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Spatio-temporal analysis of land use transition and urban growth characterization in Benin metropolitan region, Nigeria

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A B S T R A C T

Over the years, urban spatial growth has initiated enormous amount of changes in land use configuration worldwide. Such modification has provoked the development of urban sprawl and massive land use replacement which poses serious threat to sustainable development. Consequently, numerous researches on urban growth and land use change have emerged from mostly developed countries. In cities of developing countries like Nigeria cities, there is limited understanding because of the few amount of studies in this topic, and most of which lack empirical groundwork. Hence, the need to conduct more quality researches arises in order to achieve significant understanding of the spatial pattern of land use transformation and dynamics of urban landscape. Such information would assist spatial planners to enact legislation pertaining to urban system, especially in cities of developing countries like Nigeria where empirical studies on this topic are limited and state-of-the-art tools for analyzing and measuring sprawl processes are lacking. Multi temporal remotely sensed data was utilized in this study in collaboration with GIS techniques, spatial metrics and indications. Landsat data of three temporal periods covering Benin metropolitan region were classified this revealed unprecedented and unique land use transition process were urban and forest lands have substantially replaced agricultural lands. As evident from the result of the study, substantial amount of agricultural communities mostly along the inter-state roads have become urbanized. The analysis shows that urban growth tend to double in size every 12 years with high magnitude of region-wise sprawl as shown by Shannon's entropy and such sprawl degree is largely influenced by the existing trunk roads. Zone-wise, metrics and Shannon's entropy revealed that Northeast and Southeast zones exhibit stronger sprawl tendency and have also turn out to be growth hotspot in the region. In addition, incremental spatial autocorrelation identified two distinct regime of urban expansion in the region, compaction regime covering 7 km radius from the centroid and edge expansion regime which exhibits dispersion with intermittent cluster peaks. This is supported by the result of landscape spatial metrics which indicates that urban land use aggregative force is more pronounced around the centroid and became more fragmented as built-up patches sprawl towards the city edge. The results show the effectiveness of integrating GIS methodology, spatial metrics and indicators to analyze spatiotemporal remote sensing data in order to assist urban planning and legislation.

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1. Introduction

Urbanization is an anthropogenic phenomenon of development that will perpetually increase with time. It is a fundamental process that cut across every countries of the world especially where humans dwell and is chiefly heightened by rapidness in population growth, increase in production, exploitation of natural resources, economic and infrastructural advancement etc. Urbanization which has been identified (Bhatta et al., 2010a) as an aspatial and social process initiating behavioral changes in lifestyle of the people living in towns and cities, often follow from the

impact of cities on society, is a product and aftermath of urban growth. Urban growth, on the other hand, is a combination of both spatial and demographic processes, with the latter being the driver of the former. It occurs when local patches of settlement are forced to agglomerate based on population change and this process may lead to sprawl.

Urban growth over the years, has become a powerful centrifugal force and this has initiated substantial amount of changes in land use and ecological landscape globally (Moghadam and Helbich, 2013). Unplanned and unchecked urban growth, often loosely referred to as urban sprawl, poses serious problems such as loss of arable land, flooding, over utilization of public infrastructures, distortion of initial urban design, environmental degradation, strain on available sanitation and health services,

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increase in crime rates, decrease in job, congestion and other traffic related issues (Aitieri et al., 2014; Kahn, 2006; Kit et al., 2012; Moghadam and Helbich, 2013; United Nations, 2009; Wang et al., 2003; Weng et al., 2007). These issues are fast becoming a threat to sustainable development in both developing and advanced regions of the world.

Urban sprawl initially was a North America issue which is driven by imbalance in population and development triggering unsustainable land use and land cover change. This phenomenon has over the years become a global issue and highlighted as a significant research activity, particularly rooted in developing countries where sustainable development is greatly impede. However, there exist no universally accepted definition of urban sprawl in the literature. Most scholars do not make any attempt at defining this dynamic process, instead a general discussion of its characteristics is presented (Hu et al., 2015; Hennig et al., 2015; Zeng et al., 2015). Others gave a loosely and not all round rigorous definition (Helbich and Leitner, 2009; Harvey and Clark, 1965; Brueckner, 2000). Urban sprawl is a specific kind of growth and morphological development often resulted from rapidly uncontrolled urban expansion. Thus, a definition of urban sprawl accepted by many researchers because it contains vital characteristics of sprawl and the basic consequences, although can still be debated, is presented by Bhatta (2010) and Sudhira and Ramachandra (2007). Their definition perceived urban sprawl as unplanned and irregular pattern of city growth, triggered by a host of multidimensional processes which often result to inefficient resource utilization, changes in land use and land cover, increase in landscape fragmentation and built-up area.

However, the spatial configuration and dynamics of urban growth are important topics in the analysis of contemporary urban studies (Aitieri et al., 2014). This is owing to the stark reality that over half the world's population resides in urbanized regions. This proportion as estimated by United Nations (2012) will rise to more than 72% by 2050. Most of these hysterical and pervasive urban growth will occur in developing countries (Girard et al., 2007; Moghadam and Helbich, 2013). This has given rise to diverse empirical and descriptive researches on urban growth and land use conversion (Antrop, 2004; Gomez-Chova et al., 2006; Herold et al., 2003; Messerli, 1997; Moghadam and Helbich, 2013; Wu et al., 2006; Yu and Ng, 2007).

Rapid growth in urbanization, which has been predicted to be a major pervasive problem for the ecological landscape of urban regions in developing nations, will remain as one of the critical concerns of global change in the 21st century that will distress the human wellbeing (Sui and Zeng, 2001). This rising level of urbanization and land use change also threatens the ecosystem of large cities found in advanced countries in the globe, initiating several landscape and ecological issues that are feared to impede sustainable human development (Li and Yeh, 2004; Liu et al., 2007; Wolch et al., 2014). Rapid and uncontrolled land use transition and sprawl in response to urbanization has high propensity to initiate challenges such as flooding, shortage in potable water and food supply, negative microclimatic condition due to rising temperature, thereby escalating the global issue of climate change. Such disturbing rapid urban expansion in the world, observed especially in part of Asia and North America (Ramachandra et al., 2012; Kit et al. 2012; Bhatta, 2009; Warwade et al., 2013; Sui and Zeng, 2001; Hamidi and Ewing, 2014; Xiao, et al., 2006; Xian and Crane, 2005) has motivated scholars to conduct researches on urban growth globally.

Achieving considerable amount of understanding of the spatial patterns, configuration and dynamics of urban system is paramount if the goal of spatial planning is to attain sustainable development and strike a balance between the components of the environment and sociological behavior of the people. To match these factors, more information-mostly high quality and with empirical basis-is needed for urban planning and decision making especially in developing countries.

The review of available literature shows that there exist plethora of researches in urban growth, sprawl, morphology and land use transition, much of these are dedicated to cities in more developed nations of the world (Antrop, 2004; Brown et al., 2000; Chen et al., 2000; Civco et al., 2002; Deng, et al., 2009; Dietzel et al., 2005; Foresman et al., 1997; Gaubatz, 1999; Gomez-Chova et al., 2006; Hathout, 2002; Ji et al., 2006; Lo and Yang, 2002; Luck and Wu, 2002; Masek et al., 2000; Muller and Middleton, 1994; Phinn and Stanford, 2001; Quan et al., 2013; Wu et al., 2006; Yang et al., 2003; Yu and Ng, 2007). Cities of most developed countries, like the ones of developing nations of the world, though, have high tendency to experience urban sprawl, because of their proactive characteristics, their well-established technological foundation and policies, the problem of unprecedented urban growth and uncontrolled urban expansion have been drastically curtailed. This success was achieved through forecast, modeling and systematic predictions from earlier empirical researches on urban land use and development (Batty et al. 1989; Burgess, 1925; Ellefsen et al., 1973; Harris and Ullman, 1945; Hart, 1976; Hoyt, 1939; Lo and Welch, 1977).

In Nigerian cities few studies have been conducted on this topic, and most of which adopted descriptive approach towards assessing the spatial patterns and examining the various changes that have taken place in the urban landscape (Adeoye, 2012; Ejaro and Abdullahi, 2013; Fabiyi, 2006; Garba and Brewer, 2013; Ogunbodede and Balogun, 2013; Oyinloye and Kufoniyi, 2013), indicating that the quality of information and level of understanding gained so far is inadequate, thus, will not be enough for meaningful planning purposes. This is because in most Nigeria cities, the issue of urban sprawl and land use dynamic have not been fully understood neither has it been taken seriously by policy maker and urban planners. Urban sprawl, expansion and land use conversion remain an overwhelming challenges for most researchers and policy makers in the world. Such problems have been so neglected by researchers and stakeholders in Nigeria. This explains the few amount of empirical literature emanating from the country regarding this topic.

Benin metropolitan region which is taken here as a local study point present a unique case which is worthy of attention. It is located in a country were urban planning and land use management have been deserted by government and other relevant agencies and left in the custody of private developers whose purpose is to make profit with little concern for the balance of the ecosystem and landscape suitability. In the past two decades, the city (Benin) has witnessed rapid population growth and this has out weighted the available infrastructure, coupled with the rising need for shelter. This has resulted in massive loss of arable and forest lands to impervious surfaces. In addition, many large contiguous agricultural and rural settlements have also been converted to dense urban land use. A combination of such processes with multitudes of associated urban problems have serious threat and implication for the city's landscape and ecological balance. Therefore, there is an urgent need to understand and assess the state of affair regarding this topic and conduct robust researches that will likely fill the gap in literature.

Literature review however, suggested that several studies emanating from other countries have dealt with this issue from multidimensional perspective using robust and empirical methodologies. For example, Bhatta et al. (2010a, 2010b) comparing the central theme of related literature found that urban land use dynamic and sprawl development have been looked at from three perspectives: spatial patterns of urban land use (Galster et al., 2001; Ramachandra et al., 2012; Taubenbock et al., 2009b; Wilson