Prediction of Urban Sprawl in Hyderabad City using Spatial Model, Remote Sensing and GIS Techniques

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ABSTRACT
This paper presents a study that integrates Remote Sensing, GIS, and dynamic spatial modelling for predicting urban spatial growth, given the different development conditions. The prediction is based on SLEUTH, a modified Cellular Automata model consisting of an urban growth and land cover change transition sub models was chosen to calibrate urban growth in Hyderabad city. The calibrated model allows us to fill gaps in the discontinuous historical time series of urban spatial extent, since maps and images are available only for certain period between 1950 and 2004. Using the model a spatial forecast of urban growth is done till 2055. The predicted mode of growth in Hyderabad is organic or edge growth and road influenced growth due to very high coefficient of spread and road gravity. This study reveals that there will be increase in urban growth of 120% between 2005 and 2055.

1. INTRODUCTION
The urban sprawl refers to the areal expansion of urban concentrations, it refers more to the pace and magnitude of land conversion to urban use and areal expansion of the city. As the city expands in area with more population growth the land use gets changed with the hitherto non-urban areas like forest, agricultural lands, other vegetative areas, water bodies etc., getting replaced by concrete structures and black-topped roads (Strahler, 1975). The main aim of this study is to apply spatial modeling for urban growth prediction from 2005 to 2055 using Remote sensing and GIS.

2. STUDY AREA
Hyderabad, the historic beautiful city is the capital of Andhra Pradesh, India and extends from longitude 78° 23' to 78° 33'E and latitude of 17° 17' to 17° 31' N. The study area shown in Figure 1 covers about 2,172 km² and encompasses the administrative districts in the integrated town and city planning scheme which are greatly influenced by urban sprawl.

3. THE SLEUTH MODEL
SLEUTH is a modified cellular automata model which consists of an urban growth sub model and a land cover change transition sub model (Clarke, 2002). The urban growth model is the main component of SLEUTH which is tightly coupled with the land cover change transition model (Silva and Clarke, 2002). SLEUTH simulates four types of urban land use dynamics: Spontaneous growth, New spreading center growth, Edge growth and Road influenced growth (Clarke et al., 1997). The growth rules are applied sequentially during each cycle and are controlled by five coefficients, namely: Diffusion, Breed, Spread, Slope Resistance and Road Gravity.

4. MATERIALS AND METHODS
4.1 Data sources
This study utilized data from various sources, including GIS digital data, satellite images and topographic maps. The satellite data for the study area were received from NRSC and topo maps from Survey of India.

4.2 Data Preparation
The input data requires by the SLEUTH model includes Slope, Land use, Exclusion, Urban extent, Transportation and Hillshade. Data preparation depends greatly on GIS and remote sensing techniques, for example, data conversion, recategorization and data import/export. The software used for preparing the input data includes ERDAS Imagine version 8.5, ArcGIS version 9.1 and Adobe Photoshop version 7.0.

Input data for the study area is prepared at three resolutions to calibrate the SLEUTH model. The cell size of images 200m, 100m and 50m corresponds to the resolutions of 120 m, 60 m and 30 m. The selection of these spatial resolutions was based on Dietzel (2003) and Candau (2002).

4.3 Calibration of SLEUTH Model
The calibration has been carried out based on SLEUTH version 3.0 beta program. The code is written in C programming language, and supports three modes: test, calibration, and prediction. For this study, all three modes viz. test calibration and prediction modes are used. The model is operated by a Linux Redhat version 9.0 on PC microcomputer. All input grey scale gif images at different resolutions are verified in the SLEUTH test mode. Brute-force calibration involves fitting the model to historical data on land use, transportation, and urban extent. Using the best coefficients derived from calibration, SLEUTH is run for the historical time period to initialize forecasting. Coefficient values are shown in table 1 which is derived from forecasting mode to predict growth of the study area.

Table 1: Coefficient values to predict growth:

<table>
<thead>
<tr>
<th>Coefficient Type</th>
<th>Prediction Best Fit Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion</td>
<td>1</td>
</tr>
<tr>
<td>Breed</td>
<td>1</td>
</tr>
<tr>
<td>Spread</td>
<td>79</td>
</tr>
<tr>
<td>Slope</td>
<td>31</td>
</tr>
<tr>
<td>Road Gravity</td>
<td>49</td>
</tr>
</tbody>
</table>

5. RESULTS AND DISCUSSION
When the calibration mode is completed, the results are used for forecasting studies in the prediction mode. SLEUTH forecasts rely on replicating growth trends from the past. Once a coefficient set is found that can best describe how urban change has occurred over time, these values are used to forecast future growth.
The urban expansion in Hyderabad City is a mixture of spread and road gravity expansion. The urban expansion is mainly by spread (about 79%), but is resisted by slope. The reason for the urban expansion is due to IT industries, educational institutes and historical/tourist places. The high Road Gravity coefficient value derived from final calibration (49) indicates the abundance of urban growth along the road side and as a result many new buildings or urban centres are being developed on road side. The spread value is adjusted to the local characteristics at the final calibration.

Figure 2 Predicted Urban Growth of Hyderabad City

The predicted urban area change in Hyderabad City is shown in Figure 2 between 2005 and 2055. The prediction of the city continues to expand more and more rapidly. Much of the growth in Hyderabad is now taking place due to the growth of the Information Technology (IT), Business Process Outsourcing (BPO) and other software services, which are increasingly concentrating in the outer areas that are designated for them by the State Government. Besides, large manufacturing and integrated Special Economic Zones (SEZs) are expected to be coming up in these areas. Film industry is also a major driver of the various services and of the employment generation. Recently, large real estate and construction activity has been playing a major role in the economic development and employment generation, and much of it is occurring in the areas outside the urban agglomeration.

Figure 3 Modelled Future Urban Growth

It is seen from figure 3 that the spread coefficient is continuously increasing which indicates the Organic Growth of the city is continuously spreading. In the same way Road Gravity coefficient is also progressively increasing which indicates the Road influenced growth more along the road side. However, the rise of increase of Road Gravity coefficient is more than that of Spread coefficient. Therefore, the urban sprawl would be more influenced by the road than the organic growth in Hyderabad city beyond 2055.

The extension of urban sprawl of Hyderabad has been inhibited. The hitherto unoccupied area of places like Banjara hills and Jubilee hills are occupied. The boulders and tors which are lying protected are broken to be used for foundation stones of buildings coming up on the sites. In the northern direction the sprawl have crossed Bolaram and reached Hakimpet. As observed the pull factor is the Poultry farms and grape gardens, especially around Shamirpet. Some of the measures taken by the transportation department to develop Shamirpet lake as a holiday resort has been attracting people along the transportation artery linking the city with the lake. The areas along the Highway are being built up. The urban sprawl in Hyderabad city is not only in radial direction that is from the core of the city but also in linear along road sides.

6. CONCLUSIONS

SLEUTH provides key functionalities like interactive scenario development and the ability to visualize and quantify outcomes spatially. The availability and consistency of historic data sets, especially those that are earlier than satellite availability, is a potential issue for some applications. Empirical calibration of the model using Landsat TM image maps of past change aids the model predictions of future change. Calibration at high level of spatial detail remains a computationally intensive process, requiring sufficient use of a parallel computing environment and may prevent the use of the model by local or nongovernmental agencies where computing resources may be a limiting factor. Despite these considerations, we find SLEUTH to be a useful tool for assessing the impacts of alternative policy scenarios.

Calibration of the SLEUTH model for Hyderabad indicates a very high spread coefficient, which means that the predicted mode of growth in Hyderabad is organic or edge growth. Hyderabad has been experiencing organic or edge growth and road influenced growth due to very high coefficient of spread and road gravity. Among Hyderabad Urban Agglomeration (HUA), Municipal Corporation of Hyderabad is the major area that drives the population and urban growth in HUA.

The quality of the input data and the selection of optimal parameter ranges should be considered carefully to improve the calibration result. Since the calibration of SLEUTH is computer intensive, it should be implemented on a super computer or to be run on a parallel processing and high performance computing methods (e.g. cluster computer) in order to obtain the result in a timely manner. In conclusion, applying the SLEUTH model to Asian countries has just started and this being the first attempt in India, there is still a need for modellers to explore in more aspects of using this model. This calibration experience has provided us some insights to SLEUTH model and more understandings on how the Cellular Automaton adapted to the urban environment in India.

REFERENCE