Urban sprawl and urban growth detection analysis: A comparative study of Kolkata municipal corporation and Haora municipal corporation

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ABSTRACT

The present paper highlights a comparative study between Kolkata and Haora Municipal Corporation on the basis of urban issues urban growth and urban sprawl. This study aims to quantify the urban sprawl and growth using some statistical techniques and GIS and Remote Sensing techniques. In this study built-up area of Kolkata and Haora is derived from three temporal satellite imageries on which several statistical techniques like Shannon Entropy, Weights of Evidence and Pearson’s Chi-Square Method are applied to analyze the urban growth and sprawl. The result shows overall increasing urban sprawl for the city of Kolkata and Howrah with time.

Keywords: Urban growth, urban sprawl, shannon entropy, weights evidence, chi-square method

1. Introduction

This study takes into account a comparative study between Kolkata and Haora Municipal Corporation on the basis of some urban issues like urban growth and urban sprawl. Urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. Analysis of urban growth by using the historical and present data is an essentially performed operation in the urban geographic studies and for future planning. Urban growth can be mapped, measured and modelled by using remote sensing data and GIS techniques along with several statistical measures (Bhatta.B). Urban sprawl is defined as low density residential and commercial development on undeveloped land. Most of the time, people will move from these areas to try to find better areas to live. This has been the way of the world since the beginning. Cities and their suburbs are now becoming overcrowded because of this, but now it is time to look at the causes and the effects of the urban sprawl.

Urban sprawl can be caused by a variety of different things like lower land rates, improved infrastructure, rise in standard of living, lack of urban planning, lower house tax rates, rise in population growth etc. As a result some effects can be occurred like increase in public expenditure, increased traffic, and health issues, environmental issues etc. In this study three temporal satellite images of 15 years interval (1975, 1990 and 2012) have been classified to determine the urban extent and growth of Kolkata-Howrah (West Bengal, India) in eight different directions within a circular region. Pearson's chi-square test and Shannon's entropy method have been applied to calculate the degree-of-freedom and degree-of-sprawl towards the analysis of urban growth. A new measure, degree-of-freedom, has also been proposed for the analysis of urban growth. The result shows that the city of Kolkata has a high degree-of-freedom, high sprawl, and less growth in Howrah than Kolkata. Apart from the derived results, this study also shows the potentials of remote sensing data and effectiveness of
demonstrated/proposed models in urban geographic studies. The present study areas are shown as Figure 1. The present study area is Kolkata Municipal Corporation and Haora Municipal Corporation. Kolkata is one of four metropolitan cities of India and is the capital of the state of West-Bengal. The city is centred on latitude 22°34’ N and 88°24’ E. The KMC area comprising about 187 sq km having population 4,328,111 as per 2011 census and have a density 2,425.2 persons /sq km. The HMC has an area 51.74 sq km and its present population is 10.07 lakh. It lies between 22°48’ N to 22°12’ N and 88.23E to 87.50E.

1.1 Materials and methods

The present study involves the collection of satellite images and block boundary map from department. Processing the imagery and image interpretation is done in “ERDAS Imagine”, “ARCGIS” and “ARCVIEW” software and then some statistical techniques has used to analysis the urban sprawl and urban growth. The obtained maps are studied and analysed to detect urban sprawl and urban growth. The methodology adopted in detail is shown below.

Figure 1: Location map of Kolkata Municipal Corporation and Haora Municipal Corporation
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Volume 7 Issue 1, 2016

Figure 2: Methodology
2. Literature review

Literature review of the study is related with various national and international journals, books and articles. The international journal like “International Journal of Advance Scientific Research and Technology”, “International Journal of Geomatics and Geoscience”, “Journal of Theoretical and Applied Information Technology” and the book like “Changes in land use and land cover: A Global perspective” – William B.Neyer are related with this study. “Land use/Land cover changes detection and urban sprawl analysis” article of “International Journal of Advance Scientific Research and Technology” is helpful for our methodology purpose. “Remote Sensing and GIS Application in Change Detection Study in Urban Zone Using Multi Temporal Satellite” article of “International Journal of Geomatics and Geoscience” deals with Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land. In the study, Remote Sensing and geographic information system (GIS) were used in order to study land use/land cover changes. An article like “Spatio –temporal analysis to detect urban sprawl using Geoinformatics: A case study of Kolkata” is very much related with our study. In this article urban sprawl and urban growth analysis has been discussed. The book “Analysis of urban growth and urban sprawl from remote sensing data”- Basudeb Bhatta is related for urban growth and urban sprawl analysis.

3. Results and discussion

3.1 Urban growth and urban sprawl analysis and comparisons of KMC and HMC

a) Urban growth analysis

For urban growth analysis of KMC & HMC, we have used here some statistical techniques like weights of evidence method and Pearson’s Chi-square method.

<table>
<thead>
<tr>
<th>Zone</th>
<th>1975</th>
<th>1990</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>41.56</td>
<td>47.4</td>
<td>64.56</td>
</tr>
<tr>
<td>North East</td>
<td>35.72</td>
<td>52.4</td>
<td>54.21</td>
</tr>
<tr>
<td>East</td>
<td>24.07</td>
<td>49.47</td>
<td>64.9</td>
</tr>
<tr>
<td>South East</td>
<td>24.38</td>
<td>43.51</td>
<td>61.57</td>
</tr>
<tr>
<td>South</td>
<td>29.03</td>
<td>55.44</td>
<td>64.21</td>
</tr>
<tr>
<td>South West</td>
<td>36.97</td>
<td>50.8</td>
<td>56.96</td>
</tr>
<tr>
<td>West</td>
<td>20.26</td>
<td>24.36</td>
<td>28.54</td>
</tr>
<tr>
<td>North West</td>
<td>23.62</td>
<td>41.33</td>
<td>47.4</td>
</tr>
</tbody>
</table>
Table 2: Table Showing Observed Increase in Built-up Area of KMC

<table>
<thead>
<tr>
<th>Zone</th>
<th>1975-1990</th>
<th>1990-2012</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>25.4</td>
<td>15.43</td>
<td>40.83</td>
</tr>
<tr>
<td>North East</td>
<td>16.68</td>
<td>1.81</td>
<td>18.49</td>
</tr>
<tr>
<td>East</td>
<td>5.84</td>
<td>17.16</td>
<td>23</td>
</tr>
<tr>
<td>South East</td>
<td>19.13</td>
<td>18.06</td>
<td>37.19</td>
</tr>
<tr>
<td>South</td>
<td>26.41</td>
<td>8.77</td>
<td>35.18</td>
</tr>
<tr>
<td>South West</td>
<td>13.83</td>
<td>6.16</td>
<td>19.99</td>
</tr>
<tr>
<td>West</td>
<td>4.1</td>
<td>4.18</td>
<td>8.28</td>
</tr>
<tr>
<td>North West</td>
<td>17.71</td>
<td>6.07</td>
<td>23.78</td>
</tr>
<tr>
<td>Column Total</td>
<td>129.1</td>
<td>77.64</td>
<td>206.74</td>
</tr>
</tbody>
</table>

Figure 3: Built-Up Area of KMC

Figure 4: Percentage of Observed Increase in Built-Up Area of KMC
4. Analysis for expected increase in built-up area of KMC

4.1 Weights of evidence method

For calculating the expected built-up growth, this method is used here. For expected built-up growth for each variable is calculated by the products of marginal total/grand total (Ameida et al., 2005). Therefore, the expected expansion $M^E_{ij}$ for the i-th row and j-th column is:

$$M^E_{ij} = \frac{M_iM_j}{M_g}$$

$M_i$ = Marginal totals for the sum of the i-th row of the observed increase in built-up area and, $M_j$ = Marginal total for the sum of j-th column of the observed increase in built-up area. $M_g$ = Grand total of the observed increase in built-up area.

Table 3: Zone comparison

<table>
<thead>
<tr>
<th>Zone</th>
<th>North</th>
<th>North East</th>
<th>East</th>
<th>South East</th>
<th>South</th>
<th>South West</th>
<th>West</th>
<th>North West</th>
</tr>
</thead>
</table>

Figure 5: Percentage of Expected Increase in Built-Up Area of KMC

Table 4: Table for Difference between Observed and Expected Increase in Built-up Area of KMC

<table>
<thead>
<tr>
<th>Zone</th>
<th>North</th>
<th>North East</th>
<th>East</th>
<th>South East</th>
<th>South</th>
<th>South West</th>
<th>West</th>
<th>North West</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975-1990</td>
<td>-0.87</td>
<td>5.49</td>
<td>0.7</td>
<td>-3.37</td>
<td>5.13</td>
<td>1.76</td>
<td>-4.94</td>
<td>3.32</td>
</tr>
<tr>
<td>1990-2012</td>
<td>0.87</td>
<td>-5.49</td>
<td>-0.7</td>
<td>3.37</td>
<td>-5.13</td>
<td>-1.74</td>
<td>4.94</td>
<td>-3.32</td>
</tr>
</tbody>
</table>
Analysis: By calculating the difference between observed and expected increase in built-up area, we can identify the disparity for each zone. Whereas negative values indicate less growth and positive values show more growth than expectations of KMC.

Analysis for Degree of Freedom for Expansion of Built-up Area in Each Zone of KMC: Pearson’s Chi Square Method: To determine the degree of freedom chi square test was performed with the Pearson’s chi square expression \((\text{observed} – \text{expected})^2 / \text{expected}\). Chi square static for each zone is calculated as:

\[
X^2 = \sum_{i=1}^{n} \frac{(M_i - M_i^E)^2}{M_i^E}
\]

**Table 5: Table Showing Degree of Freedom for Urban Growth of KMC**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>0.05</td>
</tr>
<tr>
<td>North East</td>
<td>6.28</td>
</tr>
<tr>
<td>East</td>
<td>11.84</td>
</tr>
<tr>
<td>South East</td>
<td>1.27</td>
</tr>
<tr>
<td>South</td>
<td>3.13</td>
</tr>
<tr>
<td>South West</td>
<td>0.64</td>
</tr>
<tr>
<td>West</td>
<td>7.19</td>
</tr>
<tr>
<td>North West</td>
<td>1.94</td>
</tr>
</tbody>
</table>
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Degree of Freedom for Urban Growth of KMC

**Figure 7:** Degree of Freedom of KMC

Degree of Freedom for Urban Growth of KMC (1975-2012)

**Figure 8:** Map for Urban Growth of KMC

Analysis: There has a lower limit 0, when the observed value exactly equals to the expected values. It shows that degree of freedom is low for north and south-west, moderate for south-east and south, high for west and north-east, very high for east area of KMC. Higher degree of freedom for a zone is an indication of unstable development within zone with the change of time.

Table 6: Table Showing the Percentage of Built-up Area of HMC

<table>
<thead>
<tr>
<th>Zone</th>
<th>1975</th>
<th>1990</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>3.54</td>
<td>6.69</td>
<td>7.79</td>
</tr>
<tr>
<td>North East</td>
<td>12.66</td>
<td>16.27</td>
<td>20.86</td>
</tr>
<tr>
<td>East</td>
<td>5.68</td>
<td>13.43</td>
<td>15.18</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Zone</th>
<th>1975-1990</th>
<th>1990-2012</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>3.15</td>
<td>1.1</td>
<td>4.25</td>
</tr>
<tr>
<td>North East</td>
<td>3.61</td>
<td>4.59</td>
<td>8.2</td>
</tr>
<tr>
<td>East</td>
<td>7.75</td>
<td>1.75</td>
<td>9.5</td>
</tr>
<tr>
<td>South East</td>
<td>4.31</td>
<td>2.82</td>
<td>7.13</td>
</tr>
<tr>
<td>South</td>
<td>2.37</td>
<td>1.53</td>
<td>3.9</td>
</tr>
<tr>
<td>South West</td>
<td>0.71</td>
<td>1.29</td>
<td>2</td>
</tr>
<tr>
<td>West</td>
<td>0.38</td>
<td>0.88</td>
<td>1.26</td>
</tr>
<tr>
<td>North West</td>
<td>1.49</td>
<td>1.95</td>
<td>3.44</td>
</tr>
<tr>
<td>Column Total</td>
<td>23.77</td>
<td>15.91</td>
<td>39.68</td>
</tr>
</tbody>
</table>

Analysis: By this comparative study between KMC and HMC on the basis of degree of urban sprawl for different time. In KMC from 1975 to 2012 the urban sprawl is increasing continuously. It clearly shows that the city is becoming spatially dispersed or sprawled with time. But in HMC 1975 to 1990 have increased at an alarming rate, which shows that from
1975 to 1990 the city had sprawled but from 1990 to 2012 the entropy values has declined, which shows the city is becoming compact rather than sprawling.

**Figure 10:** Percentage of Observed Increase in Built-Up Area of HMC

5. Conclusions

The urban growth scales provided by such models can help local authorities in general to establish investment goals in terms of establishing social and other infrastructure equipments. The urban sprawl scales on the other hand can help in understanding and restricting the sprawl in consideration of sustainable development. GIS and Remote Sensing and various statistical techniques have proved to be useful for analyzing the change detection analysis, urban growth and urban sprawl. By analysing these urban issues we have got good result for future planning of KMC and HMC. By analysing the urban sprawl we see that the degree of sprawl is very high for south east zone in KMC but in HMC the degree of sprawl is very high for north east and north west zone. But here urban growth is low for these zones. We can see that in KMC the urban growth rate is very high in the eastern zone where as in HMC there is no higher urban growth rate, but only in the eastern zone of HMC the moderate growth rate is observed.

6. References


7. Bhatta.B. Analysis of urban growth and urban sprawl from remote sensing data.