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An application of Remote Sensing and GIS to Analyze Urban Expansion and Land use Land cover change of Midnapore Municipality, WB, India

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Abstract

Urban expansion has brought severe losses of crop land, natural vegetation coverage and water bodies because urban expansion is responsible for different types of issues related to urban environment like declining of air quality, increasing of local temperature, increasing of surface run-off and consequent flooding causes deterioration of water quality etc. Continuous growth of urban area is responsible for changing land use land cover pattern of any urban centre. Therefore, change in land use or land cover has become an essential part in modern strategies for the management of natural resources and monitoring different social and environmental changes. Present study focuses on the urban expansion (urban sprawl) and land use land cover change that occurred in the span of 20 years 1991 to 2011 in Midnapore municipality as case to study. During the study period remote sensing and GIS technologies are adopted to study the occurrence of geo-physical land use changes. Landsat TM and ETM+ images of Midnapore municipality area are collected from earth explorer (USGS). After image pre-processing, to classify the images into various land use classes supervised and unsupervised classification has been done. Eight land use categories have been identified as settlement (urban built-up), water bodies, dense vegetation, degraded vegetation, grass land, agricultural fellow land, lateritic soil cover area and fellow land. The field knowledge obtained from field survey is also used to estimate the classification accuracy. The resultant accuracy is between 76 to 83% for all the land use categories. Change detection analysis has been done which shows that the dense vegetation and degraded vegetation has been reduced by 83.63% and 30.04% respectively but the built-up area has been improved by 72.35%, agricultural area reduced totally. The information about urban growth and land use land cover change of the study area is very helpful to urban planners and local government for suitable future planning of sustainable development of the municipality.

Keywords: Urban expansion, land use change, remote sensing, GIS, change detection analysis.

Introduction

In any particular area land use and land cover change is an essential driving force for change in environmental condition. This is a central key issue to the sustainable development question. There are some researchers who show their attention in the study of land use land cover changes and its related consequences on surroundings[1-3]. Land cover, as the biophysical shape of earth's surface and instant subsurface, is interacted between the geo-sphere and biosphere and also shrunk for most of the energy and material movements. Land use and land cover changes have effects on a broad range of landscape and environmental parameters as well as the quality of water, land and air resources, eco-system process and function, biotic diversity, soil quality, run-off, and the climate system itself through greenhouse gas emission and resultant effects[4]. In a particular region, the land use or land cover pattern is a result of natural and socio-economic factors which is used by human beings in different time and space. Now-a-days, the massive agricultural and population pressure is gradually increasing the scarcity of land resource. The land use change occurs through natural processes even in the lack of human activities whereas land use change is the handling of land cover by people for numerous purposes like food, fodder, timber, fuel wood, leaf, waste, medicine, raw materials etc. Therefore, numbers of socio-economic and environmental factors are engaged for the transformation in land use and land cover. From different standpoints land use and land cover change has been studied in order to identify the diversity, factors, process and consequences of this land use and land cover change. Generally, urban growth is the movement and expansion of commercial and residential land towards periphery of an urban centre. This movement has long been considered as a symbol of regional economic strength for this particular urban centre. But, the benefits from it are progressively more balanced against the impacts on eco-system, including deterioration of water and air quality, rising the land surface temperature and loss of vegetation coverage, social fragmentation, socio-economic disparities, and infrastructure costs[5,6]. Remote sensing and GIS are well-established information technologies, which are broadly recognized in managing land and natural resources. Recently, some researchers have acknowledged that some diverse approaches for data gaining, land-use classification and analysis operate remote sensing satellite imagery as a source data in the origin of spatial data sets with high spatial and temporal resolution[7]. To understand landscape dynamics, remote sensing and GIS is a cost effective and perfect alternative tool. It has been accepted that combination of remote sensing and geographic information systems (GIS), has been extensively applied as an influential and useful tool in determining land use and land cover change[8-13]. On the basis of multi-spectral and multi-temporal remotely sensed data, digital change detection techniques and land surface temperature estimation techniques have demonstrated a great possiblity as a means to understand landscape dynamics to perceive, map identification, and monitor temporal differences in land use types. In the natural science communities satellite imagery has been utilized perfectly for measuring quantitative and qualitative changes of terrestrial land cover. In recent years, in China, to study the temporal and spatial patterns of land use change the remote sensing and Geographical Information System techniques have been progressively used particularly related to urban expansion[14-17]. Landsat data are most extensively used for measuring the surface temperature and changing scenario of land use and land cover.

By assessing physical or environmental condition of the study area, our objectives of this present study are to analyze temporal changes of land use land cover and the causes behind this. Another objective of this study is to analyze the effects of urban expansion with temporal extension of built-up area and population growth of Midnapore municipality.

Study area: Midnapore Municipality is an administrative head quarter of West Midnapore district in West Bengal (figure-1). The city consists of 24 wards with an area of 1855.19 hectares and has a population of 169,127 according to Census Report 2011. Midnapore municipality is located in the central part of Midnapore district. It extends from 87° 17' 18.57" to 87° 20' 30.12" East Longitude and 22° 23 '44.56" to 22° 26' 34.91" North Latitude. It is situated by the banks of the Kangsabati River (differently known as Kasai and Cossye).

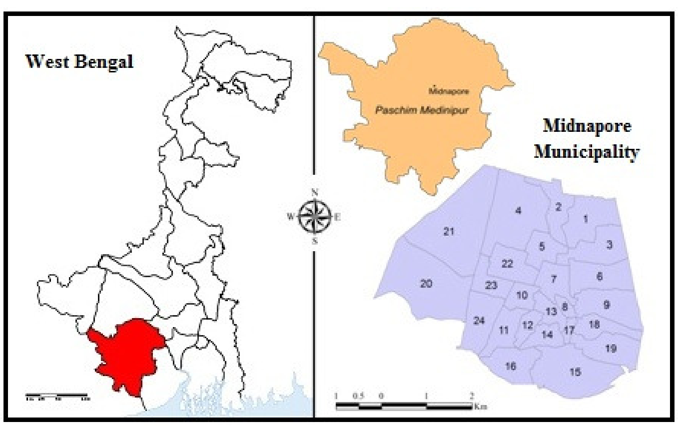


Figure-1
Location map of the study area

The municipality is well-connected with roads and railway lines and also urbanized with good infrastructure facilities. Not only the larger towns in this region, but also the smaller towns and villages in the district are well connected by so many bus routes with Midnapore city (figure-2). Due to the increasing population and settlement, the vegetation coverage in the Midnapore municipality area is decreasing day by day. Vegetations are mainly Sal dominated forests form part of the Dalma range (Bengal-Jharkhand) including Eucalyptus on the northwest side of town. Under India's first Joint Forest Management (JFM) scheme, Arabari forest range was a part of this scheme, which is only 30 km away from Midnapore.

Midnapore railway station has connection with Howrah station. A bus terminus provides bus service to the greater Midnapore area. Although, some of the less important roads in the city are unpaved and utilizable during and after the rainy season (monsoon) an ongoing "Megacity" project started in 1997 have been extended and maintained some selected thoroughfares of Midnapore town. The enormous majority of roads are in a state of deprived condition. If the problems faced by people are observed, it is seen that there is a few number of bridges over the Kasai River affording entrance from Kolkata (NH-60). However, for inhabitants to arrive shortly at Kolkata, an ongoing project of the new interstate highway connection has constructed, passes through Midnapore. To control huge traffic pressure recently a set of traffic signals was established in the city.

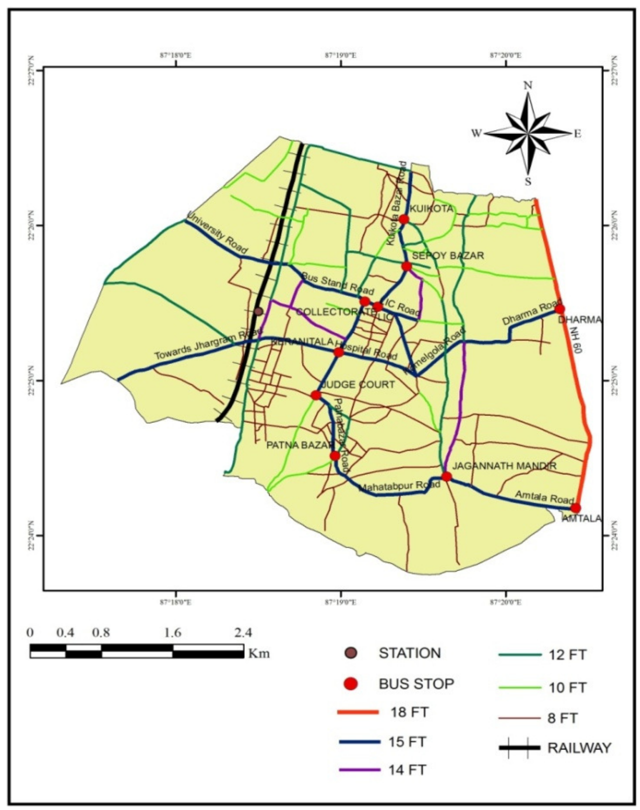


Figure-2
Transport and communication system of Midnapore municipalities (2011)

Material and Methods

In our present study, both the primary and secondary data were collected from various sources. The primary data like the topographical sheets of 1:50,000 scale and cloud free multispectral Landsat satellite imagery data of three dates available in the past three decades for the related region were collected from Survey of India (SOI) and earth explorer (USGS) respectively. The Table-1 shows the sources of collected satellite imagery data. Here, true color Google satellite image of study area, 73 N/7 topographical sheets from Survey of India and different time municipal boundary map of the study area from Midnapore municipal office are also collected. The secondary data were collected including the demographic information from the primary census data of the study area for 1991, 2001 and 2011, from the Directorate of Census Bureau (Census of India). The ward map of the municipality area was obtained from Midnapore municipality office, Paschim Midnapore.

Table-1
Details of Landsat data collected from USGS

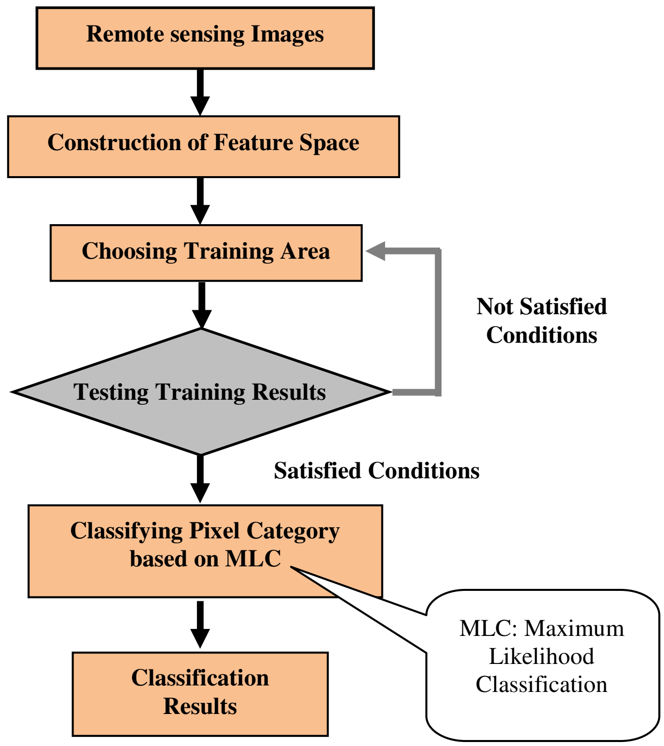
No.	Date of image	Satellite / Sensor	Reference system / Path / Row
1	21-11-1991	Landsat5 / TM	WRS-2 / 139 / 44
2	26-10-2001	Landsat7 / ETM+	WRS-2 / 139 / 44
3	05-08-2011	Landsat7 / ETM+	WRS-2 / 139 / 44

Laboratory Work: In laboratory different techniques were performed with the help of ERDAS IMAGINE-9.O and ArcGis-9.3 software, using satellite images.

Image Processing and Geo-referencing: To get the composite images, different types of bands and stacking are performed of all the collected images content. Some image improvement techniques like data scaling and histogram equalization are also performed on each image to improve the image quality. Then, satellite images were rectified with the help of pre-referenced topographical sheet by the image to image rectification process with geographic co-ordinate system (lat/long), spheroid – Everest and Detum-1830, using ERDAS IMAGINE software.

Create AOI layer and Subset: Extract of our study area is done with the help of AOI tools in ERDAS software. After creation of AOI, the study area is extracted by subset from main images. After creation of the AOI layer sub setting is done to extract the interested area.

Classification of Images: Supervised as well as un-supervised classification methods are applied to classify the pre-processed images. According to the required number of classes and the digital number of the available pixels the ISO DATA clustering algorithm is built in the ERDAS Imagine software by un-supervised classification method. On the other hand in the supervised classification the maximum likely hood algorithm will classify the image based on the training sites (signatures) obtain from field knowledge given by the user. The user input the training data into the software to understand, that what type of pixel is to be selected for certain land use type. To understand and for reference about the distribution of pixel with different digital numbers the unsupervised classified image has been used. Finally, both the classifications give the land use land cover image of the study area to investigate the changing scenario (figure-3).



Figure–3
The technique sketch of supervised classification

Following land cover classes are identified in the study area.

Table-2
Classification of land use land cover of different year

The classes of year 1991		The classes of year 2001 and 2011	
1	Water bodies	1	Water bodies
2	Dense Vegetation	2	Dense Vegetation
3	Degraded Vegetation	3	Degraded Vegetation
4	Grass Land	4	Grass Land
5	Agricultural Fellow Land	5	Built-up Land / Settlement
6	Built-up Land / Settlement	6	Fellow Land
7	Fellow Land	7	Lateritic Soil Cover Land
8	Lateritic Soil Cover Land		--

Land use and land cover (LU/LC): There is no doubt that human actions have extremely changed land use land cover in the Midnapore municipality area throughout the last twenty years. The entire ecosystem of the land is comprised with water, soil and plant. Therefore, land is one of the most significant natural resources for human beings because the human society demands food, energy, water and other daily requirements for livelihood. Now it is very crucial to understand the temporal influence of the human activities on their natural resource base by observing the earth from space. In situations of quick and often unrecorded and undocumented changes in land use patterns, observations of the earth from space give intent information of human actions and use of the landscape. The classified images provide all the relevant information to understand the land use and land cover change of the study area.

Built-up area extraction: Three years variations of built-up areas were extracted from the previous classified images, from which we can know the dynamic changes of urban sprawl in Midnapore municipality. For the Landsat TM images, the built-up areas were extracted after image processing and image classification and then built-up areas were regarded as one of the indicators to measure urban sprawl (figure-4).

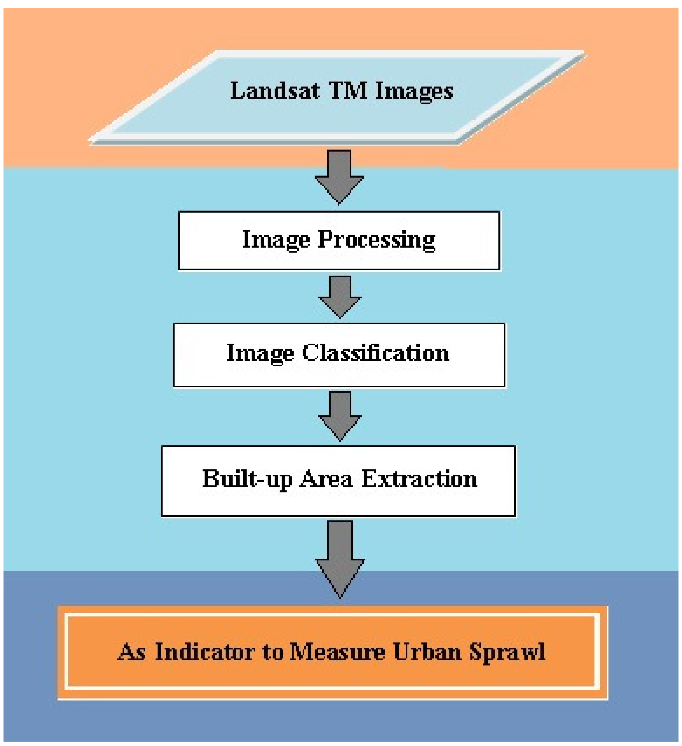


Figure-4
The technique sketch of built-up area extraction

Land surface temperature mapping: Generally, urban expansion gives rise to a significant change of the Earth's surface. The natural vegetation coverage is removed and replaced by non-transpiring and non-evaporating surfaces such as concrete, asphalt and metal. Therefore, most of the land surface is covered by cementing materials which have the capacity of absorption of temperature. Increasing concretization and reduction of natural vegetation and soil coverage both are responsible for increasing surface temperature and changing land use pattern of an urban centre. So, land surface temperature change is an indicator of the change of land use and land cover. Relationship given between the texture of land cover and the surface radiant temperature and the impact of urban growth on surface temperature in the Midnapore municipality can be measured.

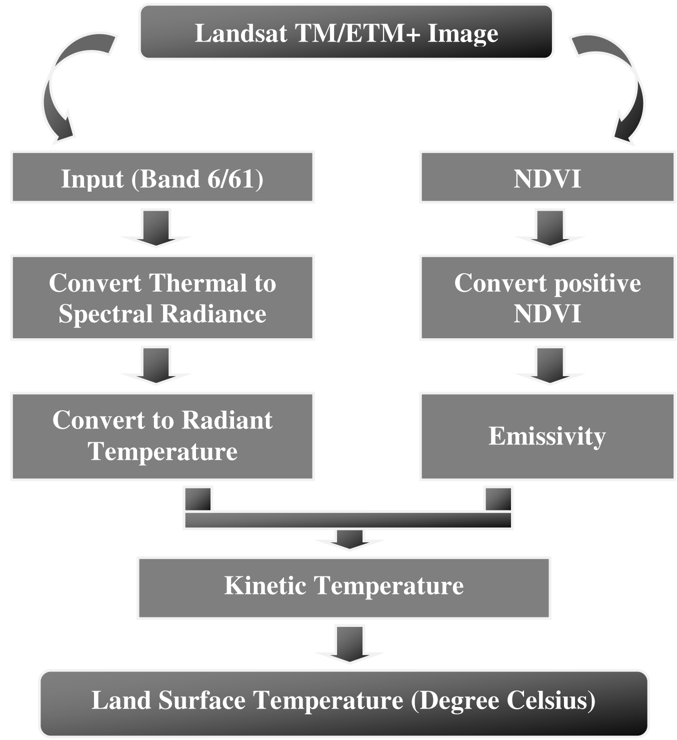


Figure-5
The technique sketch of land surface temperature measurement

NDVI: Normalized Difference Vegetation Index (NDVI) is an excellent indicator to measure surface radiant temperature and land use or land cover change. To establish the density of green on a piece of land, some researchers have observed the distinct colors (wavelengths) of visible and near-infrared (coming from sun) reflected by the vegetation. The NDVI images are calculated for 1991, 2001 and 2011 from visible (0.63-0.69 µm) and near-infrared (0.78-0.90 µm) by using the following mathematical formula:

NDVI = (NIR – RED) / (NIR + RED)

Built-up Index: Built-up Index is also a good indicator for monitoring the changes of land use and land cover. The built-up index is computed in 1991, 2001 and 2011from near-infrared (0.78-0.90 µm) and middle-infrared (1.55-1.75 µm) by using the following formula:

BUI = (MIR – NIR) / (MIR + NIR)

Recode: In Geographical Information System analysis of 'recode' is a process, which allows assigning a new class value number to any or all classes of an existing image file. The new class numbers are used to create an output file. The function can also be used to merge classes by recoding more than one class to the same new class number. This recode process can do with the help of ERDAS Imagine software.

Change Detection Analysis: Change detection analysis is used to explain and quantifies temporal differences between images of the same scene. The classified images of three dates are used to estimate the area of various land covers changes of different time span. The change detection analysis is an important useful technique to identify different changes occurrence in different land use classes like increasing urban built-up area or decreasing vegetation coverage and so on.

Results and Discussion

Analysis of Vegetation Density or Vegetation Abundance: In 1991, the NDVI values are estimated in range of -0.60 to 0.60, having a mean and standard deviation value of 0.207 and 0.118 respectively. Higher NDVI values (0.226 - 0.60) are shown in the northern, southern and south-western part of the image. The southern and south-eastern part of the image is covered by lateritic soil, built-up areas and water bodies which show lower NDVI values. In 2001, the NDVI values are estimated in range which has been changed from previous year (1991). The range is -0.284 to 0.482, having a mean and standard deviation value of 0.002 and 0.046 respectively. The highest values are observed over dense vegetation and degraded vegetation. Lowest values are seen over water bodies as well as highly built-up areas. In 2011, the NDVI values are observed in range again change from previous year (1991 and 2001). The range is -0.125 to 0.474, having a mean and standard deviation value 0.087 and 0.062 respectively. Higher NDVI values are observed over a very small part of the image (figure-7). Water bodies and built-up areas show lower NDVI values.

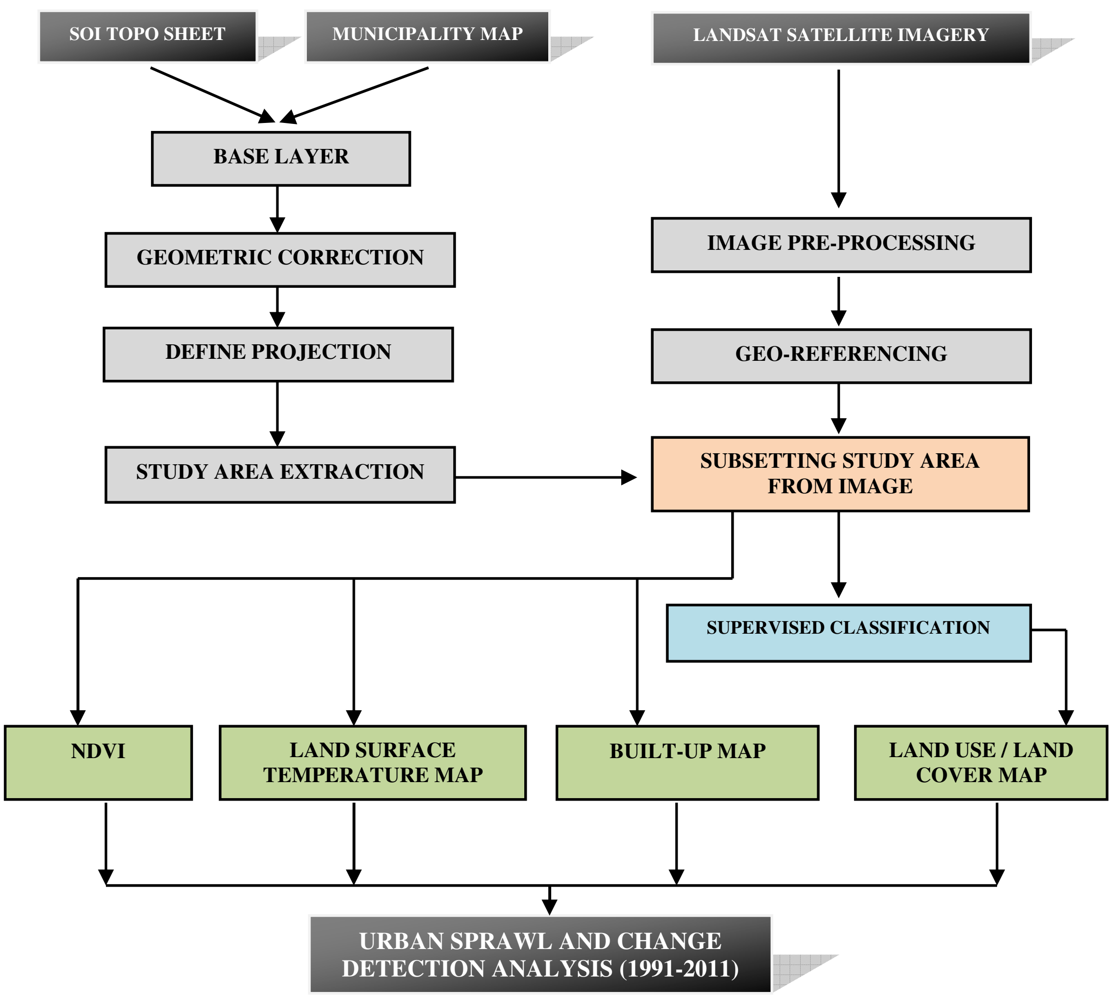


Figure-6
Overall flow chart of the methodology

In the analytical view of comparison study of NDVI of 1991, 2001, 2011; it is said that the vegetation of the Midnapore municipality is going to decrease rapidly day by day due to the increases of built-up area as well as population.

Analysis of Land Surface Temperature and Relationship with Land Use/Land Cover: The spatial distribution of surface temperature of 1991, 2001 and 2011 are estimated using Landsat TM satellite images (figure-8). The estimated LST ranges from 15.32° to 28.79°C having mean and standard deviation value 19.32°C and 1.821 respectively. The western part of the study area mostly covered by lateritic soil and fellow land causes higher temperature 22.57° - 28.79°C,. The eastern part of the study area exhibits low temperature ranges from 15.32° – 20.39°C, due to the presence of high vegetation cover lands and water bodies. The spatial distribution of land surface temperature of 2001 shows that the estimated LST ranges from 15.08° to 29.75°C having mean and standard deviation value 21.69°C and 1.943 respectively. The west and some part of the east of the study area showing maximum temperature due to lateritic soil cover range 24.80° - 29.75°C. In 2011, the estimated spatial distribution of land surface temperature ranges from 20° to 35.31°C (mean value 27.78°C and standard deviation 1.512). It is observed in the figure-8, that the western and southern part of the study area have maximum surface temperature as a result of lateritic soil cover and fellow land. On the other hand, in the centre of image thermal gradient temperature also increases from built up area to fellow land and lateritic soil cover. In the central part of the image, several high temperature locations are also seen. Water bodies and its surrounding land cover show low surface temperature ranges from 20° to 26.26°C. The highest surface temperature over lateritic soil cover land is from 30.98° - 35.31°C.

Extent of Urbanization: Increasing population pressure and consequent rapid urbanization is the cause of enormous change in the centre of the municipality. Therefore, the problem of central growth of the municipality is complicated by the situation that, it should take place in the built-up area which is impossible. Thus, continue increasing pressures of municipality area progressively change the adjoining environment and neighborhoods. Urban sprawl or extension gradually refers to sometime of development with consequence such as loss of crop land, vegetation cover land and fellow land. In other words, as population pressure increases, the area also expands to provide accommodation of this population growth, this growth is considered as urban sprawl. The following maps are showing the urban built-up extension from 1991-2011 (figure-9).

In 1991, 2001 and 2011 we have mapped the city expansion using topographical maps, Municipal boundary map and Landsat TM imageries (figure-10). However, in 2012 GPS has been used to get coordinates and positions of the roads, railway-lines, municipal boundary and streets of Midnapore municipality. The study reveals that the rate of physical expansion of Midnapore municipality was not the same in all the decades, it was fluctuating.

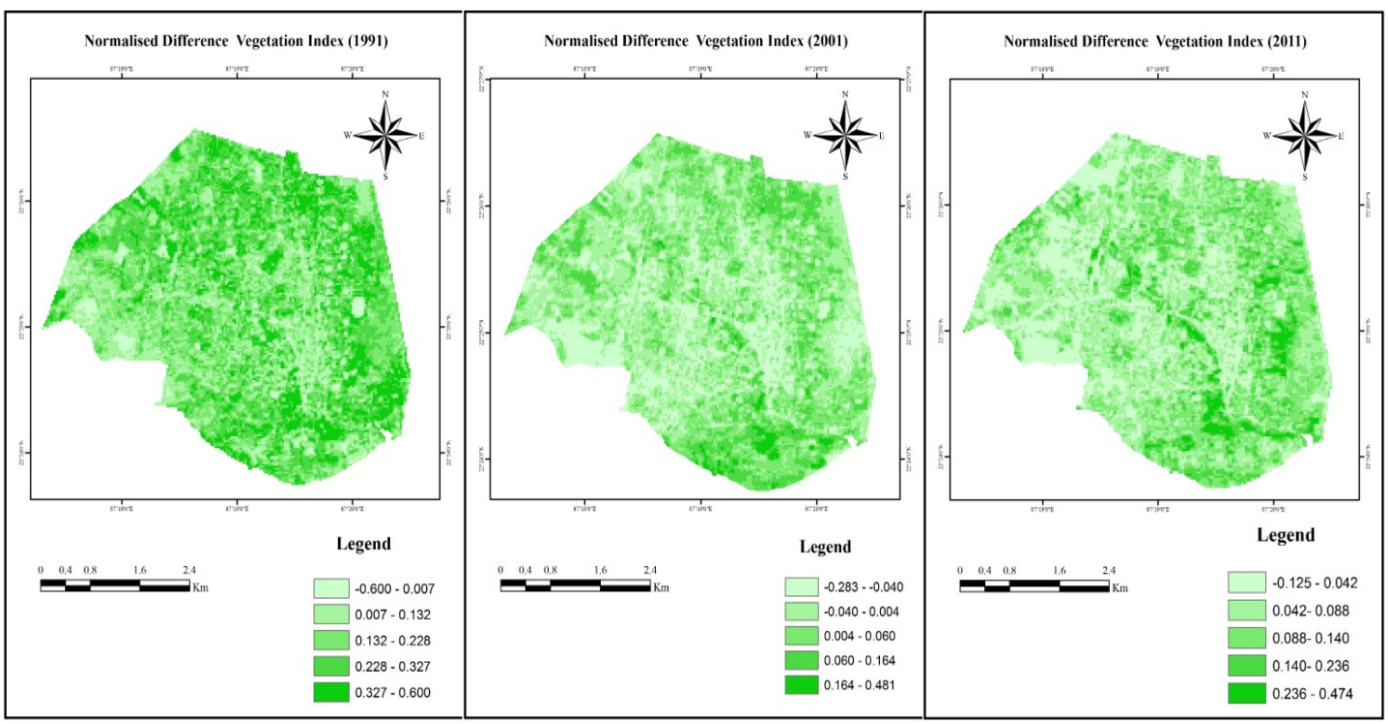


Figure-7
Normalized difference vegetation index of different year (1991, 2001, 2011)

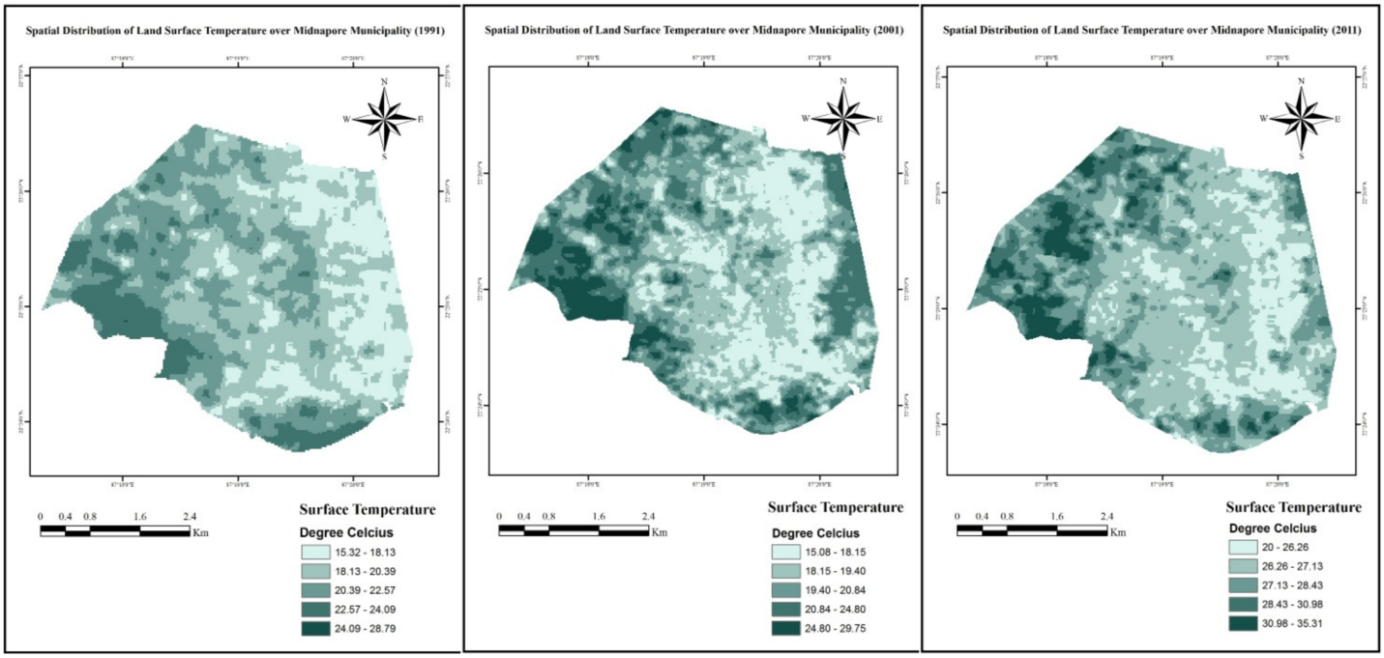


Figure-8
Spatial distribution of land surface temperature of different year (1991, 2001, 2011

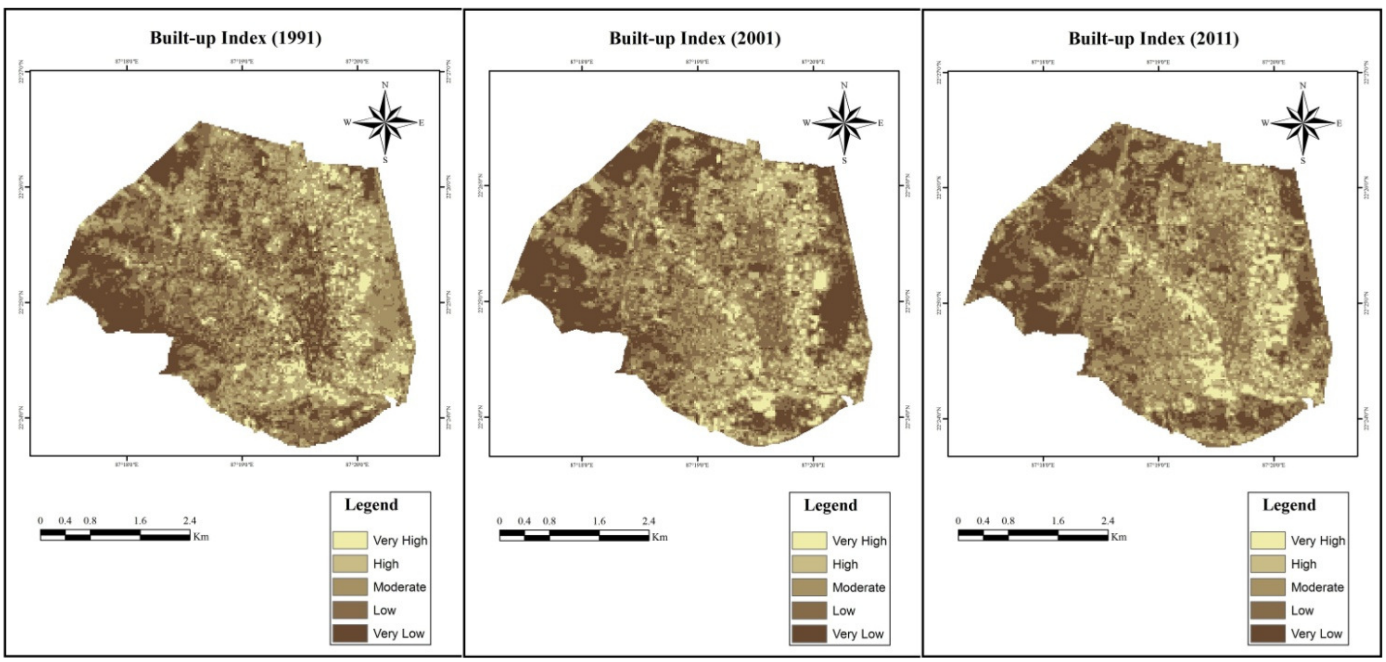


Figure-9
Built-up area extension of Midnapore municipality in different decades (1991, 2001, 2011)

In 1991, the settlement area of Midnapore municipality was only 609.96 hectares with 125498 numbers of people and the total area of the municipality boundary was 14. 76 square km. For the period of 1991-2001 population of the municipality went up to 149769 (19.34%) and the area also widened along with the increase of the population, the total settlement area was 796.88 (30.64%) hectares.

During 2001-2011 again the city showed a marginal growth of population as well as area. The settlement area is 1051.29 (31.92%) and the population is 169127 (12.92%). All the maps are overlaid to know the decade-wise physical expansion of the Midnapore municipality during 1991-2011.

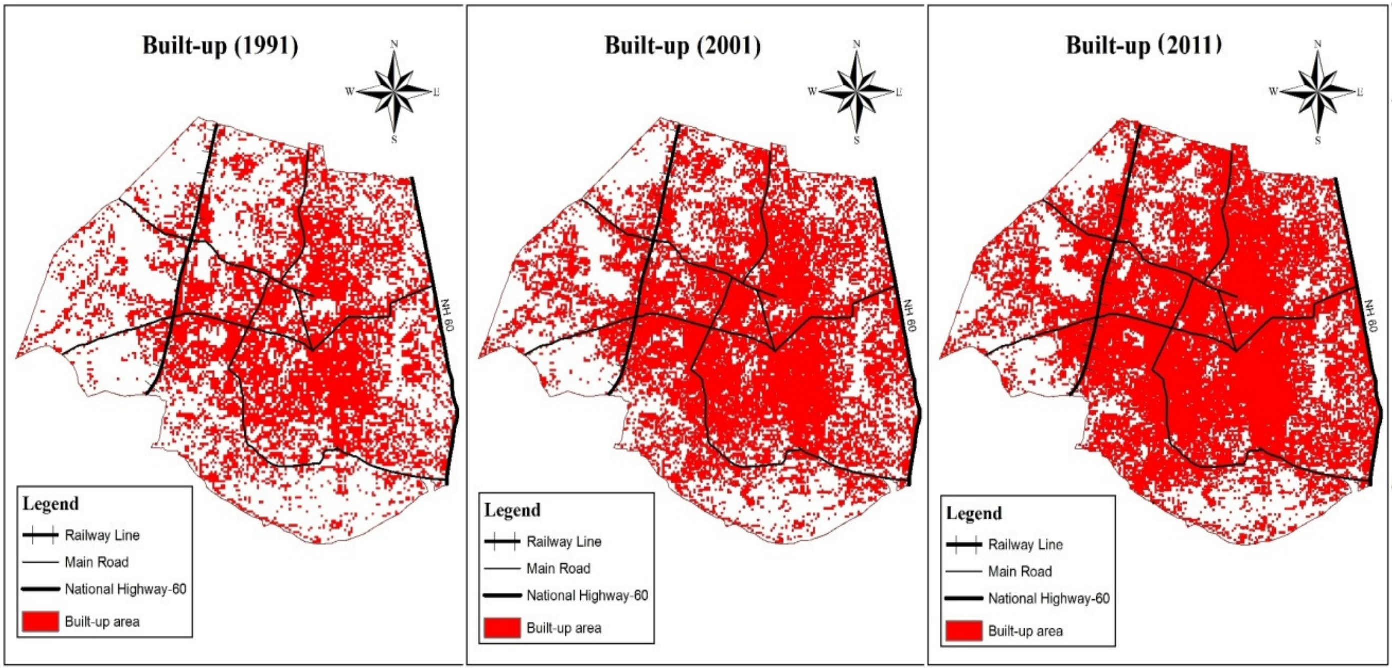


Figure-10
Physical Expansion of Midnapore municipality (1991-2011)

Table-3
Expansion of built-up area and increasing population of Midnapore municipality

Growth of Built-up Area and Population of Midnapore Municipality (1991 - 2011)					
No	**Decade**	**Built-up area (Hector)**	**% of Growth**	**Population**	**% of Growth**
1	1991	609.96	----	125498	----
2	1991-2001	796.88	30.64	149769	19.34
3	2001 - 2011	1051.29	31.92	169127	12.92
Total increase (1991-11)		441.33	62.56	43629	32.26

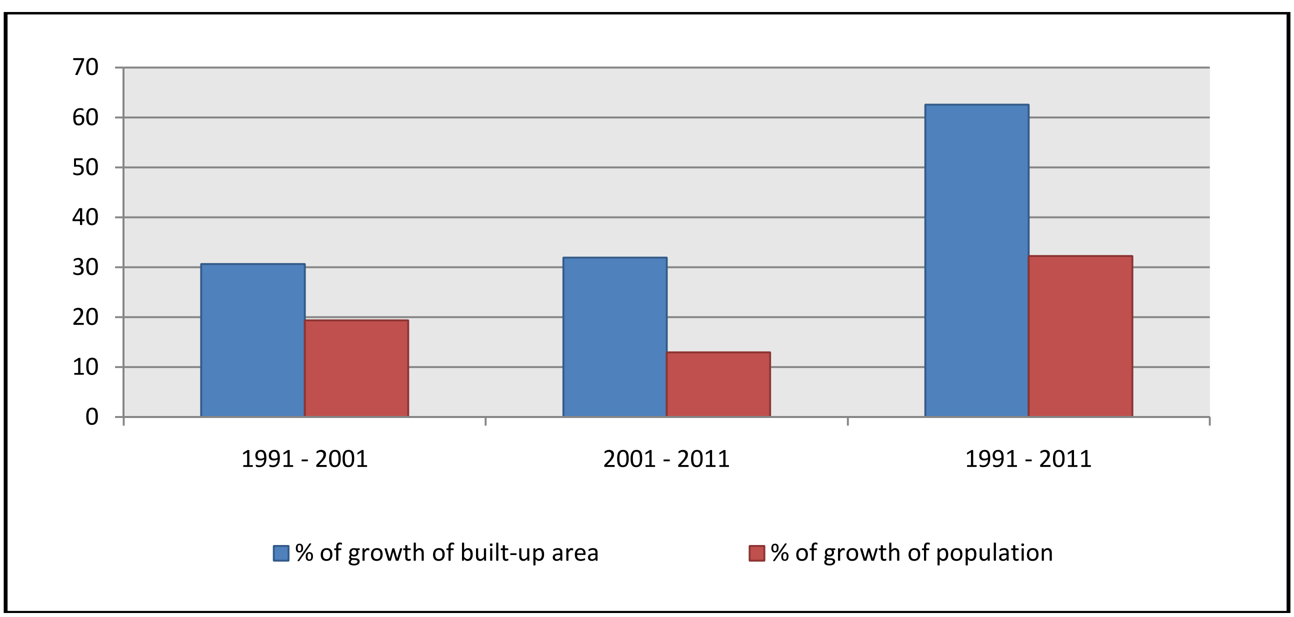


Figure-11
Showing the growth percentage of built-up area and population

Change Detection Analysis: This paper reports the urban change analysis which is based on the statistical data extracted from the three different land use and land cover maps of Midnapore municipality. Table-4 to table-6 clearly shows with diagrammatic representation (Pie Diagram) the changes of land use and land cover of 1991-2011.

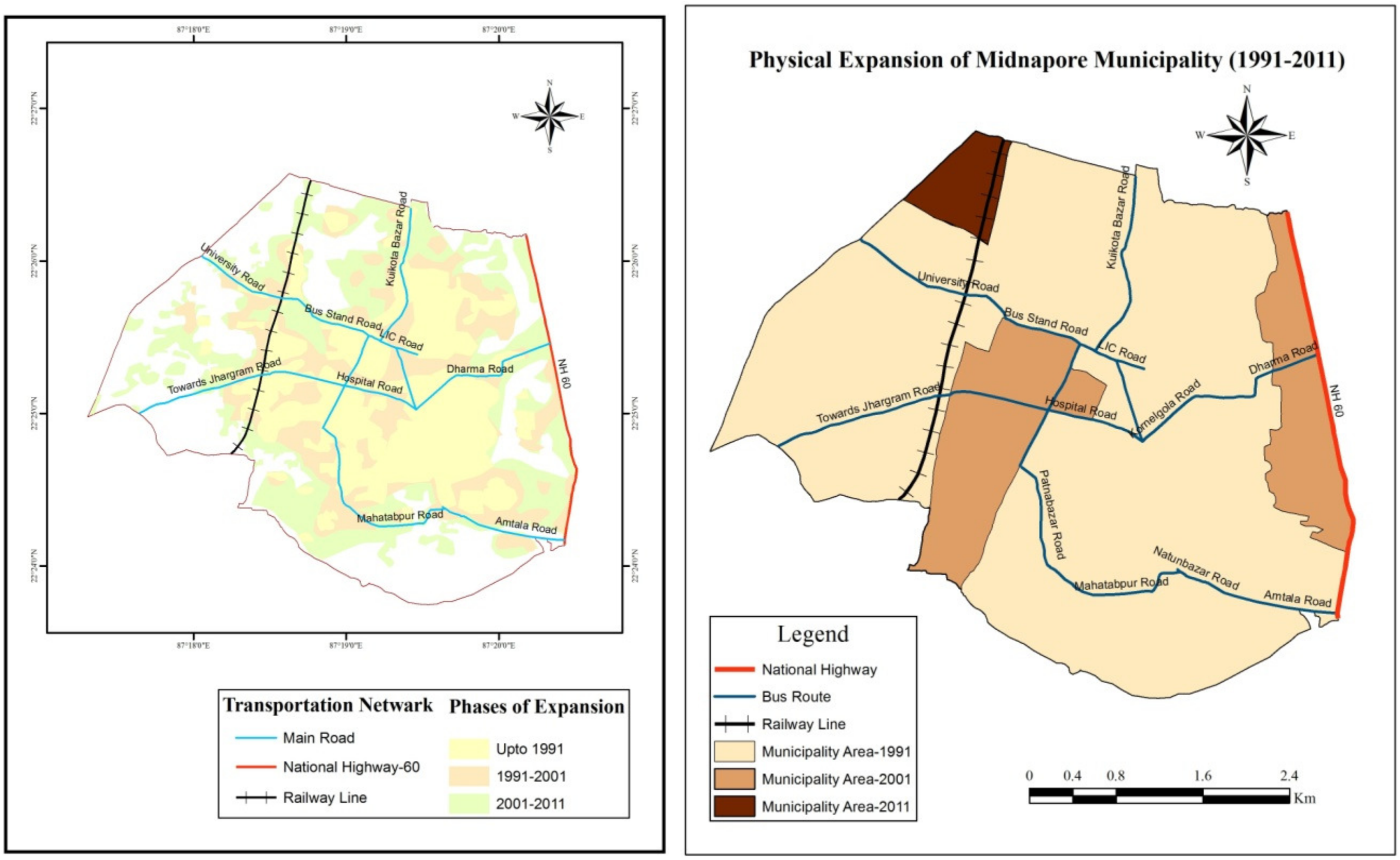
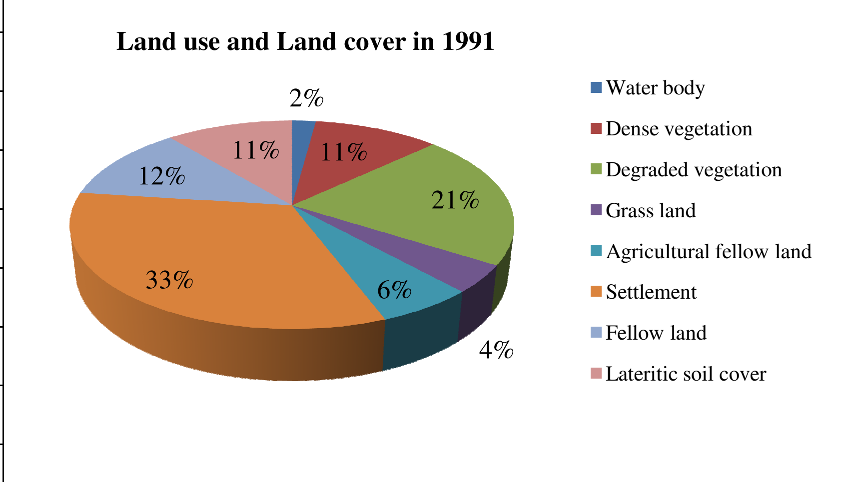


Figure-12
Growth of the Midnapore municipality area (1991-2011)

Table-4
Areal coverage of different types of Land use and Land cover of Midnapore municipality in 1991

Land use and Land cover (1991)	
Land use type	**Area in hectares**
Water body	38.592
Dense vegetation	203.8112
Degraded vegetation	391.531
Grass land	79.0037
Agricultural fellow land	111.606
Fellow land	222.6095
Settlement	609.9659
Lateritic soil cover	205.1662



The built-up area as well as vegetation cover area has been significantly changed from 1991 to 2011 (figure-15). Built-up area has been increased by 72.35%, dense vegetation decreased by 83.63% and degraded vegetation has been decreased by 30.04%. There are so many reasons behind the expansion of built-up area. Midnapore is one of the important center for educational institutions and health facilities of surrounding people. Therefore, the pressures of daily and seasonal migrated people are gradually increased day by day. The eutrophication phenomena in all the water bodies of the study area was found to occur due to the deposition of sediments and haphazard dumping of solid waste. The result of change detection analysis is presented in table-7 and figure-13. figure-14 shows positive or negative change (in percentage) of diverse land use pattern in the study area.

Table-5
Areal coverage of different types of Land use and Land cover of Midnapore municipality in 2001

Land use and Land cover (2001)	
Land use type	**Area in hectares**
Water body	37.5156
Dense vegetation	76.9706
Degraded vegetation	322.1586
Grass land	133.9412
Fellow land	288.7849
Settlement	796.8832
Lateritic soil cover	194.7127

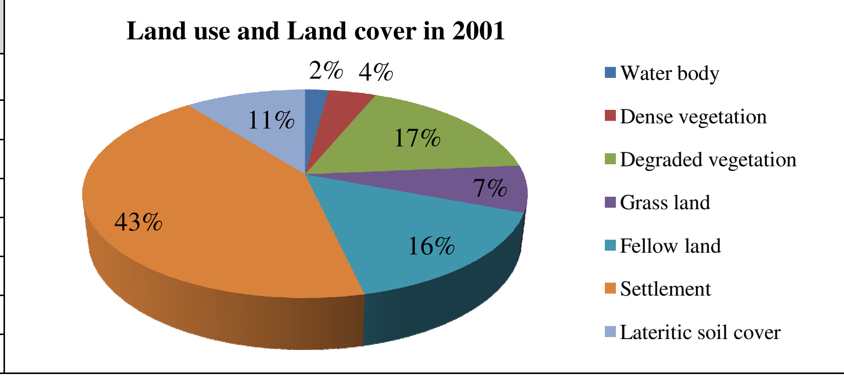


Table-6
Areal coverage of different types of Land use and Land cover of Midnapore municipality in 2011

Land use and Land cover (2011)	
Land use type	**Area in hectares**
Water body	30.9729
Dense vegetation	33.3555
Degraded vegetation	273.9063
Grass land	78.4963
Fellow land	255.5275
Settlement	1051.2927
Lateritic soil cover	161.6342

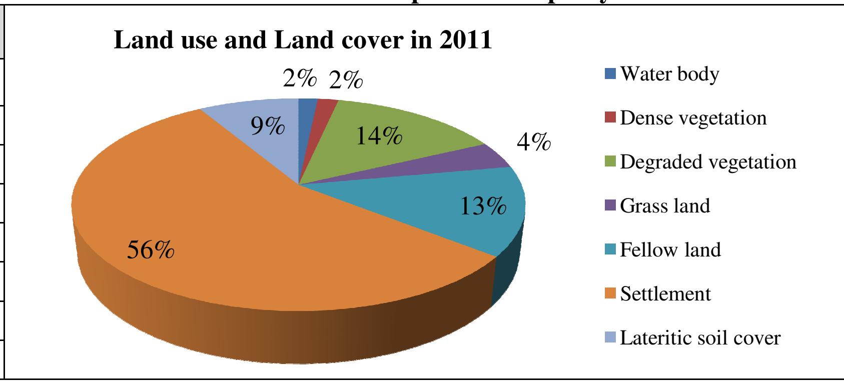


Table-7
Change of areal coverage of different land use types in different decades

Land use statistics of Midnapore municipality (1991-2011)						
Land use type	Area in hectares			Change in percentage		
	1991	2001	2011	1991-2001	2001-2011	1991-2011
Water body	38.592	37.5156	30.9729	-2.79	-19.04	-21.3
Dense vegetation	203.8112	76.9706	33.3555	-62.23	-56.67	-83.63
Degraded vegetation	391.531	322.1586	273.9063	-17.72	-14.98	-30.04
Grass land	79.0037	133.9412	78.4963	69.54	-41.39	-.064
Agricultural fellow land	111.606	0	0	-100	0	-100
Built-up area	222.6095	796.8832	1051.2927	30.64	31.92	72.35
Fellow land	609.9659	288.7849	255.5275	26.88	-21.98	-0.92
Lateritic soil cover	205.1662	194.7127	161.6342	-5.1	-16.99	-21.22

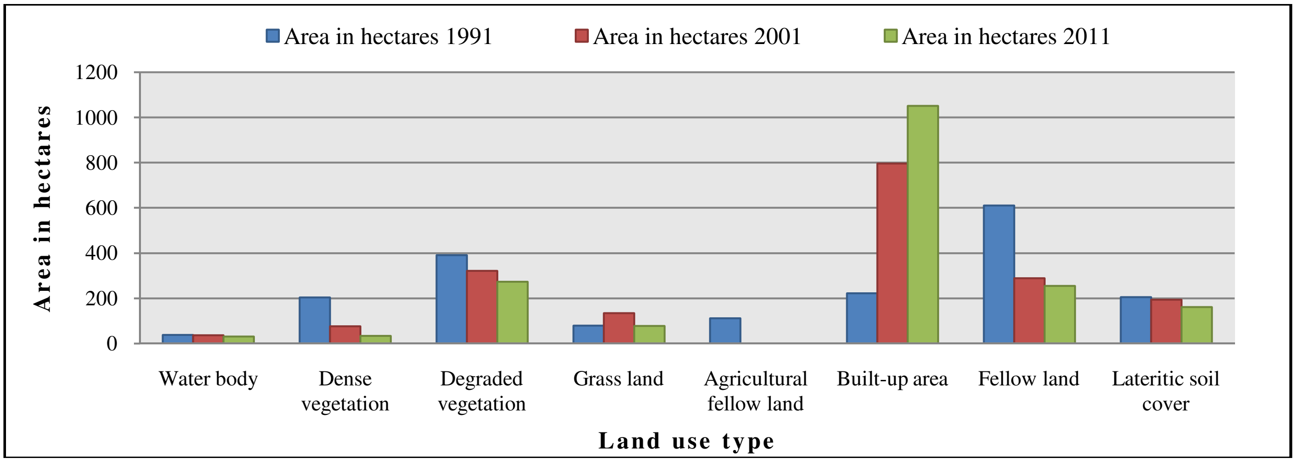


Figure-13
Change of areal coverage (hectares) of different land use types in different decades

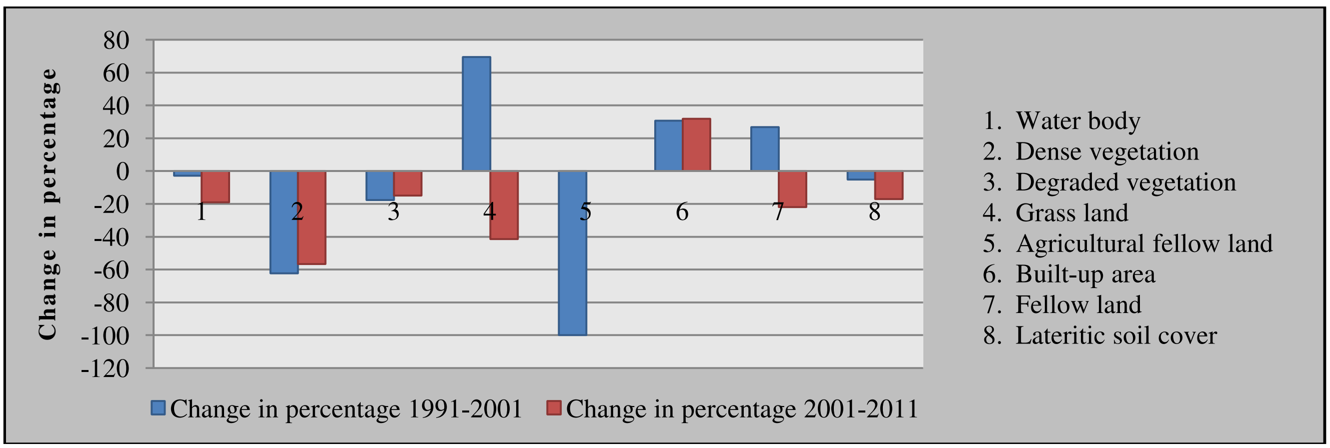


Figure-14
Change of areal coverage of different land use types in different decades

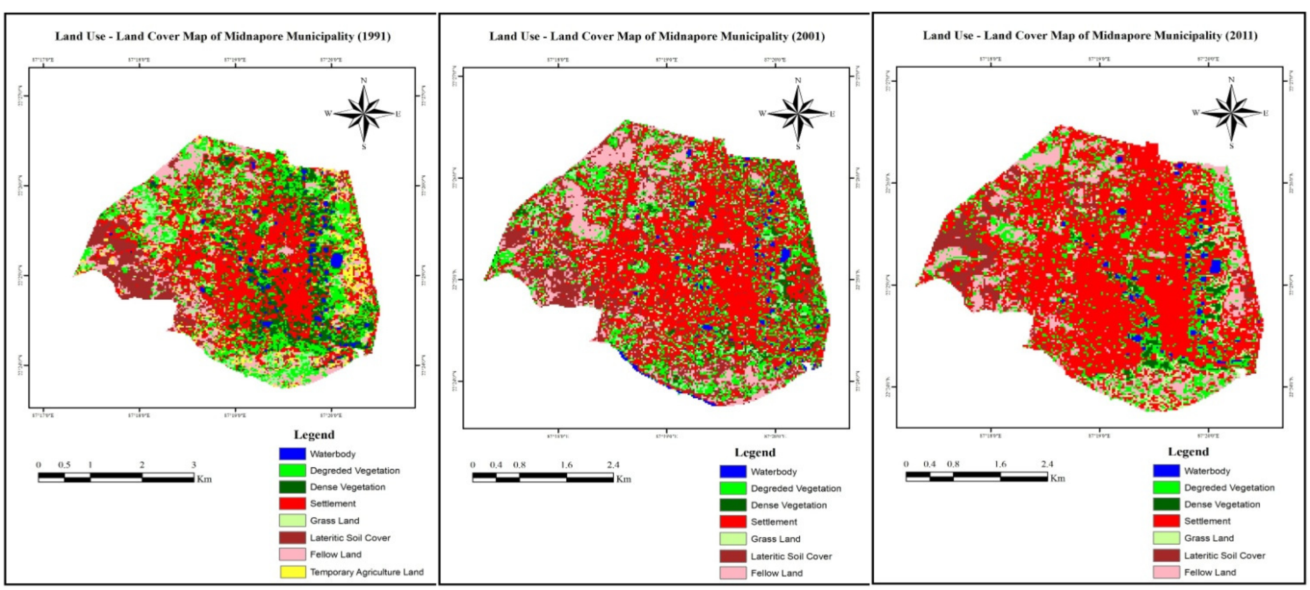


Figure-15
Land use land cover change in different decades (1991-2011)

Conclusion

Midnapore municipality is the second largest town and a main commercial and administrative place of Paschim Midnapore district. Throughout different decades this study immensely demonstrates the utilization of remote sensing and geographical information system in analyzing the urban growth mapping and to identify the urban land use or land cover changes. The extent of urbanization is seen in the study area as one of the important potential threats to environment in terms of sustainable development where utilization of land resource and urban planning are central issues.

The study has taken efforts to identify the change of such urban sprawl and land use land cover for 1991 – 2011. Remote sensing is one of the eligible techniques in monitoring such kind of changes and changing information extracted from satellite image data. This satellite data play an important role in mapping and quantifying the temporal extension of urban area. The land use and land cover map of the study area are produced by supervised classification of the images in different time. Overall classifications accuracy in 1991, 2001 and 2011 are 76%, 83% and 78.33% respectively. Using temporal changes of different land uses patterns this study provides a methodology for better judgment of population and subsequent urban development.

The remote sensing and GIS have been jointly applied to assess the land surface temperature as an effect of urban expansion. The result shows that development of urban area raises surface radiant temperature by 6.52°C. This study also confirms that the direct influence of urban land use or land cover change on one important environmental factor can cause indirect effect on the other. The study shows that the increasing surface radiant temperature is one of the important controlling factors for the decreasing biomass and biodiversity loss. It is very essential to identify the possibilities for most advantageous use of different land use or land cover for the selection, implementation and planning of land use planning scheme to meet the rising demands for human requirements and welfare. The information about land use land cover also helps in monitoring the demands of growing population associated with the dynamics of land use change. This is a very important thing for the urban planning authorities to implement a proper land use planning in developing countries where land use data generally are not sufficient.

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