AUTOMATIC DETECTION OF URBAN SPRAWLS BY EXTRACTION OF BUILTUP AREA OVER HYDERABAD CITY

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ABSTRACT

Today, urban growth is a multidimensional spatial and population process in which cities and urban settlements are considered as centers of population focus owing to their specific economic and social features, which form a vital component in the development of human societies. The analysis of urban growth using spatial and attribute data of the past and present is regarded as one of the basic requirements of urban geographical studies, future planning as well as the establishment of political policies for urban development. Mapping, modeling, and measurements of urban growth can be analyzed using GIS and remote sensing-based statistical models. In the present study, the aerial photos and satellite images of 5 periods, were used to determine the process of expansion of the urban boundary of Bandar Abbas. Here, in order to identify the process of expanding urban boundaries with time, the circular administrative border of the city of Bandar Abbas, was divided into 32 different geographical directions.

Here, Pearson's Chi-square distribution as well as Shannon's entropy is used in calculating the degree of freedom and the degree of sprawl for the analysis of growth and development of the cities. In addition to these models, the degree-of-goodness was also used for combining these models in the measurement and determination of urban growth. In this way, it was found that the city of Bandar Abbas has a high degree of freedom and degree of sprawl, and a negative degree of goodness in urban growth. Regardless of the results achieved, the current study indicates the capability of aerial photos and satellite imagery in the effectiveness of spatio-statistical models of urban geographical studies.

INTRODUCTION

Cities in India are experiencing massive urbanization apart from economic growth, a direct result of globalization, bringing about drastic changes in population, ecology, social and economic aspects. Aristotle once said that people come together in cities to live, however they remain together to live the good life. Cities have become junctions in the flows of people, freight, finance and information and no longer a conducive place for people to live and work. The topic of urbanization has evinced a lot of interest among researchers including experts in the field of ecology, sociology, civil engineering apart from city planners, policy makers and administrators. Urbanization results in sprawl which is the scattered development of peripheral rural areas of the city.

Uneven development usually alongside the highways or in the peri-urban region surrounding the city resulting in destruction of farm lands and eco-sensitive habitats is referred to as sprawl. Sprawl may also be characterized as fragmented spaces consuming excess land, lower densities with less choice of transport and types of housing. Urban sprawl being a complex phenomenon has no measurable or specific definition. Sprawl being a multi-dimensional phenomenon can cause a lot of confusion. Urban expansion or spatial growth exceeding growth in population in metropolitan areas may also be considered as sprawl. Urban sprawl is however considered a negative outcome of urban growth, which is nothing but the increase in population and size of an urban area.

The prominent effect of urban sprawl is felt on water bodies, agricultural land that is productive and thereby changing and creating a new hydrological environment. Urban sprawl can be mapped in order to identify areas facing threats in the form of degradation of environmental and natural resources and also to suggest possible directions of future growth. As a phenomenon of land use, American literatures have characterized sprawl as

- Consuming excess land
- Lesser choice in ways to travel
- Lower peripheral densities as compared to city centres
- Scattered appearance due to wide open spaces and gaps in development
- Single storey development
- Very few community centres and public spaces
- Shortage of choice in housing types

With people moving to cities in search of better opportunities, especially in developing countries, sprawl happens largely out of necessity. Urban ecosystems are intrinsically linked to humans living in a group as social beings, which eventually led to the initial settlements, forming villages, towns and finally cities. Urban ecosystems, a result of unprecedented growth in population, migration and rapid industrialization have been transformed into a social, political, cultural and economic hub. A holistic approach is needed while dealing with the various processes involved in the formation of these ecosystems.

Scientific and technological innovations play a major role in driving the urban ecosystems and hence need to be considered in the prevailing conditions. Rapid urbanization coupled with changes in lifestyle influence material and energy cycles in the urban ecosystem. Sustainable development is the need of the hour and it can be defined as "the development that meets current needs, without compromising the ability of future generations to meet their needs".

Rapid urbanization and population growth, particularly in developing countries, are expected to increase pressure on agricultural production by expanding into croplands, competing for resources, and leading to loss of biodiversity. By 2050, China, India, and Nigeria alone are expected to add about 900 million urban residents in the megacities of these countries. Managing urban expansion in the future is critical for ensuring agricultural growth and food security, while also providing common amenities such as housing, water, and employment for the growing population. Four of India's cities, which currently have 5–10 million inhabitants, are projected to become megacities (population of >10 million) in the coming years, with a total of seven megacities projected in the country by 2030.

LITERATURE REVIEW

Gumma, M.K.; Thenkabail, P.S.; Maunahan, A.; Islam, S.; Nelson, A. (2014) This research paper analyzed urban spatial pattern and trend of urban growth in Kolkata urban agglomeration, India using urban sprawl matrix during 1990–2000 & 2000–2015. Seven urban classes viz. urban primary core, urban secondary core, sub urban fringe, scatter settlement, urban open space, non-urban area and water body were chosen for analyzing the magnitude and direction of urban expansion. Landsat TM and Landsat 8 OLI satellite data for 1990, 2000 and 2015 were used for assessing land use land cover change, urban land transformation, urban spatial pattern and trend in urban growth. The study revealed that the built up area has increased drastically. This increase in built up area is attributed to decrease in prime agricultural land and open space. The land use/land cover change matrix showed that built up area has expanded by 16.6% during 1990–2000 and 24.5% during 2000–2015.

Angel, S., Parent, J. and Civco, D. (2007) The urban expansion is a result of large share of land transformation from agricultural land at the rate of 153.1% during 1990–2000 and 66.9% during 2000–

2015. Analysis of trend of urban growth in 38 municipalities and 3 municipal corporations of Kolkata urban agglomeration revealed that municipalities located along the east bank of river Hooghly and surrounded by Kolkata Municipal Corporation have experienced a very fast urban growth. Urban primary and secondary cores have increased in newly developed municipalities. Sub urban fringe has increased in the municipalities located away from river Hooghly while open space has decreased in all the old municipalities. Pattern of land transformation and trend of urban growth of Kolkata urban agglomeration for the last 25 years may help in guiding future planning and policy-making for the urban agglomeration. Integrated approach of remote sensing, GIS and urban sprawl matrix has proved instrumental in analyzing urban expansion and identifying priority areas for effectives planning and management.

Barnes, K.B., Morgan III, J.M., Roberge, M.C. and Lowe, S., (2001) Many Indian capitals are rapidly becoming megacities due to industrialization and rural–urban emigration. Land use within city boundaries has changed dynamically, accommodating development while replacing traditional land-use patterns. Using Landsat-8 and IRS-P6 data, this study investigated land-use changes in urban and peri-urban Hyderabad and their influence on land-use and land-cover. Advanced methods, such as spectral matching techniques with ground information were deployed in the analysis. From 2005 to 2016, the wastewater-irrigated area adjacent to the Musi river increased from 15,553 to 20,573 hectares, with concurrent expansion of the city boundaries from 38,863 to 80,111 hectares. Opportunistic shifts in land-use, especially related to wastewater-irrigated agriculture, emerged in response to growing demand for fresh vegetables and urban livestock feed, and to easy access to markets due to the city's expansion. Validation performed on the land-use maps developed revealed 80–85% accuracy.

Fan, C.; Myint, S.W.; Rey, S.J.; Li, W. (2017) The process of land use change and urban sprawl has been considered as a prominent characteristic of urban development. This study aims to investigate urban growth process in Bandar Abbas city, Iran, focusing on urban sprawl and land use change during 1956–2012. To calculate urban sprawl and land use changes, aerial photos and satellite images are utilized in different time spans. The results demonstrate that urban region area has changed from 403.77 to 4959.59 hectares between 1956 and 2012. Moreover, the population has increased more than 30 times in last six decades. The major part of population growth is related to migration from other parts the country to Bandar Abbas city. Considering the speed of urban sprawl growth rate, the scale and the role of the city have changed from medium and regional to large scale and transregional. Due to natural and structural limitations, more than 80% of barren lands, stone cliffs, beach zone, and agricultural lands are occupied by built-up areas. Our results revealed that the irregular expansion of Bandar Abbas city must be controlled so that sustainable development could be achieved.

Parece, T.E.; Campbell, J.B. (2017) Mega cities, the largest category of urban agglomerations, attract considerable attention because of their population size, economic, socio-cultural, environmental and political influence and geographical complexity. Until 1975 there were just three mega cities in the world: New York, Tokyo and Mexico City — today there are 27 cities having more than the defined 10 million inhabitants. This paper presents a straight forward, application-oriented approach using multi-temporal remotely sensed data to systematically monitor the spatiotemporal dynamics of the world's urban giants. Object-oriented and pixel-based classification image analysis techniques are applied to Landsat as well as to TerraSAR-X data in order to define urbanized areas of the mega cities at different points of time. Subsequently post-classification change detection is performed on urban footprint level. With time intervals of about 10 years almost 40 years of urbanization are monitored, showing different dimensions, dynamics and patterns across the analyzed cities. The generated urban footprint products show accuracies consistently higher than 80%, allowing for further applications in fields such as urban planning, risk management, or population assessment.

Mougeot, L.J. (2000) Urban areas are the most dynamic region on earth. Their size has been constantly increased during the past and this process will go on in the future. Since there is no standard policy and guidelines for construction of buildings and urban planning, cities tend to have irregular growth. Many cities in the world face the problem of urban sprawl in its suburbs. So issues of urban sprawl need to be settled with the help of technologies such as satellite remote sensing and automated change detection.

Deelstra, T.; Girardet, H. (2000) This paper presents a wavelet based post classification change detection technique that is applied to 1996 and 2004 MSS images of Madurai City, South India to determine the urban growth. The classification stage of the technique uses coilflet wavelet filter to correlate with the MSS land cover images of Madurai city to derive texture feature vector and this feature vector is inputted to a fuzzy-c means classifier, an unsupervised classification procedure. The post classification change detection technique is employed for identifying the newly developed urban fringe of the study area. The error matrix analysis is used to assess the accuracy of the change map. The performance of the presented technique is found superior than that of classical change detection methods such as image differencing, change vector analysis and principal component analysis.

Guderyahn, L.B.; Smithers, A.P.; Mims, M.C. (2016) The urban density gradient illustrates radial pattern of urbanisation for the period 1973–2010. Bangalore grew radially from 1973 to 2010 indicating that the urbanisation is intensifying from the central core and has reached the periphery of the Greater Bangalore. Shannon's entropy, alpha and beta population densities were computed to understand the level of urbanisation at local levels. Shannon's entropy values of recent time confirms dispersed haphazard urban growth in the city, particularly in the outskirts of the city. This also illustrates the extent of influence of drivers of urbanisation in various directions.

METHODOLOGY

Datasets used for the study, at medium and coarse resolution, were obtained from different satellites at different stages of analysis.

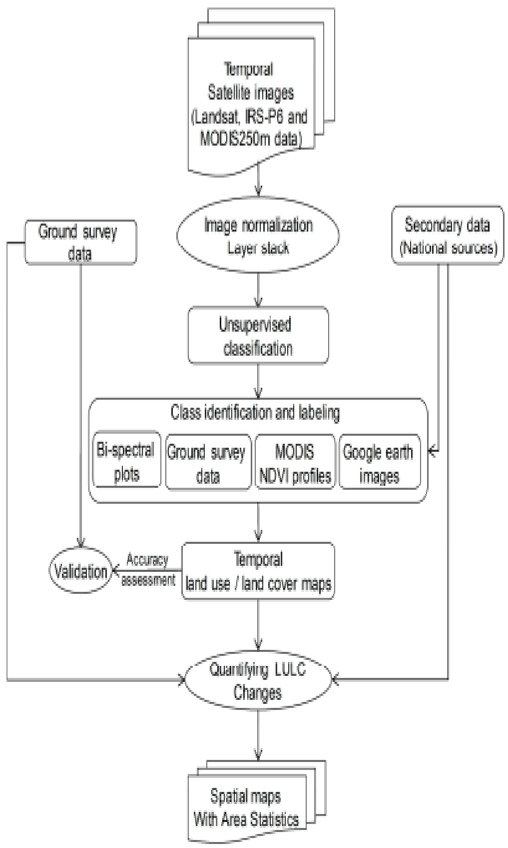

Figure An overviews of the methodology used to map urban areas and other land-use/land-cover (LULC) changes using Landsat-8 data

Satellite Images

Three IRS-P6 images obtained from the National Remote Sensing Centre (NRSC, ISRO) were used for monitoring LULC changes in the study area. Two Landsat-8 images and three IRS-P6 images, which were captured in rabi, were extracted from USGS Earth Explorer. Image preprocessing started with image normalization, which involved converting digital numbers (DN) to reflectance values. MODIS vegetation indices (MOD13Q1 product) were used for class identification and labeling processes. MOD13Q1 data were obtained from USGS LPDAAC. MODIS data were acquired in 12-bit format (0 to 4096 levels) and later stretched to 16-bit (0 to 65,536 levels) and were prepared for the cropping year (June to May) 2004–2005, 2007–2008, 2010–2011, 2013–2014 and 2015–2016.

Image Normalization

The main purpose of normalization is to normalize the multi-date effect of IRS-P6 and Landsat-8 images, for better classification. Data from different periods have differing radiometric resolution, and hence their respective digital numbers (DNs) carry different levels of information and cannot be directly compared. Therefore, all data were converted to absolute units of radiance ($W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$), then to apparent at-satellite reflectance (%), and finally to surface reflectance (%) after atmospheric correction. Details of these conversions are provided below, due to the uniqueness of the sensors involved.

Mapping Land-Use/Land-Cover Changes

A comprehensive methodology for mapping cropland areas using IRS-P6 and Landsat-8 data was taken. Each image was classified using unsupervised ISOCLASS cluster Iso data classification, with 40 classes and 40 maximum iterations and with convergence threshold of 0.99. The main purpose of unsupervised classification is to capture different LULC types within the image across a study area. Simultaneously, we generated mean spectral values for all classes using a signature set option. Class identification and labeling were performed based on spectral properties (bi-spectral plots), ground survey data, and Google Earth high-resolution imagery.

Spectral values of red and NIR bands extracted from unsupervised classification were plotted as shown in Figure, with reflectance values of red on the x-axis and reflectance values of NIR on the y-axis). In Figure, the diagonal line represents the soil line, which differentiated the classes with vegetation. Classes with similar spectral reflectance depict nearby clusters, which may represent the same category (same classes) with a slight variation in reflection. Other classes, like water bodies and shrub land/trees, show large variations in vegetation and can easily be identified and labeled. Classes closer to the soil line and the two-band (red and NIR bands) reflectance values were similar and high; they are classified as built-up areas. More highly vegetated areas, like irrigated cropland, have high reflectance values in NIR and lower reflectance in red.

RESULTS

The maximum built-up expansion took place at the cost of agricultural land. In the period 1927–75, 33.12 km2 of agricultural land was transformed to built-up land, which increased to 8.16 km2 in 1975–86, 29.34 km2 in 1986–96 and 28.82 km2 in 1996–2005. The annual increase in agricultural land transformation to built-up land was raised from 0.69 km2 per year during 1927–75 to 0.74 km2 per year during 1975–86, 2.93 km2 per year during 1986–96 and 3.20 km2 per year during 1996–2005. Insignificant area comprising seasonal water bodies was also converted to built-up land. During 1927–75, the built-up land transformation to agricultural land was high (5.31 km2) which could be attributed to use of topographical sheet of 1927, in which the spatial expansion of built-up was not as accurately marked as evident on satellite images. Significant amount of area under water body was converted to agricultural land.

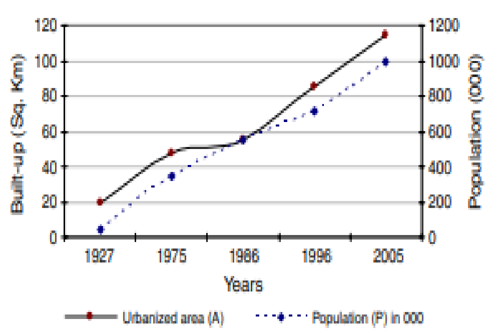

Figure Built-up and population in RUA (1927–2005)

The 4.83 km2 area of water body converted to agricultural land during 1927– 75, 4.40 km2 areas during 1975–86, 3.63 km2 during 1986–96 and 4.66 km2 during 1996–2005. The maximum annual land transformation under this category was observed during 1996–2005 (0.52 km2). On the other side, significant amount of agricultural land was also transformed to water bodies. In 1927–75, 10.48 km2 of agricultural land was converted to water bodies due to construction of some major reservoirs like Hatia Reservoir. During 1975–86, 5.39 km2 , 1986–96, 2.91 km2 and during 1996–2005 it was 0.1 km2 . This resembles that such inter-conversion of agricultural land and water bodies was influenced by anthropogenic activities. The final loss of agricultural land and water bodies may be credited to expansion of built-up land which has greater significance in the recent decades.

Table Population and Built-up characteristics during different periods

Characteristics Type	1927–75	1975–86	1986–96	1996–2005
Urban Land increases (km2)	27.40	8.15	29.65	29.08
Population Increase (Periodic)	295,839	207,000	163,000	278,000
Population growth (Periodic) in%	640.89	60.53	29.69	39.04
Population growth (Yearly) in%	13.35	5.50	2.97	4.34
Land consumption - Periodic (m2)	92.60	39.36	181.91	104.62
Land consumption - Yearly (m2)	1.93	3.58	18.19	11.62

The water bodies were also significantly transformed to agricultural land and partially to built-up land in urban core area as evident in satellite images. The rapid growth rate of Ranchi urban agglomeration leads to 308.65 ha of agricultural land loss per year in recent decade (1996–2005), which represents loss of 1051.26 metric tons per year in food grain (mainly rice and maize). If agricultural productivity of 2006 will assumed static, then productivity loss would be 235.7 metric tons per year during 1927–75, which increased approximately 4.5 times till 1996–2005. This indicates towards urgent requirement of judicious and sustainable planning for future built-up growth keeping in view the sustainable utilization of land and water resources of the region.

Examination of Landsat-8

OLI data Spectral responses of built-up, vegetation and water areas were examined in OLI multispectral bands 2-7 and thermal bands 10 and 11. All three land cover types had a unique signature in optical bands which indicated that they can be segregated from each other through proper application of their respective indices. Compared to the other two land cover types, the spectral reflectance curve of vegetation had a prominent slope between bands 5 and 4. This indicated that the NDVI could be more efficient in terms of accuracy compared to NDBI or MNDWI. Another relevant finding was the difference between temperatures of the three land cover types.

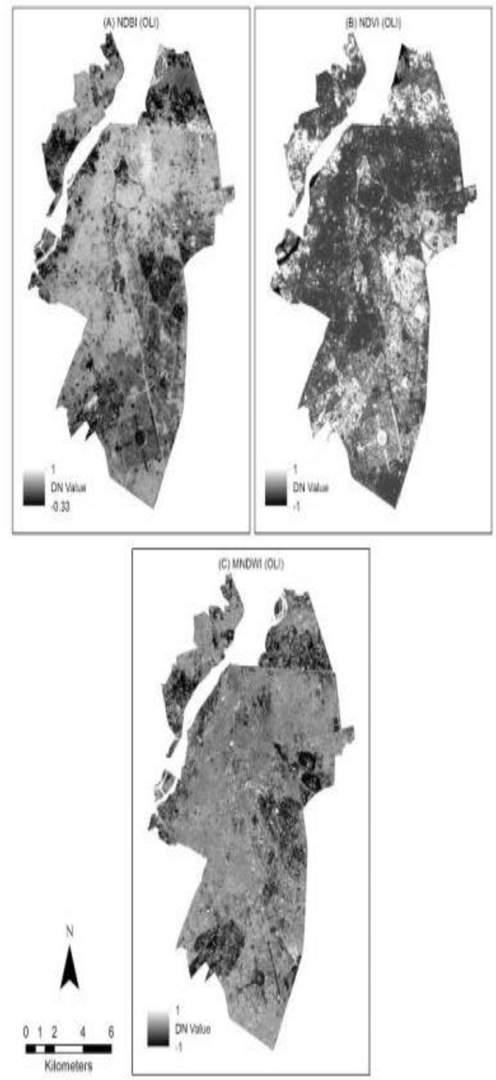

Figure The resultant images of (A) NDBI, (B) NDVI and (C) MNDWI derived from the Landsat-8 OLI image.

Both thermal bands 10 and 11 exhibited the highest temperature values for built-up areas (around 50°C), followed by vegetation (around 46°C) and water (around 40°C). The primary reason for this characteristic of built-up areas is the usage of construction materials that absorb heat during daytime and release it at night. Compared to other land cover types, the cooling process in construction materials is very slow which subsequently increases the overall temperature in built-up areas. Higher temperature readings of built-up areas in the thermal bands implied that temperature can be used as an aiding factor to separate built-up areas from vegetation and water.

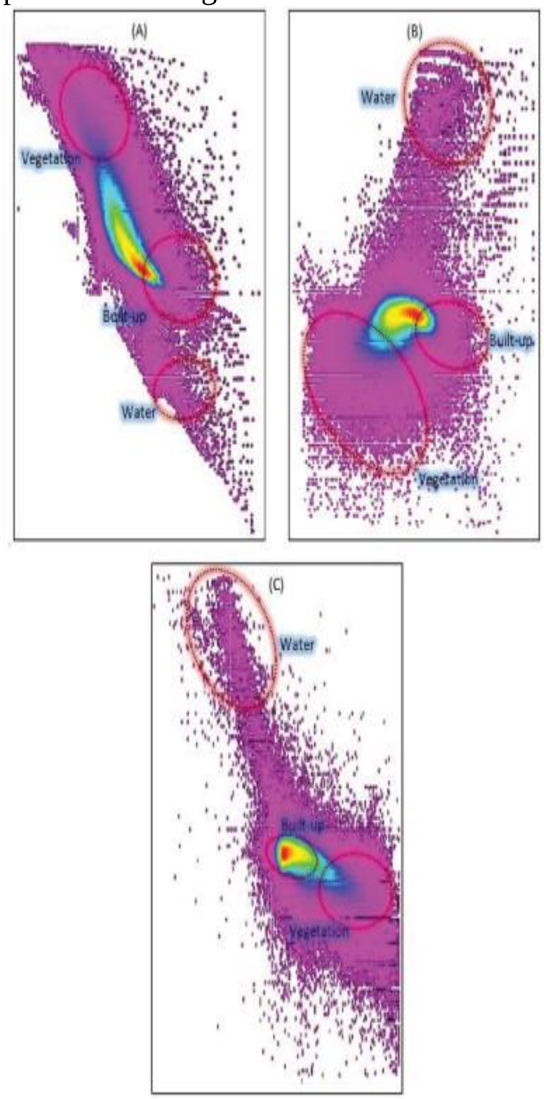

Figure Scatter plots showing the correlation between (A) NDBI (x-axis) and NDVI (y-axis), (B) NDBI (x-axis) and MNDWI (y-axis), and (C) NDVI (x-axis) and MNDWI (y-axis).

A considerable difference in reflectance of vegetation in OLI bands 4 and 5 was the basic reason for this characteristic of the NDVIOLI image. The MNDWIOLI imagery generated using Equation is illustrated in Figure. Water is shown as white pixels in this image, whereas other land cover types are depicted in the tones of grey and black. Areas with dense vegetation appear dark whereas the built-up areas are shown in variable tones of grey.

CONCLUSION

Urban expansion and other LULC changes were analyzed in this study using multi-sensor satellite data such as IRS-P6, Landsat-8, MODIS time series data, and ground survey data. Land-use classes were identified based on bi-spectral plots and ground survey data, and the classes obtained were compared with those in Google Earth high-resolution imagery. The major LULC classes were mapped with error matrix accuracy between 80% and 86%. The results demonstrate significant strengths in using IRS-P6 23.6 m and MODIS data together with ground survey data in identifying fragmented and minor cropland areas with irrigation sources, such as wastewater irrigation and rain-fed agriculture. However, fragmented mixed cropland areas are better mapped using IRS-P6 data in fusion with coarser-resolution time series data.

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