3-D Digital Modelling using Multi-Spectral Remote Sensing Imagery: A Study of Million+ City, Faridabad, Sub-Region of Central NCR, Haryana State, India

Madan MOHAN, India

Key words: Geoinformation/GI, Land management, Remote sensing, Urban sprawl, Economic development, Spatial planning

SUMMARY

Remote Sensing imagery provides valuable information for urban mapping and 3-D modelling of urban landscape. The 3-D models can increase the understanding and explanation of complex urban scenarios and supports in the decision making processes. The geospatial remote sensing information have a complex structure involving space, time and presentation. Urban building models are typically acquired by semi-automatic processing of Laser scanner elevation data or aerial imagery. For large urban scenarios LIDAR data can be utilized. Most of the 3-D urban modeling methods are designed to use remote sensing data. The main source of data for the production of urban landscape models and 3-D city models were aerial images, terrestrial images, map data, and data derived from ancillary mapping and surveying. So, the multiple interactively linked views are providing different perspectives into the data which has become a kind of standard in geovisualisation of urban landscape. There are various concepts, algorithms, and approaches used in the 3-D digital modelling which requires proper evaluation before their usages for real world 3-D urban landscape. Whereas it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial pattern of urban sprawl. The urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infra-structure development. The 3-D models have become important for various applications as urban planning, enhanced navigation and visualization of urban objects in geography and urban studies.

3-D Digital Modelling using Multi-Spectral Remote Sensing Imagery: A Study of Million+ City, Faridabad, Sub-Region of Central NCR, Haryana State, India

Madan MOHAN, India

1. INTRIDUCTION

The 3-D Digital model based on remote sensing data in support of detailed terrain surface elevation model assists urban and regional planners to visualize the urban landscape in three dimensions. The 3-D models can increase the understanding and explanation of complex urban scenarios and supports in the decision making processes. The 3-D models have become important for various applications as urban planning, enhanced navigation and visualization of urban objects in geography and urban studies. In other words, the accurate cartographic feature extraction, map updating, digital 3-D city models for urban areas are essential for many applications, such as mapping of buildings and their heights, simulation of new buildings, updating cadastral databases, change detection, disaster management and virtual reality. While these are not only for general use to simply visualize the urban built landscape; but these are being used as 3-D interfaces to more sophisticated simulation for urban models. So, the 3-D models of the urban landscape gives the possibility for simulation and rehearsal, to “fly through” the local urban structures with multiple perspective viewing, and to visualize from different positions and perspectives.

The geospatial remote sensing information have a complex structure involving space, time and presentation for urban landscape. The 3-D digital modelling involves of spatial and non-spatial information integration for geographic visualisation in context to the real world. The geospatial information visualisation is also known as geovisualisation. The multiple interactively linked views providing different perspectives into the data has become a kind of standard in geovisualisation. There has been a paradigm shift in creating, viewing and utilizing geospatial data for planning, navigation and traffic management of urban areas. 3-Dimensional information is preferred over conventional 2-Dimensional maps. Buildings are important objects of any 3-D City model. The algorithms for fully automatic extraction of buildings have not yet been full-fledged developed as a result many researchers in this field opt for semi-automatic methods for 3-D urban landscape modelling (Gruen and Wany, 1999).

There are found different approaches to generate the necessary models for the urban scenario as discussed in the literature. Building models are typically acquired by semi-automatic processing of Laser scanner elevation data or aerial imagery. For large urban scenarios LIDAR data can be utilized. Another study uses projective geometry for a 3-D reconstruction from image sequences. Similarly a study use stereo approaches for 3-D building reconstruction (Fraser et al., 2002). Aerial images have the advantage of very high geometric resolution and low noise levels. In the recent past, there have been considerable improvement in the technology to provide better resolution images from remote sensing space platforms.

The images from Cartosat-2, Quickbird, IKONOS, Worldview-1/2, and Geoeye-1 etc. satellites have geometric resolution less than one meter. But, these geometric resolution levels are not sufficient to generate finer models, however, extraction and representation of major urban features are still possible with uses of these remote sensing imagery.

Multi-spectral satellite imagery provides valuable information for urban mapping and 3-D modelling of urban landscape. Indeed, images can be projected on top of digital elevation models to create a digital terrain model (DTM), which are used by urban geographers to interpret the orientation of 3-D urban features such as building, trees, network etc. At a higher resolution, LIDAR mapping also provides detailed information about urban features. The use of such exhaustive surface data for urban landscape description is attracting wide range of interest in the geographic information, GI Science community, due to progresses in obtaining accurate surface geometry from remote sensing data. Most of the 3-D urban modeling methods are designed to use remote sensing data. The main source of data for the production of digital city models and 3-D city models were aerial images, terrestrial images, map data, and data derived from ancillary surveying. The process of geospatial information extraction from these sources usually performed manually using heads-up digitization or digitally using image classification algorithms. So, at present, the high-resolution satellite sensors available at the less than 0.5 m resolution, hence it becomes more practical and economical to utilize stereo satellite imagery to generate less than 3.0 m digital surface model's (DSM's) without any requirements for aerial mapping permits, licenses or mapping in restrictive air space at the regional and global levels.

More recently, due to impacts of globalization, there has been observed the establishments of number of national and multinational companies, resulting to urban and economic development, with the inception of Faridabad as an industrial city. So, it is noteworthy to mention that there has been occurred a continuous urban sprawl in the rural-urban fringe of the Faridabad City over the recent periods. It has largely been responsible in the transformation of physical landscape which is creating socio-economic and environmental concerns at large. Urban sprawl has been quantified by considering the built-up area as the key feature of sprawl, which can be obtained either from physical field survey or through remote sensing satellite imagery. A large number of studies are dealing with quantification of the spatial patterns of urban sprawl with the help of Remote Sensing and GIS. In all these studies, however, concluded with different methodologies in quantifying the urban sprawl. But it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial pattern of urban sprawl. So, the urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infra-structure development over the periods. However, the 3-D modeling of objects, scenes, and urban landscape, consisting of geometry and texture of visible surfaces, are useful in a variety of applications such as urban planning, and simulation for urban landscape for further development.

1.1 3-D Visualization Modelling

In most of the cases, the models of buildings, urban features, terrain surface, and vegetation are the primary features of interest in 3-D digital urban modelling. The remote sensing, LiDAR (Light Detection And Ranging) data along with the SRTM (Satellite Remote Sensing Terrain Model) and CartoSat DEM (Digital Elevation Model), is an advanced technology for obtaining the Digital Surface Models (DSMs) for the urban landscape. Such kinds of data when combined with remote sensing and aerial imagery can be useful to create highly detailed DSMs. The 3-D models can be used as a user-friendly interface for enquiring the urban landscape and environment, for hyper-linking web-based information, for visualizing model results, and for accessing functional simulation models. A general classification of 3-D city models, based on their operational purposes, can be organized into four main types such as (a) 3-D CAD (computer aided design) models of cities; (b) Static 3-D GIS (geographic information systems) models of cities; (c) Navigable 3-D GIS models of cities; (d) 3-D Digital urban simulation model. So, the 3-D terrain modeling and visualization requires detailed information pertaining to the terrain features and slopes such as an accurate digital terrain model (DTM) and a digital surface model (DSM) for critical decisions making process and simulation.

Besides the remote sensing imagery, the topographic maps have been used to express and transfer geographical information to the real world. Due to the map's abstract and plane expression, there is an urgent need to establish the 3-D modelling for real world surface landscape. The 3-D visualization involves geospatial technologies to build digital surface models with utilization of digital image processing, digital photogrammetry and other advanced space imaging technology. It would result into the generation of 3-D digital image maps using the remote sensing imagery, orthophoto processing, multi-spectral, multi-resolution multiple-date imagery data fusion, high precision DTM generation and the processing of mosaicked imagery. There are wide prospects to use the 3-D visualization of remote sensing images models for urban landscape resources exploration, urban expansion and such other kinds for urban mapping and planning.

During the process of urban planning, the design drawings program is visualized based on 3-D visualization of urban terrain. Such as, three dimensional GIS modeling for urban studies and the spatial distribution of several elements in context to the urban and regional development at various levels. More recently, there has been creation of textured 3-D models from LiDAR data and single image. But the advantage of a quick and fully automatic generation of the geometric model is still obstructed by the process of data fusion which is necessary to map the images correctly on top of the surfaces of the 3-D urban models. Whereas, it is well-known among photogrammetrists and in the computer vision programmers to retrieve structure from motion. Several images taken from different perspectives or the video stream of a moving camera provide enough information to reconstruct both, the sensor pose and trajectory along with calibration parameters for the camera, and the 3-D scene viewed by the camera (Hartley and Zisserman, 2004) for the 3-D visualization of building structure and the urban landscape.

1.2 Urban Object Extraction Models

There are various concepts, algorithms, and approaches used in the 3-D digital modelling which requires proper evaluation before their usages for real world 3-D urban landscape. The cadastral maps provide useful information for approximation of the ground map of buildings. The boundaries of the buildings are determined using cadastral map. In many cases the cadastral information may be not available. So, the object boundaries have to be generated from the image data by subtracting the digital terrain model (DTM) from the digital elevation model (DEM). Besides this, the 3-D modelling involves the texturing of complex forms of the detailed structures of urban buildings which are restricted to describe objects through simple polyhydric models. A simple texturing of the models delivers important additional information on the object e.g. position of windows and doors without a detailed expensive model extension. The process of texturing of 3-D building models is described as (a) the projection of the 3-D models onto the 2-D images; (b) the dissolution of occlusion situations; (c) the selection of the optimal image part for each 3-D model surface; and (d) the preparation of the description file for the textured 3-D model.

There are methods of deriving a Digital Terrain Model (DTM) and a Digital Surface Model (DSM) from the data for 3-D urban landscape modelling for the built-up area. Although for some applications geometric data alone is sufficient, for visualization purposes a more realistic representation with textured surfaces is necessary. The associated textures from buildings are extracted either from airborne imagery or, especially for facades, from images taken by ground based cameras. The 3-D models can be based on the selection of optimal texturing images from the acquired data including occlusions and multiple representations. Whereas the simulation of a virtual urban environment can be modeled, in context to the real scenarios of the urban objects which have to be extracted from the reality, to represent the real urban landscape situation. Particularly, in real time situations, the 3-D models must be generated for a simulation process. This requires automatic tasks utilizing all information available as the images, maps, DEM, DTM and DSM. In most cases the necessary object models are not available in the simulation data base and a data acquisition has to be performed.

There are different approaches followed for 3-D modelling of urban landscape which have been critically evaluated for their applicable usages in the literature (Fan and Meng, 2012). In case of the LIDAR data, the 3-D information is directly available. Due to the vertical view of the sensor to the nadir during data acquisition, the building structures are bounded by the ground projection of the roof surfaces. There are many studies deriving a DTM and a DSM from the available data. In a coarse model, detection of the buildings is only possible. A DSM rendered with texture may be considered as coarse city model (Thomas, K. et al., 2008). On the other hand, the inputs required for generating finer details includes aerial images, terrestrial images, LIDAR measurements and building plans (Vosselman and Dijkman, 2001). The geometric resolution and radiometric quality of the images are important as it should be possible to identify and delineate features.

Large-scale urban modeling technologies use a variety of sensors and data acquisition techniques. As in case of the many government agencies, urban models are used for development planning as well as environment impact assessment in terms of climate, air quality, fire propagation, and public safety studies. Most of these users are primarily interested in models of buildings, terrain, vegetation, and traffic networks. Whereas the early planners created city models with wood from elaborate manual measurements. Due to the advancement in computation and processing speed in the recent computer technology, computer graphics, computer-aided design (CAD) and geographic information systems (GIS) which offer powerful tools for creating and visualizing 3-D digital models for cities and urban landscapes. These latest technological and geospatial tools require large data sets to model the real world structures. Manual measurement and data entry are unrealistic for 3-D models. So, the researchers use various sensors to acquire accurate data for 3-D urban landscape by integrating the resulting 3-D building models into spatial databases and geographic information systems (GIS) to support urban development and planning.

2. OBJECTIVES

The present study main aim is to develop a semi-automatic system to generate urban site model from remote sensing imagery. The study not only focuses on the extraction and reconstruction of complex building structures; but it visualized to generate a photorealistic site urban landscape model. So, the objectives of the study are mentioned as follows:

i. to geovisualize population pressure on urban landscape;
ii. to identify spatio-temporal patterns of urban land transformation;
iii. to developed 3-Dimensional urban landscape simulation model;
iv. to suggest suitable strategies for urban and regional development.

In view of this, the present research made an attempt in building and simulation of 3-D urban landscape model in order to help local, regional and state level urban land use planners and policy makers. The study further supplement to better understand and address the issues attributed to urban sprawl in context to the real world 3-D urban landscape scenarios.

3. STUDY AREA

Faridabad City is situated between 28^o 20’ to 28^o 13’ north latitudes and 77^o 13’ to 77^o 19’east longitudes. The geographical location of the Faridabad City is presented in the Figure 1 and Figure 2. The city is located in the southern part of Haryana State. It is located at about 32 kms. from the National Capital Territory (NCT) Delhi. The city is bounded on the north by Delhi State, on the east by Agra and the Gurgaon canals and on the west by the Aravalli Hills. The River Yamuna flows very near to the city at its northern side and moves away as it goes southern side as is evidenced by the Figure 3. The present geographical area of Faridabad City is 207.88 sq. km. The major part of Faridabad city is underlain by Quaternary Alluvium consisting of sand, clay and silt. In the western and northwestern part of the city, the quartzite ridges of the Delhi system can the observed. Whereas the Yamuna River flood plain found exists towards the eastern part of the city. Faridabad city experiences a semi-arid climate which is characterized by wide temperature variations and scanty and irregular rainfall. During summer, temperature may reach up to 45^{o} C in June while in winter it drops to 1.9^{o} C in February. The city is also functioning as the district headquarter of Faridabad District.

Fig. 1. Sub-NCR Region

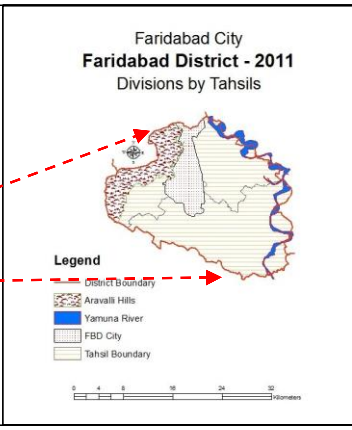


Fig 2. Faridabad City

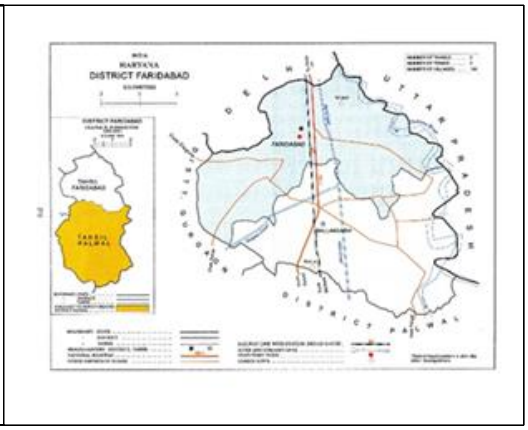


Figure 3. Faridabad District

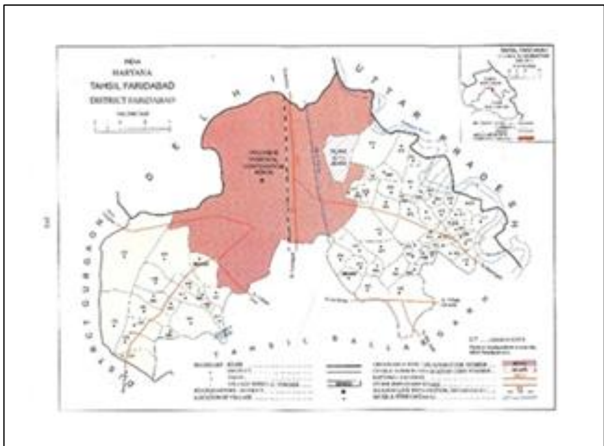


Figure 4. Faridabad Tehsil: 2011

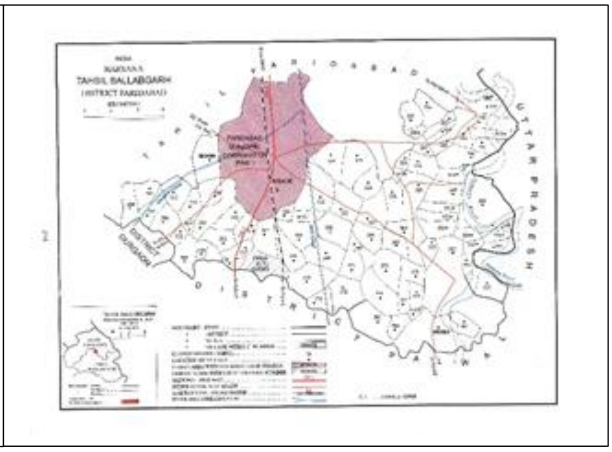


Figure 5. Ballabgarh Tehsil: 2011

It is well connected with both the roadways and the railways transport networks lines as is evidenced by Figure 4 and 5. In other words, the city evolved linearly along these two major transport corridors. The National Highway, NH-2 from Delhi-Mathura passes through the length of the city and is the central axis of Faridabad city. The city has strong transport network linkages with Delhi. It has importance both commercially and economically. Further, the NH-3 and NH-4 also pass through the city. It is connected with the Gurgaon District by the Gurgaon-Faridabad road. As part of NCR proposals, connectivity is proposed for further improvement through the western peripheral expressway (Kundli-Manesar-Palwal –"KMP") and eastern peripheral expressway (Kundli-Ghaziabad-Palwal – "KGP"). The Faridabad City is one of the important million+ population city of the Haryana State in the Sub-Region of National Capital Region (NCR). In other words, the Faridabad city is the only million+ population city in the state and has Municipal Corporation. The city is an important industrial and trading center in Delhi Metropolitian Area (DMA). Unfortunately, the city has reached a point where the lack of infrastructural facilities is having an impending impact on its horizontal and vertical growth. The pride of this million+ city, which it enjoyed earlier and more appropriately in the recent past years, was robbed by the emergence of the cities in its neighborhood like the Gurgaon City, Haryana and the NOIDA City, Uttar Pradesh.

4. DATABASE

In the recent past, a lot of attention has been paid to build the 3-D urban models in order to understand and analyze the process of spatial patterns of land transformation due to urban sprawl in context to urban landscape. It is noteworthy to mention that over the periods, there has been continuous process of urban sprawl in the rural-urban fringe of Faridabad City due to the liberalization of economy, development plans and policies of the State Govt. of Haryana and Central Govt. of India. In view of this, the conventional surveying and mapping techniques are expensive and time consuming for the estimation of urban sprawl. Such information is not easily available for most of the urban centers and cities. So, as a result, increasing research interest is being directed to the mapping, modelling and monitoring of urban sprawl using geospatial technologies which are best suited for geovisualiation through multi-spectral and multi-resolution imagery for spatio-temporal land use mapping as well as for 3-Dimensional modelling of the urban landscape.

There are several benefits of 3-D urban model based on remote sensing imagery and lidar imagery for applications like urban and regional planning. Cartosat-2 satellite was launched in 2007 by the Indian Space Research Organization (ISRO), Department of Space (DOS), Govt. of India. The satellite obtains high resolution imagery with imaging geometry - the spatial resolution of better than one meter in panchromatic band. In addition to this, the present study also used the multispectral digital imagery of the IRS series of satellites which were procured from the National Remote Sensing Centre (NRSC), Indian Space Research Organization (ISRO), Department of Space (DOS), Hyderabad, India. Besides this, the multi-resolution, multispectral digital imagery of the Landsat satellites have also been obtained from the United States Geological Survey (USGS) website. The details of the remote sensing satellite imagery used in the present study is given in the Table 1.

The survey of India (SOI) open series topographic sheets numbers H43X3, H43X7, H43X8 and H43X12 drawn on scale of 1: 50,000 projected on the UTM projection and referenced on WGS 84 datum based on World Geodetic System have been used in the present study. Besides this, the spatial information have been extracted in form of the boundary, elevation, drainage, transport network, and cultural features and other relevant spatial information from the SOI, open series topographic sheets on the scale of 1: 25,000. These Open Series

Topographic sheets have been obtained from the Survey of India, Department of Science and Technology, Govt. of India, Hathibarkala Estate, Dehradun Uttaranchal State.

Date of Acquisition	Satellite	Sensor	Spatial Resolution (in meters)	No. of Spectral Bands	No. of Spectral Bands Used	Wavelength (in micrometers)
1972	Landsat-2	MSS	80	4	4, 5, 6	0.50-0.60 | 0.60-0.07 | 0.70-0.80
1997	IRS-1C	LISS-3	23.5	4	2, 3, 4	0.52-0.59 | 0.62-0.68 | 0.77-0.86
1999	Landsat-7	ETM+	28.5	7	2, 3, 4	0.52-0.60 | 0.63-0.69 | 0.76-0.90
		PAN	14.5	1	8	0.52-0.90
2006	IRS-P6	LISS-3	23.5	4	2, 3, 4	0.52-0.59 | 0.62-0.68 | 0.77-0.86
2009	Landsat-5	TM	28.5	7	2, 3, 4	0.52-0.60 | 0.63-0.69 | 0.76-0.90

Notes: Image courtesy of the U.S. Geological Survey (USGS), United States of America; and the National Remote Sensing Centre (NRSC), Department of Space, Govt. of India, Hyderabad, India.

Table 1. Details of the multispectral satellite imagery.

In this context, the present study is also based on the latest data available from the different sources to achieve the specified objectives of the research. Such as the ancillary data available from the records of the Census of India 2001 and 2011 have been used in the study. So, the Primary Census Abstract, Final Population Total, Village and Town Directory and the Census Atlas – Faridabad District and Haryana State, 2011 have also been used in the present research. In addition to this, a number of development plans and policies, records, reports and documents published by the States and Central Government departments and ministries have also been used in the present study. All these published documents were collected from the Department of Urban Development, Ministry of Urban Development, Govt. of India, New Delhi.

5. METHODILOGY

The selected multi-source and multi-scale data have been used to ascertain the 3-D visualization of remote sensing images through digital processing and high precision DEM modeling. Digital Elevation Model (DEM) shows terrain factor, and images of surface textures cover the real situation. With ERDAS Imagine software support, a 3-D model has been prepared for the virtual three-dimensional urban landscape simulation by integrating the image data and the DEM perspective surface to overlay a variety of cultural as well as natural features information. The urban information was obtained by the spectral characteristics of remote sensing information extraction and information classification. GIS spatial analysis tools have been applied to combine three-dimensional images directly for the design of urban landscape environment. Moreover, the virtual reality technology is used to simulate three-dimensional flight, to preview urban landscape, and penetrate to simulation design on various aspects of urban landscape to greatly enhance the rationality and accuracy for 3-D modelling and city design for urban sprawl.

The remote sensing digital imagery were processed using the ERDAS Imagine and Lieca Photogrammetry Suits software's to build the 3-D model for urban landscape. The remote sensing data of the CartoSat-2 and IRS P-6 high resolution satellite imagery and the Landsat, ETM+ imagery were used of which details are given in the above Table 1. The images with 15-meter, 23.5-meter and 30-meter resolution were used after images fusion in order to improve the accuracy of remote sensing imagery. In addition to this, the geographical controlling points (GCP) and digital camera landscape photos have also been processed which were collected from the primary field survey for the Faridabad City. Secondly, the digital elevation model (DEM) is prepared based on contours extracted from the topographic sheets on the scale 1: 50,000 for the Faridabad City through scanning and digitalization process in vector data format. The contour data of the urban area is selected to compute and to construct the 3-D, digital elevation model (DEM) using the triangulated integrated network (TIN) algorithm of the ArcGIS software. Besides this, the Kriging interpolation method is applied to generate digital elevation model (DEM) based on the spot height elevation data. Henceforth, thirdly, the 3-D model is built to visualize urban landscape based on the remote sensing images and ancillary digital data with the help of image enhancement and processing, high-precision DEM generation, 3-D visualization of the urban landscape for the Faridabad City.

The 3-D digital urban modelling has also been generated using the CityEngine algorithm which was developed by the Environmental System Research Institute (ESRI), Redlands, California, United States. The software started incorporating the data georreferenced specialization logic interesting for a work in the direction of the urban landscape 3-D modelling. In addition to this, it is important to mention that the concepts of the regulation norms of the urban landscapes transformations and the more appropriate tools selection regarding the necessities of the planning and the landscape management have also been followed in 3-D generalization of the urban landscape model. Finally, the urban landscape preview has been constructed which allowed for model evaluation whether it is leading the city towards an urban expansion aligned with the logic of maintenance of the city's physical and socio-economic functions. The results showed and enlighten a great evolution within the urban scenario modelling, which is innovatively developed in 3-D urban landscape modelling.

6. RESULTS ANALYSES AND DISCUSSIONS

6.1 Growth Trends of Population

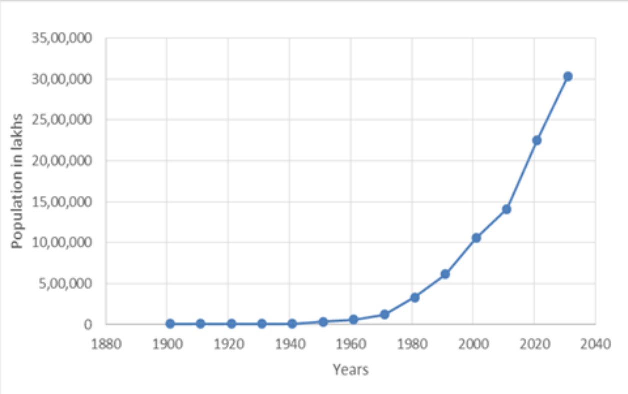
The Faridabad as a town is known to have been founded in 1607 A.D. with the objective of protecting the highway which passed through the town. It was having a population of 9,816 in 1901 which remained stagnated until 1931. Since then, there has been increasing concentration of population in the city as is evidenced by the Table 2. The entire Faridabad city is developed in a planned way on modern town planning lines based on the urban-industrial development. The Master Plan of Faridabad provides for 56 sectors out of which 27 are residential. Faridabad city is virtually a suburb of Delhi. It is located about 11.26 to 32.19 kms. away from Delhi, and 1.61 to 6.44 kms. from the Old Town of Faridabad. Faridabad

City spreads over an area of 207.88 sq. kms. on the western side of the Delhi-Mathura National Highway (NH-2). In addition to this, the growth trends and density of population for the Faridabad City is presented in the Table 2 and Figure 8 respectively. The Faridabad town was categorized as the Class-I City with a population of 6.25 lakhs in 1991.

During the initial periods of the 20th Century, the growth rate of population was highly fluctuated due to the occurrence of sever epidemic and natural calamities in the north western province of the India. For instance, there is found large variation in the growth of population in the Faridabad city during 1901-11 to 1911-21 as is evidenced by the Table 2 and Figure 7. Thereafter, the city population increased to three-fold 37,393 in 1951 as compared to 11,475 in 1941. Such sudden increase in population in 1951, as compared to the previous period was due to the huge influx of in-migrants during the partition of the country, India. Later on, the city expansion was based on the planning in which more emphasis was given for the urban-industrial development. It has resulted into more population concentration as the population more than doubled in 1971 as compared to 1961 as is evidenced by the Table 2 and Figure 6.

There has been very slow population growth rate until 1931-41 period and thereafter experienced a fast growth as it is registered of 225.36 per cent during 1941-51; because a large number of refugees were settled down in the town. Whereas the growth rate slowed down during 1951-61 period to 57.89 per cent. Thereafter, it was picked up during 1961-71 and 1971-81 which was more than 100 per cent as is evidenced by the Table 2. During the periods 1981-91 and 2001-2011 the growth rate was further decreased. However, overall it still signifies that the city has been growing to its full potential as it attained of 105.59 per cent of the assigned population as per of the National Capital Region (NCR) Plan – 2001. In fact, the city has the potential for absorbing the in-migrants population as it offers a variety of employment opportunities. The Faridabad City constitutes about 35.50 per cent of the urban population of Haryana Sub–Region of the Central National Capital Region of the NCR.

Year	Area (Km^2)	Population	% Growth	Density/Km^2
1901	-	9,816	-	-
1911	-	8,540	-13.00	-
1921	-	8,058	-5.64	-
1931	-	9,296	15.36	-
1941	-	11,475	23.44	-
1951	-	37,393	225.86	-
1961	25.75	59,039	57.89	2293
1971	25.75	1,22,817	108.03	4770
1981	178.24	3,30,864	169.40	1856
1991	178.24	6,17,717	86.70	3466
2001	198.75	10,55,938	70.94	5313
2011	207.88	14,14,050	33.91	6802
2021	207.88	22,54,233	59.42	10844
2031	207.88	30,28,501	34.35	14569

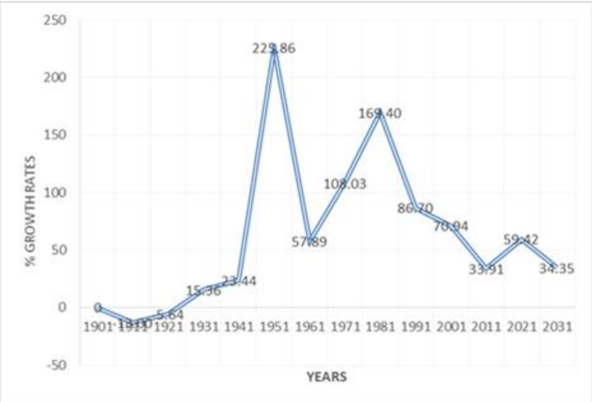


Source: COI (2001) Haryana - Provisional Population Totals, Paper 2 of 2001; and the Provisional Population Totals, Census of India 2011.

Table 2. Population Growth and Density. Figure 6. Trends of Population.

More recently, the Faridabad city became the only million+ population city in the state of Haryana as per the 2001 Census. In other words, the city population was increased to about 10.56 million persons in 2001, and become the first metropolitan city of the Delhi Metropolitan Area (DMA). In addition to this, the Faridabad City is identified as one of the important million+ population cities of the Central National Capital Region of the NCR. Besides this, in consideration with the moderate rate of population growth projection, as suggested in the NCR Regional Plan 2021, there was about 59.42 per cent and 34.35 per cent growth during the decade 2011-21 and 2021-31. The projected population estimates shows that the Faridabad City Population will be around 22.54 million by 2021 and around 30.28 million by 2031.

On the other hand, the Faridabad City accounted for the density of population of 2,293 in 1961 which was increased to 3,466 persons per sq. kms. in 1991 and further increased to 5,313 in 2001 as is evidenced by the Table 2 and Figure 8. The Faridabad city is functioning as an industrial hub for the adjoining areas as a whole. As a result, in 1992 the Faridabad City Authority (FCA) had announced an ambitious development plan to create necessary infrastructure and amenities to accommodate a population of 19.75 lakhs by 2011. The Faridabad city population will grow to around 37.10 lakhs in 2021 (JNNURM, 2006).



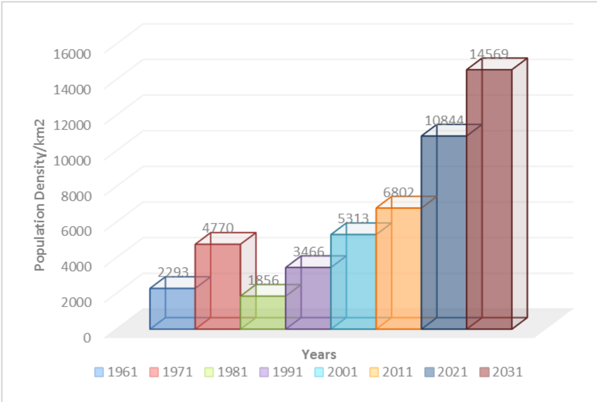


Figure 7. Population Growth: 1901-2031 Figure 8. Population Density: 1961-2031

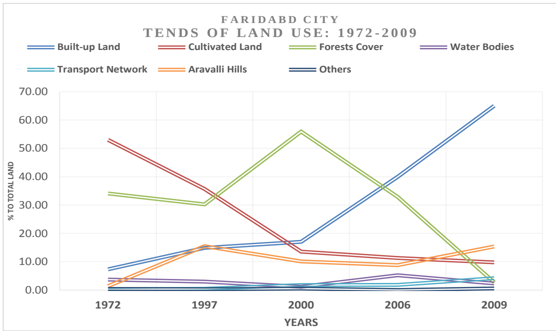
Recently, there has been observed that the areas within Faridabad district towards Gurgaon city have been on high demand for fast paced urban growth and economic development; because the real estate activity has picked-up considerably in the region. For instance, the private builders and colonizers have developed and are in the process of developing large number of apartments, housing complexes and institutions in this transitional zone between the Faridabad and Gurgaon cities. In other words, such expansion has also resulted into the institutional and recreation related developments in the transitional zone. More recently, there have been major commercial developments in the area in form of shopping malls and multiplexes etc. which are observed all along the NH-2 and its surroundings areas which is resulting into the large scale emergence of the built-up land which is responsible for the on-ward march of the process of urban sprawl in the area.

6.2 Spatio-Temporal Urban Land Transformation

6.2.1 Trends of Urban Land Use

The urban land use classification has been worked out using multi-spectral satellite imagery based on the supervised classification algorithm of the image process for the period of 37 years from 1972 to 2009 for the Faridabad City. The multispectral high-resolution satellite imagery were classified into seven thematic classes as the Built-up land, Cultivated land, Forests cover, Water bodies, Transportation network, Aravalli hills and others. The pixel-based land use classification computed for the five periods 1972, 1997, 2000, 2006 and 2009 is presented in the Table 3.

Classes	Years				
	1972	**1997**	**2000**	**2006**	**2009**
Built-up Land	7.31	14.90	17.02	39.94	65.02
Cultivated Land	53.00	35.64	13.56	11.32	9.77
Forests Cover	34.08	30.26	55.89	32.89	2.71
Water Bodies	3.67	3.00	1.14	5.21	2.33
Transport Network	0.20	0.43	1.79	1.85	4.21
Aravalli Hills	1.36	15.50	10.11	8.79	15.39
Others	0.38	0.27	0.48	0.02	0.57
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**



Source: Computed & Tabulated from the IRS and Landsat Satellites Imagery.

Table 3. Urban Land Use Classification Figure 9. Trends of Land Use: 1972-09

It is evidenced from the above Table 3 that the cultivated land comprises the largest proportion of 53.00 per cent of the total geographical area in 1972. Over the periods its proportion has been declined significantly, particularly from 1997 onwards from 35.64 per cent to 13.56 per cent in 2000 and 11.32 per cent and 9.77 per cent in 2006 and 2009 respectively. In other words, the cultivated land has decreased almost to 5-times from 1972 to 2009, due to the expansion of the built-up area, as is evidenced by the Table 3 and Figure 9.

On the other hand, the land use classification result bought out significant facts as the proportion of built-up land has continuously been increased over the periods such as it is increased for about more than nine-fold from 7.31 per cent in 1972 to 65.02 per cent in 2009. The built-up land comprises by both the compact and sparse settlements. This is due to the stiff competition from the twin cities of Gurgaon and NOIDA cities of the Central NCR Region. In addition to this, during the recent past, there was massive increase in the industrial land which witnessed a sharp decrease in the land under utilities and public/semipublic uses. This suggests that importance was given to only industrial development. This has resulted into the unbalanced growth and is accounted as one of the factors responsible for present stagnation of the Faridabad City.

In addition to this, the area under forests cover has increased from 34.08 per cent in 1972 to

55.89 per cent in 2000. It is due to the green cover regeneration and plantation of trees for development of recreation facilities in and around the built-up areas of the Faridabad City over the periods. Thereafter, the forests cover is decreased to 32.89 per cent in 2006 to 2.71 per cent in 2009. This is due to the expansion of the built-up land during the recent times. Whereas the water bodies comprises by the Yamuna River and the lakes and ponds which together accounted for 3.67 per cent in 2007 of the total geographical area which has been further remained stagnated over the periods as is evidenced by the Table 3. Whereas there is an increase in the land under transportation. The transport network area proportion has been marginally increased from 1972 to 4.21 per cent in 2009. Besides this, a negligible proportion of area is accounted by the other land use class which comprises by the wastelands like barren lands widespread over the small areas in the surrounding vicinity of the Faridabad City, as is evidenced by the Table 3.

With the increase in population, the residential areas have seen tremendous increase, however, the pace of development could not match the provisions for both physical and social infrastructure and services as per the requirement of the growing population. It has been observed in the context of urban land use pattern that there is exorbitant increase in land prices which has led to the development of multi-storied apartments and residential units. The decade 2001-11 has also witnessed the decline of developed industrial areas due to economic liberalization and impingement of other uses on industrial areas have increased alarmingly with invasion of development of commercial activities like Shopping Malls and Multiplexes etc. Moreover, with the increase of privatization of education, the educational and technical institutions have also sprung up all over the Faridabad. Such educational institutions have largely came up on land acquired from agricultural use and some industrial areas which have been converted into the usage for educational and institutional areas development over the recent periods.

6.3 Spatial Patterns of Urban Landscape

The Faridabad City has a clearly defined linear shape due to its evolution along the linear and parallel transportation corridors. There are large industrial plots lined-up along both sides of these transport corridors. The area west of the railway line is primarily industrial. When industrialization began, first the least productive lands under agriculture were lost to the industries. The area surrounding the Agra Canal was agriculturally more productive and survived initially. As the need for urban housing increased, the land between the canal and the railway line was developed as residential. So, the only agricultural lands left are the ones to the east of the Agra Canal. The area east to the Agra Canal is presently being developed as industrial sectors as is evidenced by the Figure 10.

The Faridabad City is a sprawling home for industries, which are trying to match the development in the neighboring cities of Gurgaon, NOIDA and Greater NOIDA of the Central NCR Region. More recently, with the moving away of number of mother industrial units, the growth is not what it should have been in the Faridabad city. Although the traditional units are still continuing, the city has not been able to attract the hi-tech environment-friendly industries as electronics etc. in comparison to the adjoining NOIDA, Grater NOIDA and Gurgaon cities of the Central NCR Region.

Figure 10. SOI Topo: 1992

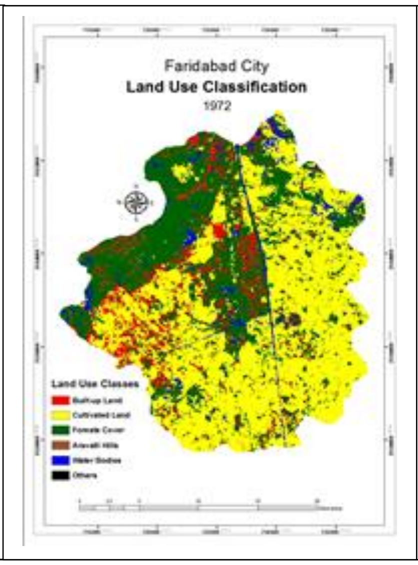


Figure 11. Land Use: 1972

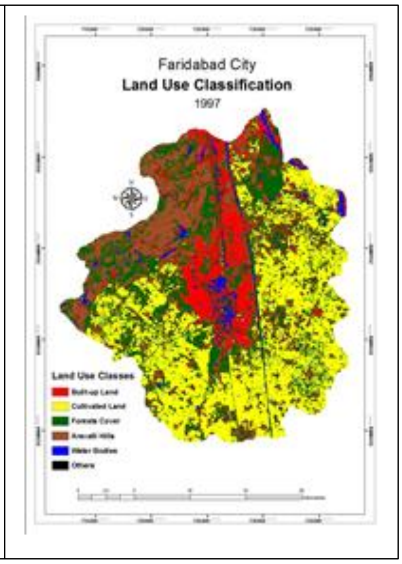


Figure 12. Land Use: 1997

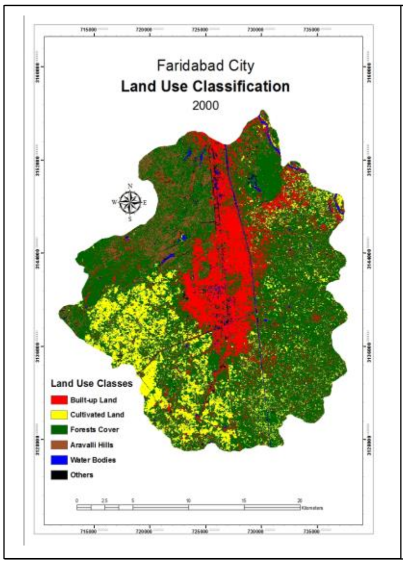


Figure 13. Land Use: 2000

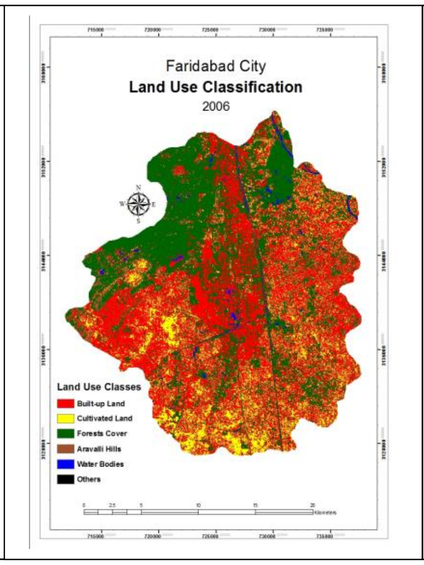


Figure 14. Land Use: 2006

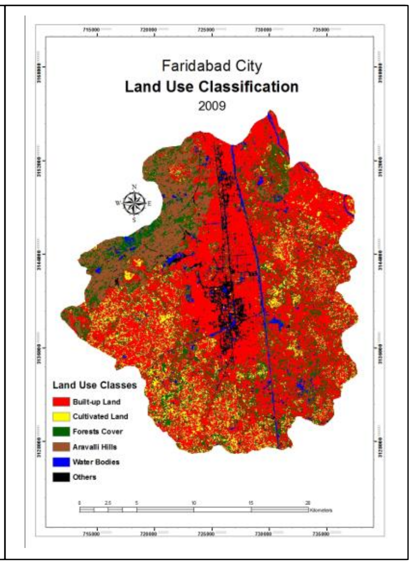


Figure 15. Land Use: 2009

So, it is noteworthy to mention that there has been occurred a continuous urban sprawl adjacent to the Faridabad City as is evidenced by the Figure 11, 12, 13, 14 and 15. There are number of factors contributing to the process of urban sprawl among them the strategic location and good connectivity is one. The city is located about 32 km. from Delhi, the

National Capital, to the south of it. It acts as a gateway to Delhi from many parts of western Uttar Pradesh, eastern Rajasthan, Madhya Pradesh, Maharashtra and Gujarat. Good connectivity in the form of NH-2 and the Delhi-Ballabgarh railway line led to its growth as an urban center. Its location and connectivity make it an economically and commercially integral part of the NCR region. Secondly, the Faridabad town was declared as ring town in 1962. The Delhi Master Plan 1962 identifies Faridabad as one of the 5 Ring Towns to share the population burden of Delhi. This declaration as a Ring Town encouraged urban development in Faridabad.

Thirdly, the industrial growth induced in-migration is responsible to the large scale urban sprawl. Because, the rapid industrialization of the city led to a high rate of in-migration to the city in search of employment. This led to population concentration resulting into the high population density. These highly populated areas needs to be urbanized. Fourthly, the growing population pressure in Delhi resulted in high real estate prices and housing shortage, therefore there is a need to provide more and cheaper accommodation in the more urban areas. Faridabad City is providing better accommodation due to its proximity to the Delhi metropolis for the working population. The urban sprawl has largely been responsible in the transformation of physical landscape which is creating socio-economic and environmental concerns at large. Therefore, the urban expansions are to be planned over the non-fertile and degraded land for sustainable urban and environment development which are the most important concerns for the new urban sprawling areas adjoining to the Faridabad City.

6.4 3-Dimensional Urban landscape

The 3-D urban landscape model has been generated by integrating the remote sensing imagery and the digital elevation model perspective surface by overlay of physical and socio-economic features. The urban landscape model for the Faridabad City and its surrounding urban environment is presented in the Figure 16. Whereas the modern urban buildings developed more recently due to the impacts of globalization on the regional economy which has been responsible at a large scale transformation in the urban landscape of the Faridabad City as it is presented and evidenced through the Figures 17 and 18a, b, c, & d, collected from the field.

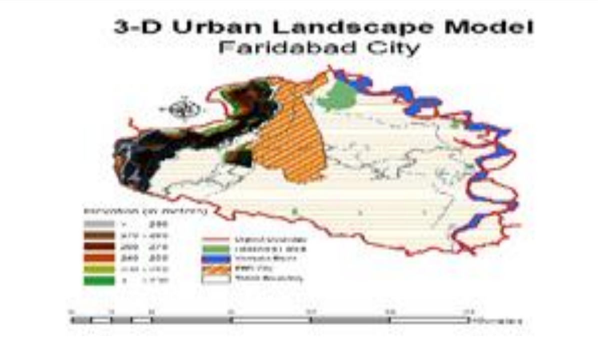


Figure 16. Urban Landscape Model

Figure 17. Urban Building Models

Figure 18a, b, c & d. Urban Building Models Impacts on Physical Landscape

The manual digitization process is used for capturing the outline of the buildings. This process too can be automated as the derived normalized digital surface model (DSM) which represents detection of buildings fairly well. Refinement of edges with canny operator improves the edge localization. Geometrically constrained image matching procedure is successful in finding conjugate points on edges. The system is primarily designed for remote sensing images, and the available resolution of Cartosat-2 and commercially available images permits extraction and representation of man-made structures. Detail roof reconstruction and representing complex roof structure may not be possible. A good photogrammetric framework provides the desired accuracy. However, sustainable urban development is the need of the hour which can be achieved by the Aravalli Ridge forest conservation, protection of land resources, controlling climate change and maintaining and conserving the biological diversity of the natural eco-regions, in order to avoid the urban landscape environmental degradation, at the regional and national and the global level.

7. CONCLUSIONS

The 3-D urban landscape model represent the area under consideration fairly well and can be used for various planning and other urban development applications. Although the Faridabad city has locational advantages being very close to the south Delhi; but it is facing numerous problems, which may hinder its all-round urban development. The city is experiencing serious traffic bottleneck on the highway as inter-state traffic passes through this stretch of the transportation network. Further, within the city, most of the arterial roads are congested. The power and water supply is not very good and has not kept pace with the growing population and demand. The pollution in the city of Faridabad has broken all records. The fact is that the both air and water have been polluted to an alarming extent. Hence, the area along the highways are very much vulnerable to unauthorized development and may come in the way of planned development thereby putting enormous constraints on infrastructure development.

The Faridabad city is slightly in disadvantageous position due to spread of the undulating topography of the Aravalli Hills, unlike the flat topography of Ghaziabad, NOIDA and Grater NOIDA cities of the Central NCR Region. So, the urban development authority has formulated the vision for a planned urban development of the Faridabad city. The Faridabad City Corporation is creating state-of-the-art infrastructure by providing incentive and encouragement to the investors both the public and private for creation of the quality infrastructure. At present, the city provides fair level of services. The 3-D urban landscape vision reflects the city's growth outlook both in terms of local potential, and to some extent its strategic positioning in the NCR region, especially near to the Delhi and also within the State's development framework. However, in order to achieve the overall vision for urban development, there should be balance in the priorities between growth related investments, poverty focused interventions and city management reforms for the urban development.

ACKNOWLEDGEMENT

I acknowledge for the financial support provided for the on-going research project on GeoVisualisation of Million+ Cities … by the Indian Council of Social Science Research (ICSSR), Ministry of Human Resource Development (MoHRD), New Delhi. Especially, my sincere appreciations to the Prof. S.K. Thorat, Chairman, ICSSR (MoHRD), New Delhi for full support to carry out this research project. The present research paper is the recent outcome of the project.

REFERENCES

Baillard, C., C. Schmid, A. Zisserman, and A. Fitzgibbon (1999) "Automatic Line Matching and 3D-Reconstruction from Multiple Views", *International Archives of Photogrammetry and Remote Sensing*, Vol. 32, Part 3-2, W5, pp. 69-80.

Batty, M. et al., (2001) "Visualizing the City: Communicating Urban Design to Planners and Decision-Makers," *Planning Support Systems*, R. Brail and R. Klosterman, eds., Environmental Systems Research Institute (ESRI) Press and Center for Urban Policy Research, Rutgers University.

Cho, Jaeseong (2005) “Urban Planning and Urban Sprawl in Korea”, *Urban Policy and Research*, Vol. 23, No. 2, pp. 203-218.

Couch, Chris, et al. (2005) “Decline and Sprawl: An Evolving Type of Urban Development - Observed in Liverpool and Leipzig”, *European Planning Studies*, Vol. 13, No. 1, pp. 117-36.

Fan, H. C. and L. Q. Meng (2012) “A three-step approach of simplifying 3D buildings modeled by CityGML”, *International Journal of Geographical Information Science*, Vol. 26, pp. 1091-1107.

Fraser, C. S., E. Baltsavias, and A. Gruen (2002) “Processing of IKONOS Imagery for Submetre 3D-Positioning and Building Extraction”, *ISPRS Journal of Photogrammetry & Remote Sensing*, Vol. 56, pp. 177-194.

Geibel R. and U. Stilla (2000) “Segmentation of Laser-altimeter Data for Building Reconstruction: Comparison of Different Procedures”, *International Archives of Photogrammetry and Remote Sensing*. Vol. 33, Part B3, pp. 326-334.

Giacomelli, A. (2006) “Integration of GIS and Simulation Models”, in M. Campagna, eds., *GIS for sustainable development*. CRC Press, pp.181 – 192.

Gruen A, Xinhua Wang, (1999) “Cyber City Modeler, A Tool for Interactive 3-D City Model Generation”, *German Photogrammetry Week*, Stuttgart, Germany.

Hartley R. and A. Zisserman (2004) “*Multiple View Geometry in Computer Vision”,* 2nd edition, Cambridge University Press.

Jat, M. K., P.K. Garg and D. Khare (2008) “Modelling of Urban Growth Using Spatial Analysis Techniques: A Case Study of Ajmer city (India)”, *International Journal of Remote Sensing*, Vol. 29, No. 2, pp. 543-567.

JUNNRM (2006) *Faridabad – City Development Plan 2006-12*, Jawaharlal Nehru National Urban Renewal Mission, Municipal Corporation of Faridabad, Haryana.

Kerry, M and K. Amnon, (2002) “Integration of Laser-Derived DSMs and Matched Image Edges for Generating an Accurate Surface Model,” *Journal of Photogrammetry and Remote Sensing*, Vol. 56, No. 3, pp. 167-176.

Mao, B., Y. F. Ban and L. Harrie (2011) “A Multiple Representation Data Structure for Dynamic Visualisation of Generalised 3D City Models”, *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol. 66, pp. 198-208.

Pollefeys, M. et al., (2003) “3D Recording for Archaeological Fieldwork”, *IEEE Computer Graphics and Applications*, Vol. 23, No. 3, pp. 20-27.

Shiode, N. (2001) “3D Urban Models: Recent Developments in the Digital Modeling of Urban Environments in Three-Dimensions,” *GeoJournal*, Vol. 52, No. 3, pp. 263-269.

Siedentop, S. and Fina, S. (2010) “Monitoring Urban Sprawl in Germany: Towards a GIS-Based Measurement and Assessment Approach’, *Journal of Land Use Science*, Vol. 5, No. 2, pp. 73- 104.

Thomas, K., Manfred L. and Peter Reintarz (2008) “Generation of Coarse 3-D Models of Urban Areas from High Resolution Stereo Satellite Images”, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVII, part B1, pp. 1091-1098.

Vosselman G, and D. Dijkman (2001) “3D Building Model Reconstruction from Point Clouds and Ground Plans”, *International Archives of Photogrammetry and Remote Sensing*, Vol. XXXIV, Part B2/W4, pp. 456-465.

BIOGRAPHICAL NOTES

CONTACTS

Title	:	Dr. Madan Mohan, Assistant Professor of Geography & Project Director, ICSSR (MoHRD), ND
Institution	:	JMI Central University
Address	:	Department of Geography, Faculty of Natural Sciences
City	:	New Delhi
COUNTRY	:	INDIA
Tel.	:	+091 011 2698 1717-3312
Fax	:	+091 011 2698 0229
Email	:	drmdnmohan@gmail.com
Web site	:	www://jmi.ac.in