Ankit Gupta¹, Sarita Swain², Maya Kumari ³  
¹,² Post Graduate Student, Amity Institute of Geo-Informatics & Remote Sensing  
³ Assistant Professor, Amity School of Natural Resources & Sustainable Development  
Amity University Uttar Pradesh, Sector – 125, Noida-201301, India

Abstract:  
Rapid development along with demographic change is the most direct influencing factors on urbanization and urban change. Urbanization further cause land use and land cover change in any area. Indian cities have not been able to cope with the pressure of industrial development resulting inadequate urban infrastructure. City planning is becoming an important concern to modern India. The integration of Geographical Information System and Remote Sensing acts as an effective tool for estimating urban growth and modeling in the recent years. The objective of this study is to identify and analyse the urban growth of Indore, the commercial capital of Madhya Pradesh state of India. Study area is situated on the western section of Malwa plateau, on the banks of the Khan River and Saraswati River. Latest boundary of the city, demarcated by Municipal Corporation of Indore has been used as base boundary for this study, which includes all extended and substantial parts of the city and nearby towns. Built-up area is marked by using the base boundary on satellite imagery of two different time periods. Index-based Built-up Index (IBI), is a normalized difference index, has been used for the extraction of built-up land features with efficient use of ArcGIS software. Pan sharpened satellite imagery of Landsat ETM+ and Landsat OLI_TIRS sensor has been used for the model. Pre-processing of satellite imagery has been done to obtain high quality information from remote sensors. Additionally, high resolution imagery has been used for the further assessment of urban growth. The study demonstrate that Indore had sprawled urban growth during the period 2005 to 2014. It has been found from the study that Index-based Built-up Index (IBI) is a good method to determine the dispersion of built-up land features in the city, within the slight limitation of model. The results of the present work conclude that Remote Sensing and GIS techniques can be efficiently used in estimation and analysing the urban growth trends with respect to the adjoining urban areas.  

Keywords: Urban Growth in Indore, Index-based Built-up Index, ArcGIS, Remote Sensing & GIS.

About the Author:  
MR. ANKIT GUPTA, M.Tech. (Pursuing)  
Ankit Gupta received his B.E. (Civil Engg.) in 2013 from RGPV – Bhopal, India and is a final year M.Tech. (GIS & RS) student at AIGIRS, Amity University – Noida, India. His research interest includes Hydrological Modelling, Snow & Flood Hydrology, Water Management Systems and Urban Planning. For additional details please refer to https://amity.academia.edu/AnkitGupta  
E mail ID: ankitgupta18may@gmail.com  
Contact No: +91 – 94257 58922

MS. SARITA SWAIN, M.Sc. (Pursuing)  
Sarita Swain, graduated in Geography (Hons.) from KNC – Delhi University and is a final year M.Sc. (GIS & RS) student at AIGIRS, Amity University – Noida, India. Her area of interest includes Climatology, Oceanography, Geography and Urban Studies.  
E mail ID: saritaswain00@gmail.com  
Contact No: +91 – 95609 23302

MS. MAYA KUMARI, Ph.D. (Pursuing)  
E mail ID: mkumar10@amity.edu  
Contact No: +91 – 98736 58891
Introduction

Urbanization is the process through which the productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost (Pathan et al., 1989, 1991; Kumar et al., 2007). Ever growing population and urbanization leads to over utilization of the resources and increase in human settlement with irregular frequency, resulting in difficult urban planning and management plans. Urban growth has resulted in the conversion of land for urban uses without any systematic development plan and without a corresponding investment in infrastructure. Taking this into account for future urban development and human infrastructure, local governing bodies should understand the trend of urban growth.

Thus to know about the urban trend of a city, long time series data of past and present years must be monitored. The main objective of this study was to do urban growth trend analysis to support improved urban management plan, which can be used for understanding the increase of human settlements and future development & management actions. Remote sensing and GIS techniques have already shown their importance in mapping urban land use/land cover, urban growth trends and to monitor the chances in land use/land cover (Pathan et al., 1993, 2004; Donnay et al., 2001). This method has proved to be a cost effective and technologically sound method of analysing urban sprawl, monitoring and planning purposes, unlike conventional surveying and mapping techniques (Jat et al., 2008; Haack and Rafter, 2006).

Remote sensing data, along with increased resolution from satellite platforms, makes an impact on urban growth trend analysis which involves many different methods including index based models. Index-based Built-up Index (IBI) is proposed for the rapid extraction of built-up land features in satellite imagery. The IBI was used for the very first time by H. Xu, by taking thematic index-derived bands rather than by using original image bands. The three different thematic indices has been used in constructing the IBI viz., Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI) and Normalized Difference Built-up Index (NDBI), which together represent the three major components of vegetation, water and built-up land, respectively (Xu et al., 2008).

Study Area

Study area is municipal extent of Indore district, situated on the Malwa Plateau (historically known as Deccan plateau) at an altitude of 553 m above sea level on the banks of two small rivers, the Khan and the Saraswati. Indore district is bounded in the north by Ujjain district, in the south by Khandwa district, in the east by Dewas district and in the west by Dhar district. It is a tier 2 city and the largest city of the Indian state of Madhya Pradesh ranked 14th largest city in India. Indore city has recorded subsequent increase in population from 5.60 lakh, 8.29 lakh, 10.91 lakh, 14.74 lakh and 19.60 lakh for 1971, 1981, 1991, 2001 and 2011 years respectively.

Latest boundary of the city, demarcated by Municipal Corporation of Indore has been used as base boundary for this study, which includes all extended and substantial parts of the city & nearby towns and extends over an area of 293.92 km², lies between the geographical extent of north 22.625° to 22.875° latitude and east 75.75° to 75.9375° longitude.
Methodology

Based upon the discourse, a methodology has been worked out to conduct the spatial-temporal analysis to envisage the growth trend of human settlements from 2005 – 2014. This study concentrates mainly upon the model which is derived from three different indices viz., Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI) and Normalized Difference Built-up Index (NDBI), highly used to represent the three major land use classes. ArcGIS 10.1 software has been extensively used for this purpose. For extraction of land features, pan sharpened multispectral satellite imagery of Landsat 7 (ETM+ Sensor) & Landsat 8 (OLI-TIRS Sensor) of resolution 15 m has been used for two different years 2005 & 2014, respectively. Images has been stacked by using composite band tool of raster processing of ArcGIS 10.1. Pre-processing of satellite imagery has been done to obtain high quality information from remote sensors, which includes focal analysis as well as other extensions of Image Processing Software for atmospheric correction.

Feature extraction has been done by using raster calculator or model builder of ArcGIS 10.1 for the below mentioned formulae –

\[
SAVI = \frac{(NIR - Red) (1 + l)}{(NIR + Red + l)}
\]

\[
MNDWI = \frac{(Green - MIR)}{(Green + MIR)}
\]

\[
NDBI = \frac{(MIR - NIR)}{(MIR + NIR)}
\]

Where NIR is a near infrared band such as ETM+_4 & OLI_5, Red is a red band such as ETM+_3 & OLI_4, Green is a green band such as ETM+ 2 & OLI_3, MIR is a middle infrared band such as ETM+_5 & OLI_6 and l is a correction factor whose value ranges from 0 – 1, depends upon the plant densities. If there is very high plant densities then value of l will be zero and vice versa. NDVI is also a good method for extraction of vegetation cover, but it is insensitive in detecting the vegetation in low plant covered areas, which are normally seen in urban areas. This is the only one reason to choose SAVI instead of the NDVI because it is more sensitive in detecting low-plant covered areas in urban area. The SAVI can work in the area with plant cover as low as 15%, while the NDVI can only work effectively in the area with plant cover above 30% (Ray 2006).

After extracting the required features in raster for all the above indices, it is time to do the final extraction by Index-based Built-up Index by using two below stated formulae –

\[
IBI = \frac{[NDBI - (SAVI + MNDWI)/2]}{[NDBI + (SAVI + MNDWI)/2]}
\]

\[
IBI = \frac{[(2 MIR/(MIR + NIR)) - ((NIR/(NIR + Red)) + (Green/(Green + MIR))]}{[(2 MIR/(MIR + NIR)) + ((NIR/(NIR + Red)) + (Green/(Green + MIR))]}]
\]

The above equation which have spectral bands in the formula can be directly used in raster calculator of ArcGIS software, in case we are trying to extract IBI by using NDVI instead of SAVI.

Results and Discussion

All the indices viz., SAVI, MNDWI & NDBI results in the extraction of vegetation, water and built-up landform from the study area, somewhat limited in built-up feature extraction as NDBI allow to extract little soil and barren land in it due to same reflectance as of built-up. This limitation is overcome by Index-based Built-up index which shows pure dense and sparse built-up feature. The built-up land is also mixed with soil and vegetation cover which were extracted through applying different indices. It has been clearly observed from index maps that the bounded area is a built-up dominated area followed by an agricultural land and water bodies which contribute to the significant economic importance of the area. It has been found that pure urban built-up land has increased between the years 2005 to 2014. Index-based Built-up Index enhanced the built-up land feature with a light grey to white tone, while vegetation and water are considerably suppressed as background noise with a dark-grey to black shade. To extract the urban built-up land features from the IBI output, a threshold value ranging from -0.11 to -0.01 and from -0.099 to -0.009 for 2005 and 2014 respectively, has been manually determined for both the years. Additionally, high resolution imagery
has been downloaded, mosaicked and clipped to cover the municipal area extent of Indore city and has been used for the further assessment of built-up land features for urban growth.

Fig: 2 – SAVI 2005

Fig: 3 – SAVI 2014

Fig: 4 – MNDWI 2005

Fig 5: MNDWI 2014

Fig 6: NDBI 2005

Fig 7: NDBI 2014

*SAVI = Soil Adjusted Vegetation Index
*MNDWI = Modified Normalized Difference Water Index
*NDBI = Normalized Difference Built-up Index
*IBI* = Index-based Built-up Index

*Satellite Imagery 2005* = Landsat 7 ETM+ Sensor (15 m) [Pan-sharpened]

*Satellite Imagery 2014* = Landsat 8 OLI_TIRS Sensor (15 m) [Pan-sharpened]
Built-up land is divided into three categories with highly dense, medially dense and less dense. Highly dense built-up land indicates unplanned settlements while medium and low dense represent planned settlements. The transportation network serves as the mode for settlement development. The model setup here is able to enhance the built-up land feature easily because the subtraction of the SAVI band which contains high vegetation pixels and the MNDWI band which contains high water pixels from the NDBI band which already contains high built-up pixels in it, will result in high built-up land pixels only.

Over the period of time Indore city is experiencing increase in residential, commercial, institutional areas. Residential segregation is experienced because of three reasons; firstly, due to the growth of the city and the evolution of housing areas; secondly, the development of residential segregation which was a result of individual locational decisions within the context of a rapidly expanding urban population; thirdly, the process of residential differentiation which was also influenced by the development of commercial and industrial areas within the city that imposed constraints on the nature of residential development. The operation and outcomes of the processes of residential segregation is a major factor in urban change. Earlier the core areas were urbanized. Now the core areas are getting depopulated and converted into commercial area. The growth of urban areas is depicted at the outer core and periphery. Indore has significant open areas which will further attract urban growth.

Summary & Conclusion

In present study an attempt has been made to extract the built-up land features, using Index based model. For analyzing the three major components viz., vegetation, water bodies and built-up land; Soil Adjusted Vegetation Index, Modified Normalized Difference Water Index and Normalized Difference Built-up Index were used, respectively with efficient use of ArcGIS software. The values of Index-based Built-up Index shows that Indore city is experiencing the urban sprawl between 2005 and 2014.

Compact settlements in the center are now expanding towards the municipal boundaries. The growth is found to be prominent in the north, northeast, south and south east directions. It was observed that settlement growth is happening within the municipal limits of the city along the transportation networks. But in coming years, the municipal extent of the city will surely increase with increase in population and merging of nearby towns in it. Rapid residential and commercial development has caused encroachment on productive agricultural and fallow land. The rate of urban growth and population is quite high and requires proper management of both human and natural resources to attain sustainable development.

We can conclude from this study that freely available geo-spatial data and ArcGIS software can be used in extraction of various land features with the help of Index based models and for analyzing the urban growth trend and urban sprawl. Index-based Built-up Index is a very useful model for evaluating urban area and productivity of different land features. The model indicates that mixed trend of urbanization is analyzed from study area. Suburbanization and Exurbanization is prominent in Indore city because inner ring or commuter belt is growing at the expense of the urban core. An improved model is realistic but due to the non-uniqueness of spectral reflectance of features over a different period of time, there will never be one best outcome. The work presented here is only a humble first step; further review of studies, analysis of data and image processing, experimental work and advance Remote Sensing and GIS technologies with expert knowledge from Civil Engineers, Geographers and Geotechnical Engineers.

Acknowledgement

Authors would like to thank Director Dr. Madhulika Singh and Assistant Professor Dr. Prafull Singh, AIGIRS, Amity University (Noida), also Professor. B.K.P. Sinha, Advisor, ASNRSD, Amity University (Noida), for their masterly guidance and timely encouragement and Aamir Lone for his very generous assistance & valuable inputs in this work.
References