Innovative use of Band Ratioing for Delineation of Urban Areas

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Abstract

Urbanization refers to the change of rural areas into urban ones. Urban areas are most dynamic in terms of land use changes. The temporal changes can be monitored through satellite data and reflects the development taking place. Pattern recognition techniques like Principal Component Analysis, band ratioing etc. are used to monitor the dynamics. In the present paper, Nagpur city urban sprawl and as well as Nagpur district has been studied using band ratioing techniques. The urban indices like, Normalised Difference Built up Index (NDBI), Index Based Built-Up Index (IBI), Urban Index(UI), Enhanced Built-Up And Bareness Index (EBBI) along with Normalised Difference Vegetation Index(NDVI) has been used to generate a five band composite map. The various combinations are used to delineate the various earth features. This work is unique as some of the features have been delineated with utmost precision.

Keywords: Remote Sensing (RS), Geographic Information System(GIS), Normalised Difference Built up Index (NDBI),Index Based Built-Up Index (IBI), Urban Index(UI), Enhanced Built-Up And Bareness Index (EBBI)

I. INTRODUCTION

Urbanization refers to the change of rural areas into urban ones [1]. Rapid urbanization and urban expansion may have significant impact on conditions of urban ecosystems [2-5]. The urban conglomerates are of immense importance to mankind as they are the source of growth and development. The rural areas are also of immense importance especially those in the vicinity of the growth centres or rapidly expanding urban areas. These rural or semi urban areas are called as peri urban, and they convert to urban areas in due course of time. Remote sensing technology uses satellite imaging to retrieve information about the changes on Earth. These changes when properly recorded and monitored, give us an insight into the growth pattern, and the suggestive reasons for the drivers for such change. Improvements in the satellite data availability, frequency of data availability and the sensor technology have given the scientist the opportunity to use different spatial, spectral and temporal data.

Remotely sensed data provide synoptic view, data with spatial resolution in range of 30 cm and more, multi spectral data, revisit etc. This data is an invaluable source of information for monitoring changes on earth surface and management of resources. Satellite imagery is an effective way to reveal the changes in land use patterns. In order to separate urban and non-urban details, plenty of spectral urban indices have been developed by scientists including Normalized Difference Built-Up Index (NDBI) [6], Index-based Built-Up Index (IBI) [7] Urban Index (UI) [8] and Enhanced Built-Up and Bareness Index (EBBI) [9].

Image processing software like ERDAS Imagine2013 is a versatile tool which can be used to formulate new algorithms for delineation of urban areas. Along with the image processing software, GIS software like ARC GIS 9.1 can also be used for conversion of classified image to vector map, topology building and statistic generation. Users can develop their own models using modeler icon and try new methods of feature extraction. In the paper, an attempt has been made to delineate urban areas using a composite image of various urban indices to be able to delineate the various structures in urban areas with better clarity [10]. Band Ratioing means dividing the pixels in one band by the corresponding pixels in the second band. The differences between the spectral reflectance of the curves of one band in contrast to other band can be brought out. The other reason is that illumination and consequently radiances may vary. However, the ratio between an illuminated and non-illuminated region of the same surface remains the same [11].

II. STUDY AREA AND SATELLITE DATA USED

The study area chosen was Nagpur city urban sprawl as well as Nagpur District. Nagpur city is the winter capital of the state of Maharashtra, India, and the third largest city in the state after Mumbai and Pune. It is the largest city in Central India. Under the scheme of the Govt. of India, to handle the large scale increase in the urbanization, Nagpur has been chosen under the smart city project and development activities are in progress. According to a survey, Nagpur is one of the most livable cities in India. Thus, an inventory and study to map the changes in the impervious layer is required to ascertain the amount of increase in urbanization. Satellite Data used is of IRS P6 LISS IV containing the SWIR as well as the NIR. An attempt has been made to use these two bands for the delineation of urban area. The model has been developed in the "Model Maker" in ERDAS 2013 and using layer

stacking a five band image has been formed. The various combinations of the indices are used for delineation of the features in ARC GIS 10.2.

III. METHODOLOGY

The Normalised Difference Built up Index (NDBI) is used. It is defined as:

$$NDBI = (\lambda_{SWIR} - \lambda_{NIR})/ (\lambda_{SWIR} + \lambda_{NIR}) \quad (1)$$

where, SWIR stands for Short Wave Infra Red (1.55-1.70 µm) and NIR (0.77-0.86 µm) for Near Infrared. Similarly the other bands used are as follows:

A. *Urban Index (UI)*

$$UI = \frac{\lambda_{SWIR2} - \lambda_{NIR}}{\lambda_{SWIR2} + \lambda_{NIR}} \quad (2)$$

B. *Index based Built-Up Index (IBI)*

$$IBI = \frac{2*\lambda_{SWIR1}}{\lambda_{SWIR1} + \lambda_{NIR}} - \frac{\lambda_{NIR}}{\lambda_{NIR} + \lambda_{RED}} - \frac{\lambda_{GREEN}}{\lambda_{GREEN} + \lambda_{SWIR1}} \Big/ \frac{2*\lambda_{SWIR1}}{\lambda_{SWIR1} + \lambda_{NIR}} + \frac{\lambda_{NIR}}{\lambda_{NIR} + \lambda_{RED}} + \frac{\lambda_{GREEN}}{\lambda_{GREEN} + \lambda_{SWIR1}} \quad (3)$$

C. *Enhanced Built-up and Bareness Index (EBBI)*

$$EBBI = \frac{\lambda_{SWIR1} - \lambda_{NIR}}{10\sqrt{\lambda_{SWIR1} + \lambda_{TIRS1}}} \quad (4)$$

D. *Normalised Difference Vegetation Index (NDVI)*

$$NDVI = \frac{\lambda_{NIR} - \lambda_{RED}}{\lambda_{NIR} + \lambda_{RED}} \quad (5)$$

An attempt has been made to use ERDAS Imaging software to build the various urban indices. The model is created and proper care is taken to avoid division by zero in the models. Then using the layer stack, a composite image of the various indices is made with the combination as follows:

- Layer1: Normalized Difference Built-up Index (NDBI)
- Layer2: Urban Index (UI)
- Layer3: Index based Built-up Index (IBI)
- Layer4: Enhanced Built-up & Bareness Index (EBBI)
- Layer5: Normalised Difference Vegetation Index (NDVI)

Figure-1 shows the interface available for various mathematical operations using various bands in ERDAS IMAGINE 2013.

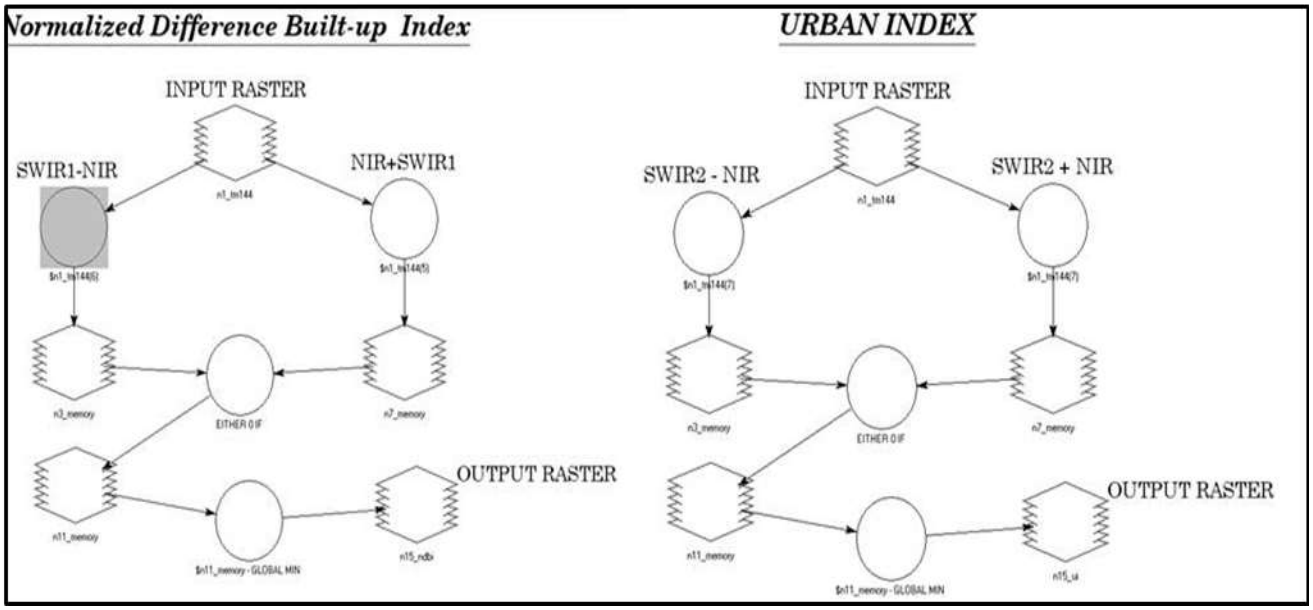


Fig. 1: Interface available for creation of models in ERDAS Imagine

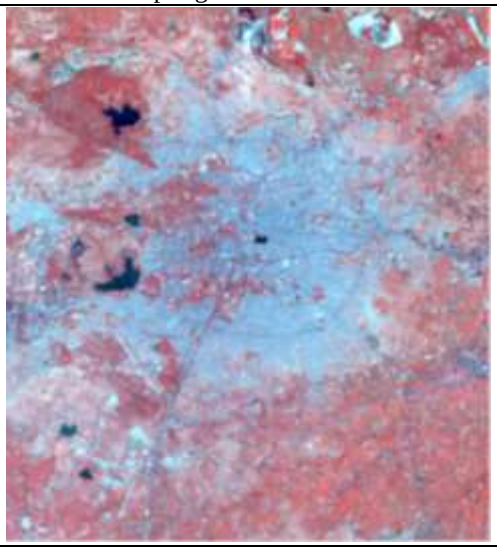
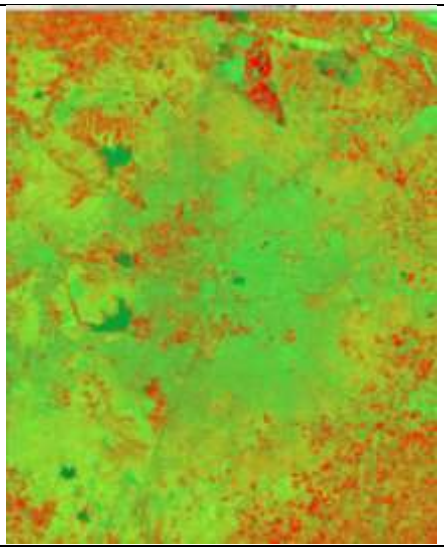
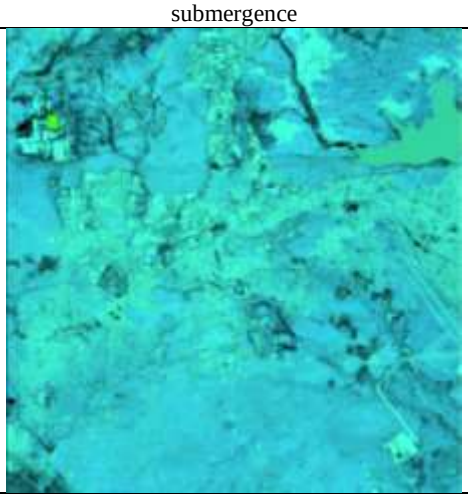
IV. RESULT AND DISCUSSIONS

The combinations of the various layers in the composite image is tried and the results are enumerated in the Table 1.

Table – 1
Composite image of urban indices

Sr.No.	*Combination of urban indices*	*Interpretation / delineation*
1.	*Layer 5,1,3 (NDVI, UI, IBI)*	*Clear demarcation of vegetative and non-vegetative classes, better image enhancement without saturation, water bodies are clearly visible along with maximum submergence*
2.	*Layer 1,2,3 (NDBI, UI, IBI)*	*Building footprints especially of sheds, wastelands, sand and water in rivers, drainage patterns and urban sprawl*
3.	*Layer 4,1,3 (EBBI, NDBI, IBI)*	*Delineation of geological features with special emphasis to ridge and valley*
4.	*Layer 5,1,2 (NDVI, NDBI, UI)*	*Variability clearly seen between vegetative, non-vegetative parts. Image enhanced, quarries, industries like brick kiln etc.*
5.	*Layer 4,2,1 (EBBI, UI, NDBI)*	*Enhancement of barren lands, drainages through the barren lands are clearly seen, Enhancement of drainages, demarcation of non-vegetative and vegetative areas, wet and dry soils*

Snapshots of Composite Image formed by Layer Stacking Urban Indices and Vegetation Index is shown in the Plate I. The various combinations used are enumerated and shows that band rationing is certainly a very good method of delineation of urban classes. Heads-up digitisation can be done later to fine tune the delineation.

	
LANDSAT TM - 2010	Vegetative and Non- Vegetative Parts (Layer 5, 1,3)(NDVI,UI,IBI) Clear demarcation of vegetative and non-vegetative classes, better image enhancement without saturation, water bodies are clearly visible along with maximum submergence
	
Urban Features and linear features	Layer 1,2,3(NDBI, UI, IBI) Building footprints especially of sheds, wastelands, sand and water in rivers, drainage patterns and urban sprawl

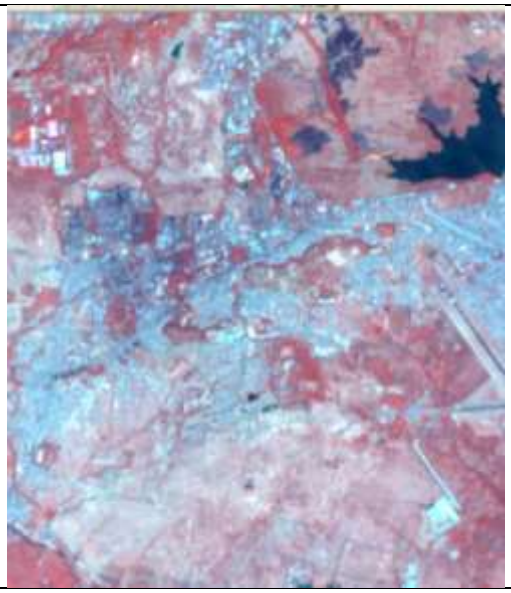
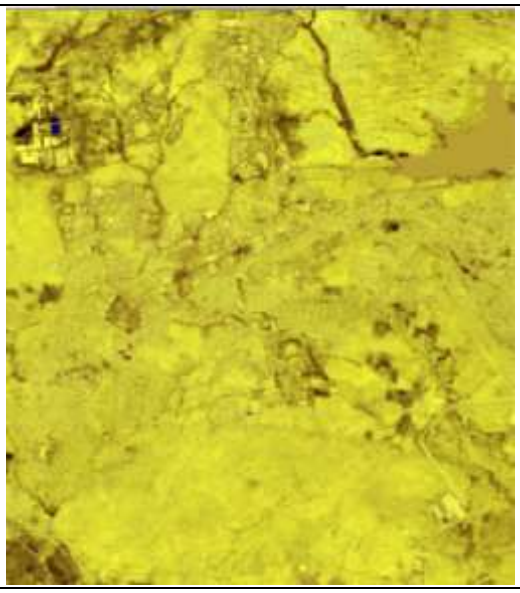
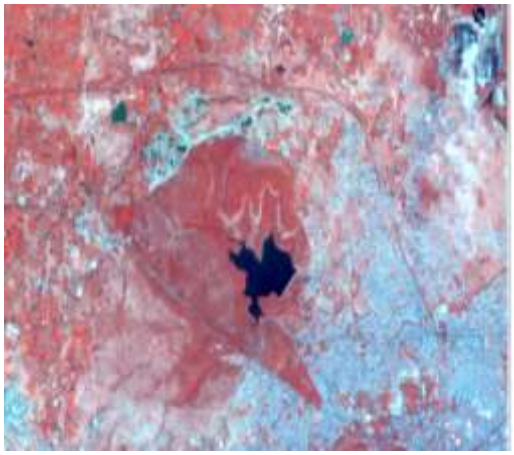
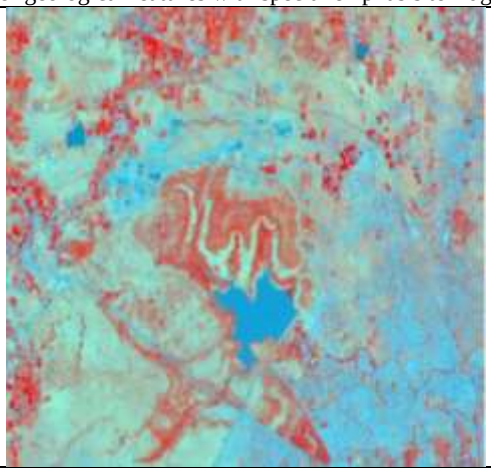
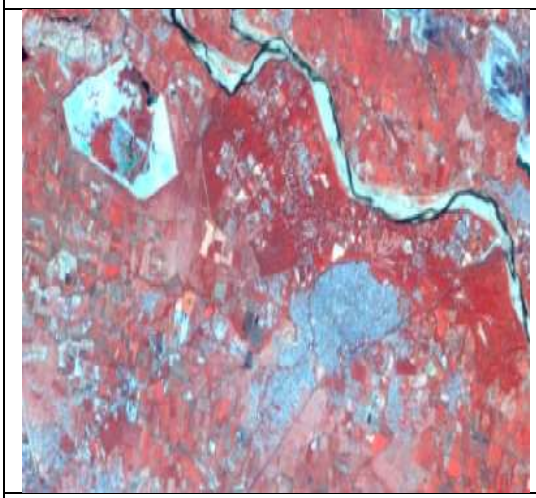
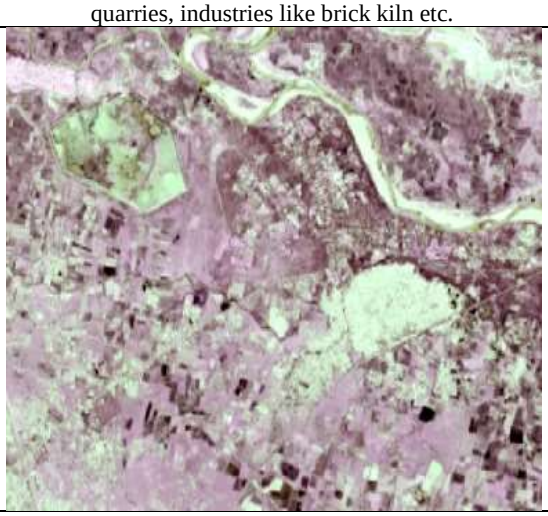
	
Geological Features	Layer 4,1,3 (EBBI, NDBI, IBI) Delineation of geological features with special emphasis to ridge and valley
	
Quarries, Brick Kiln	Layer 5,1,2 (NDVI, NDBI, UI) Variability clearly seen between vegetative, non-vegetative parts. Image enhanced, quarries, industries like brick kiln etc.
	
Quarries, Brick Kiln	Layer 4,2,1 (EBBI, UI, NDBI) Enhancement of barren lands, drainages through the barren lands are clearly seen, Enhancement of drainages, demarcation of non-vegetative and vegetative areas, wet and dry soils

Plate I showing snap shots of the various features

The present work has shown that the method of band ratioing is a very good method of identifying the built up from satellite data while a broader classification can be done on basis of fuzzy classification. The combination of the two can be used for quick and proper feature extraction.

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