Evaluation Of A Self-Modifying Cellular Automata In Modelling Urban Growth In Nyeri (Kenya)

Kenneth Mubea, Gunter Menz

Abstract: Urban growth modelling cellular automata has blossomed due to the advancement in geographic information systems (GIS), remote sensing and computer technology. Among such urban growth models, our urban growth model (UGM), was modified from SLEUTH (**S**lope **L**and-use **T**ransport **H**ill-shade) model. UGM has been integrated in the XULU modeling frame-work (e**X**tendable **U**nified **L**and **U**se Modelling Platform). In this research we evaluated a modified UGM whose transition rules were modified. In order to arrive at urban growth modelling, we used multi-temporal Landsat satellite image sets for 1987 and 2010 to map urban land-use in Nyeri. We compared our results with a normal UGM simulation. Thus, we arrived at two urban growth simulations for Nyeri in order to get a better glimpse of land-use system dynamics. Both models were calibrated and urban growth simulated until the year 2030 when Kenya plans to attain Vision 2030. Observed land-use changes in urban areas were compared to the results of both UGM models for the year 2010. The results indicate that the two models resulted in urban growth in different directions and magnitudes. This approach is useful to planners as it gives the scenarios of using different transition rules of a cellular automata model in urban growth modelling.

Keywords: GIS, Urban Growth Model, Cellular automata, XULU, Simulation

1 Introduction

Models based on cellular automata (CA) have been applied intensively in urban growth modelling [1].CAs are dynamical systems in which space and time are discrete and consists of an array of cells, each of which can be in one of a finite number of possible states, updated synchronously in discrete time steps, according to a local, identical interaction rule [2].Tobler [3] was the first pioneer who explored urban CA simulation and came up with a geographic model. The model was dynamic with several land-uses namely residential, commercial, industrial, public and agriculture, as cell states and enforced neighborhood rules in the model. Wolfram [4] did a systematic research on CA and their relationships with dynamic systems, and came up with classes of CA behavior. White and Engelen developed a constrained CA and this was a big step into urban modelling using CA [5]. They integrated the CA models in 1960s and Tobler's geographic model [3]. Models based on CA have evolved over the last decades in simulating urban development growth and patterns including SLEUTH [6]. SLEUTH is an acronym for Slope, Land-cover, Exclusion, Urban, Transportation and Hill shade. SLEUTH explores complexities of urban cells and incorporates biophysical factors namely: urban, road, transportation, slope and exclusion layer. The development of the GIS as well as the integration of a GIS and transportation with urban modelling has facilitated urban modelling with rich data sources and new techniques [7].

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Our Urban growth model (UGM) was modified from SLEUTH and applied for the German federal state of North-Rhine Westphalia [8]. Simulation of urban land-use change in North Rhine- Westphalia (Germany) with the Java-based modelling plat- form XULU. UGM was later applied in two cities in Kenya, namely; Nakuru [9] and Nairobi [10]. UGM runs in the user friendly modeling frame-work XULU (eXtendable Unified Land Use Modelling Platform) which was developed by Schmitz, Bode, Thamm, & Cremers [11]. XULU takes over the most important functions concerning model control and visualization. Cities in Africa have experienced high growth rates due to high rural to urban migration [12]. Thus this presents a good case to apply our UGM in Nyeri. In this study, we evaluated a self-modifying UGM for Nyeri based on XULU modelling platform. Urban land-use data for Nyeri was derived from annual Landsat image data acquired in 1987 and 2010. This was for the first time a self-modifying UGM has been applied in Kenya. We came up two models, our normal UGM and a modified UGM which were calibrated and validated in XULU using 2010 as the reference year. We compared the two models based on the simulated urban growth and model coefficient values. The models were used to predict future urban land-use development in the year 2030. This offers a worthwhile approach for the study of future urban land-use trends in Nyeri as Kenya plans to achieve Vision 2030, the nation's ambitious economic and social development program [13]

2 The Study Area

Nyeri municipality lies between latitudes 0° 21′ and 0° 29′ South and longitude 36° 52′ and 36° 57′ East in Kenya. The city covers an area of 136 km^2 and lies at an average altitude of 1,750 meters above sea level (Figure 1). Nyeri is located about 150 kilometers north of Kenya's capital Nairobi, in the country's densely populated and fertile Central Highlands, lying between the eastern base of the Aberdare Range, which forms part of the eastern end of the Great Rift Valley, and the western slopes of Mount Kenya. Within its administrative borders the city includes urban, agriculture, and rangeland land-uses as well as open/transitional areas, and remnants of evergreen tropical forests. The population was 98,908 in Kenya's census of 1999 (Republic of Kenya, 2000) and 125,357 in 2009 (Republic of Kenya, 2010).