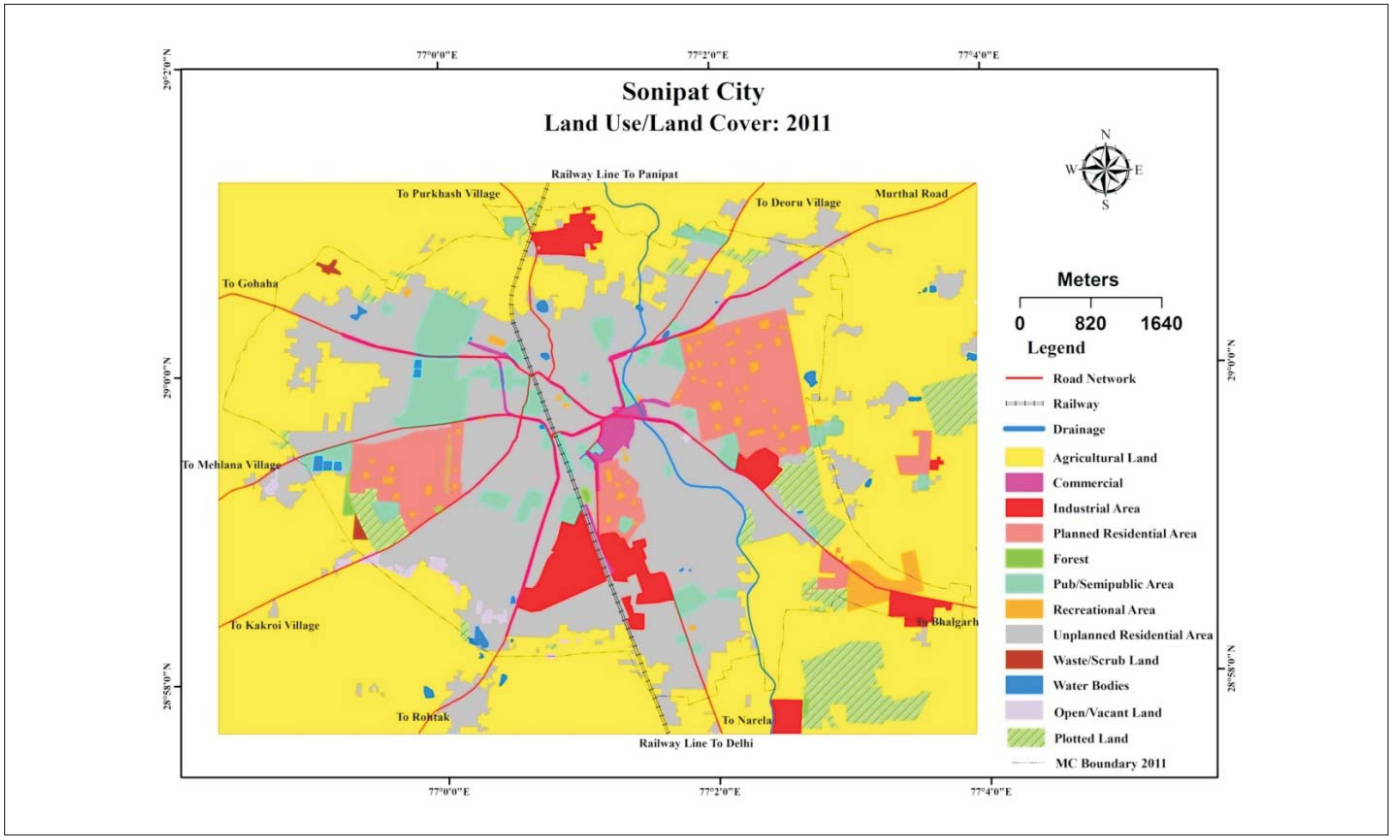

Fig. 4: Landuse / Land Cover Map of Sonipat City, 2011

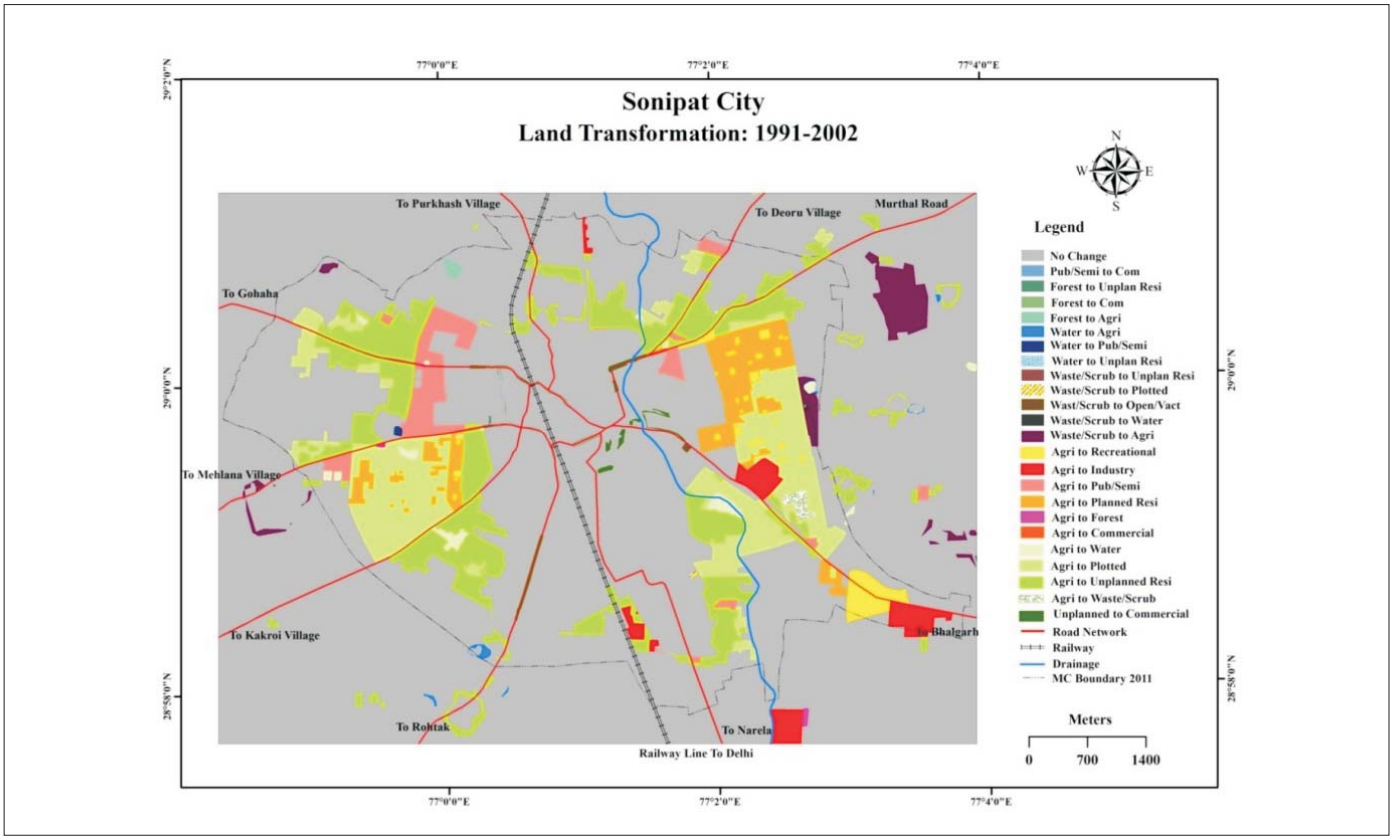

Fig. 5: Land Transformation of Sonipat City, 1991 - 2002

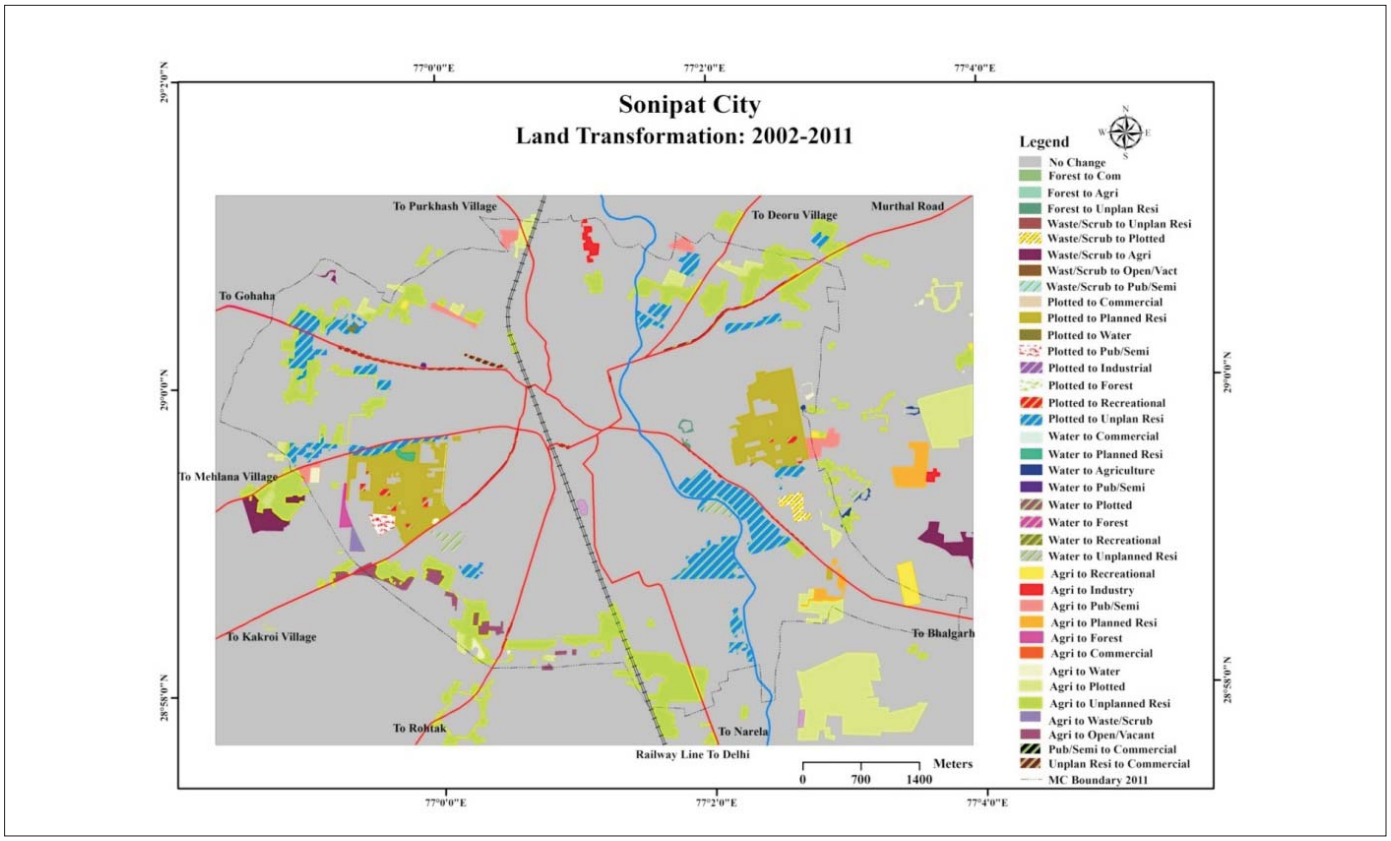

Fig. 6: Land Transformation of Sonipat City, 2002 - 2011

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