“A GEOINFORMATIC APPROACH TO STUDY URBAN AGGLOMERATION OF
BHUBANESWAR CITY (ODISHA)”

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Abstract:

Urban agglomeration is an expansion of city center with its adjoining outgrowth or suburbs. Urban agglomeration is a recent phenomenon in Indian society, which do not accommodate the haphazard growth of human settlements. The main objective of this study was to identify the recent urban changes in Bhubaneswar and its periphery. Bhubaneswar is the capital of Odisha and it was planned in the year 1948. The city could not grow in the envisaged manner as it is surrounded by the Chandaka Wildlife sanctuary in the northwest section and by flood plains on the eastern side. The present study examines the use of Index Based Model for delineation of the urban sprawl of Bhubaneswar city. Index-based built-up index (IBI), is a normalized difference index used for the extraction of built-up land features. The above-mentioned model can be efficiently used by taking three known indices viz. NDBI, SAVI & MNDWI. Satellite imageries of IRS-P6 and Landsat 7 (ETM+) & 8 (OLI) has been used in the study with the efficient use of ArcGIS. The study manifest that, there has decreased in the area under vegetation cover and the increase in the settlements and crop land. 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 feature in the city, within the slight limitation of the model. The urban development of Bhubaneswar is going in an unplanned manner which have an adverse effect on both human and natural resources. The results of this work conclude that Remote Sensing and GIS techniques can be methodical used in the study of urban agglomeration and its adjoining urban areas.

Keywords: Urban Agglomeration, Bhubaneswar, Index Modeling, ArcGIS, RS & GIS.

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Introduction:

Increasing population and increase in urban area results in unplanned activities with insufficient management plans and also leads to over utilization of the resources. It is called the process of Urbanization under 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). Urban growth has resulted in the conversion of land for urban uses without any systematic development plan, and without a corresponding investment in infrastructure (Gupta et al., 2014). Taking this into account for future urban development and human infrastructure, new tools and techniques should be implemented with the efficient use of remote sensing and by following a geometric approach which will be helpful to know the agglomeration in urban zones.

Urban agglomeration is a term referring to the extension of the urban built-up area and its population density including the main core area, suburbs or continuously settled commuters. Agglomeration is also linked with the linear development of urban areas which can also be called as Conurbation. Thus to know more about these zones, long-term temporal data of past and present years must be monitored and should be taken under consideration. Remote sensing techniques and GIS tools are the basic requirements now as their importance has already shown in the mapping of urban land use/land cover, urban growth trends and to monitor the changes in land use/land cover (Pathan et al., 1993, 2004; Donnay et al., 2001).

A geometric approach could have a different type of methods and datasets and may also include the various types of models and classification systems. Some of them known as supervised & unsupervised classification, knowledge classifier, an index based & regression models. One of which is new among all is the Index modeling technique which includes many other relevant indices in the entire process. It is possible by using a thematic set of output derived by different sensor band(s) and is highly capable of extracting the built-up features from it. The three different thematic indices have been used in constructing the IBI viz., Normalized Difference Built-up Index (NDBI), Soil Adjusted Vegetation Index (SAVI) and Modified Normalized Difference Water Index (MNDWI), which together represent the three major components of built-up land, vegetation and water respectively (Xu et al., 2008).

Study Area:

The city of Bhubaneswar is the study area for this work which was planned in 1948. The boundary has been demarcated by looking over an aerial view of the city on online map and that lies between the geographical extent of north 20.192° to 20.409° latitude and east 85.737° to 85.888° longitude. It is surrounded by the Chandaka Wildlife sanctuary in the northwest section and by flood plains on the eastern side, due to which it could not grow in an envisaged manner. It is a Tier-2 city and the largest city of the Indian state of Odisha, ranked 59th city in India. Bhubaneswar city had recorded subsequent increase in population from 16,512; 38,211; 105,491; 227,525; 423,465; 647,302 and 837,737 for 1951, 1961, 1971, 1981, 1991, 2001 and 2011 years respectively (Gopi 1978; Iyer et al., 2007; Census 2011, GOI).

Methodology:

A methodology has been planned to conduct the spatial-temporal analysis to study the urban agglomeration in 1999, 2009 & 2014. The above process is based on the model which requires three indices, namely Normalized Difference Built-up Index (NDBI), Soil Adjusted Vegetation Index (SAVI) and Modified Normalized Difference Water Index (MNDWI). These are the indices which are widely used to extract different features from remote sensing data. Data management toolbox and spatial analyst's toolbox of ArcGIS 10.2.2 package has been used for this work. For extraction of land features from the remotely sensed data of 1999, 2009 and
2014; multispectral satellite imagery of Landsat 7 (ETM+ Sensor), IRS-P6 (LISS-III) & Landsat 8 (OLI-TIRS Sensor) has been used, respectively. Landsat imageries are used after pan-sharpening to 15 m resolution for 1999 & 2014 while IRS data has been used directly i.e. default resolution 23.5 m. Pre-processing of satellite imagery has been done to obtain high-quality information from remote sensors by ESRI software package.

Feature extraction has been done by using the raster calculator of ArcGIS 10.2.2 for the below-mentioned formulae’s-

\[
NDBI = (MIR - NIR)/(MIR + NIR)
\]

\[
SAVI = ((NIR - Red) (1 + l))/(NIR + Red + l)
\]

\[
MNDWI = (Green - MIR)/(Green + MIR)
\]

Where,
- \(NIR\) = B4 (ETM+), B4 (LISS-III) & B5 (OLI)
- \(Red\) = B3 (ETM+), B3 (LISS-III) & B4 (OLI)
- \(Green\) = B2 (ETM+), B2 (LISS-III) & B3 (OLI)
- \(MIR\) = B5 (ETM+), B5 (LISS-III) & B6 (OLI)
- \(l\) = Correction factor, whose value ranges from 0 – 1 and totally depends upon the plant densities of the area. If there is very high plant density, then value of \(l\) will be zero or vice versa.

The NDVI is used 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, whereas SAVI can work in the area with plant cover as low as 15%, on the other side NDVI can only work in the areas which have planted above 30% (Ray 2006).

After getting the required features in raster form, from all the above indices, Index-based Built-up Index (IBI) can be used by applying two formulae’s, mentioned below:

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

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

(Gupta et al., 2014)

The above equation which has bands can be directly used in raster calculator if NDVI is used instead of SAVI.

After the final calculation, the raster obtained will be Index-based Built-up Index, which shows the enhanced built-up features in it. After successful reclassification, we are able to extract the built-up class only from the output index for different threshold values for different outputs. It has been validated by using the land use land cover map of the study area.

Results and Discussion:

Extraction of various land features has been done by using all the above-mentioned formulae’s, within slight limitation as NDBI also extract little soil and barren land in it due to the same reflectance as of built-up.
Fig: 1 – Satellite Image 1999

Fig: 2 – Index-based Built-up Index 1999

Fig: 3 – Satellite Image 2009

Fig: 4 – Index-based Built-up Index 2009
To overcome this limitation and get dense & a sparse built-up portion, Index-based Built-up Index is used after all processes. This Index modeling technique enhanced the built-up land feature with a light gray to white tone while vegetation and water are considerably suppressed as background noise with a dark-gray to black shade. After final calculation of the IBI for all three years, Built-up mask has been done to get the urban portion from the image by a threshold value detected manually for all three output of IBI.

Threshold value will always be within the minimum and maximum value of the output. In the present work, this value for IBI ranges from -0.164 to -0.121 for 1999, from -0.331 to -0.284 for 2009 and from -0.123 to -0.096 for 2014 and has been manually determined for all outputs. Results also show the significance of the bands and reflectance in this thematic setup as in all outputs the forest cover near to built-up portions is also eliminated easily. It is clearly visible from the built-up mask that urban land use has increased in the following years. Total area of the study boundary is 230.38 Km² and the area covered by each built-up mask is shown in the table below:

**Table 1: Area of Built-up mask with various datasets**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Month-Year</th>
<th>Satellite</th>
<th>Sensor</th>
<th>Resolution (m)</th>
<th>Area (Sq. Km.)</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oct - 1999</td>
<td>Landsat 7</td>
<td>ETM+</td>
<td>15</td>
<td>64.34</td>
<td>27.92</td>
</tr>
<tr>
<td>2</td>
<td>Oct - 2009</td>
<td>IRS-P6</td>
<td>LISS III</td>
<td>23.5</td>
<td>91.36</td>
<td>39.65</td>
</tr>
<tr>
<td>3</td>
<td>Oct - 2014</td>
<td>Landsat 8</td>
<td>OLI</td>
<td>15</td>
<td>107.29</td>
<td>46.57</td>
</tr>
</tbody>
</table>
Landsat 7 satellite image shown in Fig 1 is used to derive IBI of 1999 shown in Fig 2. Same procedure for IRS-P6 and Landsat 8 satellite image is shown in Fig 3 and Fig 5 is used to derive IBI of 2009 and 2014 shown in Fig 4 and Fig 6. Built-up mask of all three IBI layers has been shown in Fig 7. Urban Landuse of 2014 (Purple color) is placed below the urban land use of 2009 (Orange color) with the urban land use of 1999 (Green color) over it.

It is also observed from index maps and a total percentage of the urban built-up that the surrounded area is a forest and other land use dominated areas which contribute to the significant economic importance followed by an urban land and water bodies. The built-up portion is not even 50% of the total area as of now, but it will increase soon due to increase in population, urbanization and industrialization.

**Conclusion:**

There has been a drastic change in the land use pattern of the Bhubaneswar city with increasing population also experiences haphazard urban development which indicates urban sprawl and linear development along the roads & the railway lines. Many factors are responsible for this such as the availability of natural resources, social, cultural, economic, political impotence etc.

Initially, the urbanization was towards southern and southeastern portion. During 2009, the growth in the built-up area has also moved towards the southwest direction due to the proximity of NH-5. In the southeast part, the outgrowth can be attributed to the presence of NH-203. But after 2009, the growth has also added another movement in the North direction. In the west part of the city, the growth is hindered by the presence of Chandaka forest areas. So, the total development of Bhubaneswar city is in the southeast, southwest and in the north direction. Although, the city initially evolved in a rectangular shape on a grid pattern outward from the center. Now it is growing largely towards north, northwest and southwest direction along the main transport routes.

The study also concludes that using the Index Modeling technique will be very useful in studying the urban growth, trend, sprawl, agglomeration & conurbation of any growing area and also make efficient use of remotely sensed datasets within it. This technique requires good interpretation and spectral identification in it, as it is very important to get information about the land use pattern and behavior. Digital image processing techniques can give very big advancement to this work by improving image quality for analysis. Good advice/suggestion from GIS & Image analyst, urban planner & Remote sensing person can improve this type of study further and increase the possibility of fine results.

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