Article title: Urban growth monitoring using spatial landscape matrices
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Urban growth monitoring using spatial landscape matrices.

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Abstract

With over 80% of global GDP created in cities, urbanization may contribute to long-term growth if properly managed. (The World Bank, 2021). In Uganda, the population living in urban areas are rising at a rate of 2.335% since 1990 to 2020. Cities must act fast to plan for expansion and provide the fundamental services, infrastructure, and affordable housing that their growing populations require. Urbanisation occurs at the expense of transformation of other landscapes hence the process of urbanization has a large influence on landscape and ecosystem function. For assessing policy alternatives for future growth and sustainable development of urban planning must be considered. Through mapping and analyzing land use/land cover transition in urban areas, as well as monitoring their environmental effects with the help of landscape metrics was the focus of this research. Landsat Images of 1990, 2000, 2010 and 2020 were used for this study, band ratios of NDVI, NDBI, NDWI were used for image enhancement to clearly identify the vegetated areas, built up areas and the areas that were covered with water, then a maximum likelihood classification technique was used to classify the images accordingly with an accuracy assessment of above 80% was accepted, the resulting classified images were then taken to FRAGSTATS for computation of landscape metrics. The metrics examined included class area, number of patches, total core area, core area percent of landscape, splitting Index, and landscape division index. It was discovered that the urban areas that converged between 1990 and 2020 contributed significantly to the fragmentation of predominantly the primarily vegetated regions of the research area, as well as the loss of the core portions of several habitats.

Keywords: Spatial Landscape Metrices, Urbanization,
Introduction

Globally, 55% of the population lives in urban areas. By 2045, the number of people living in cities will increase by 1.5 times to 6 billion, adding 2 billion more urban residents, with more than 80% of global GDP generated in cities, urbanization can contribute to sustainable growth if managed well (The World Bank, 2021). In Uganda, 11.1% of the country’s population were living in urban areas in 1990 and by 2020, 25.0% of the country’s population was leaving in urban areas, these values are increasing at an average rate of 2.335% (Knoema, 2021). City leaders must move quickly to plan for growth and provide the basic services, infrastructure, and affordable housing their expanding populations need. The process of global urbanization is accelerating and has potentially large influences on landscape and ecosystem function in cities and surrounding areas (Li et al., 2010). The transformation of land covers from rural/natural ecosystems to built-up land that supports various types of human activity is one of the major consequences of urbanization. These changes have an impact on local geology, soil, water, flora and fauna and the human existence of the region's ecosystem services (Furberg, 2014a). For assessing policy alternatives for future growth and fostering sustainable urban planning, mapping and analyzing land use/land cover transition in urban areas, as well as monitoring their environmental effects, is critical.

For those striving toward a more sustainable developed future, urbanization presents multiple obstacles. As cities expand, internal difficulties will arise, their impact on the surrounding external natural environment upon which they depend is of critical importance (Lambin et al., 2001). Land use/land cover change (LULC) mapping and study of urban areas are critical for monitoring this "ecological footprint" and deciding policy strategies and/or solutions for future development and environmental protection. Thus, it is important for us to analyze urbanization as one of the major changes humanity does to the earth surface (Wentz et al., 2009).

The use of remote sensing and geographic information systems (GIS) technologies to capture and map urban LULC changes has been demonstrated in previous studies. e.g. (Ban et al., 2014, 2015; Qin et al., 2013; Yang, 2006) Tracking the environmental impact of these changes has often been undertaken with the help of landscape metrics (Botequilha Leitão & Ahern, 2002; Haines-Young et al., 1993; Hargis et al., 1998; Kamusoko & Aniya, 2007; Laboratory
et al., 1988; Li et al., 2010; McGarigal & Marks, 1995; Monica G. Turner, 1990; Narumalani et al., 2004). For mitigation and planning purposes, there is a need for the creation of ecosystem status indicators based on GIS and remote sensing data (Revenga, 2005). Remote sensing specialists have perhaps focused on technological issues as their principal concern, rather than ecological problems (Aplin, 2005). Yet there exists a greater potential for use of remote sensing within landscape ecology but also draw attention to a traditional divide between the remote sensing and ecological science research communities (Newton et al., 2009).

Africa is projected to have the fastest urban growth rate in the world and by 2050, Africa’s cities will be home to an additional 950 million people, much of this growth is taking place in small and medium-sized towns (OECD & Club, 2020). The overall aim of this study is to examine the scale of urban growth and/or sprawl in the areas around the selected built up areas in Masaka district and their possible effects on the ecosystem utilizing landscape metrics and other environmental indicators. The analyses will be dependent on classifications of optical satellite imagery (Landsat TM/ETM+) of 1990, 2000, 2010, and 2020. A method of supervised classification (a maximum-likelihood classification (MLC)) is to be used to retrieve class boundary.

This research intends to show how GIS techniques can be used to evaluate both the spatial-temporal dynamics of urban growth and its effects on the ecosystem in selected built-up areas in Masaka District using urban and environmental indicators derived from remote sensing data. The findings will be useful knowledge for urban and environmental planners in several different areas by comparing trends and impacts of urban development in different regions.
Major Objective.
To assess urban growth, as well as its possible effect on the ecosystem, in the built-up areas of Masaka District in Uganda, using landscape metrics.

Specific Objectives.
1. To identify analyze the extents of urbanization that has happened on the selected built up areas of Masaka District and its surroundings for the last three decades
2. To analyze the different landscapes using landscape matrices and the possible effects on the preserving biological diversity for the last three decades.

Study Area.
Masaka District was used as a case study, Masaka District is located in the southern hemisphere. The district is bordered by Bukomansimbi District to the north-west, Kalungu District to the north, Kalangala District to the east and south, Rakai District to the south-west, and Lwengo District to the west (Masaka District, 2021).
Data and Methodology

Data Used.

The datasets used include both raster dataset and vector datasets, the raster datasets include Landsat images and these include Landsat 5, which was used for the dataset of 1990, Landsat 7 that was used for the datasets of 2000 and 2010, Landsat 8 that was used for the dataset of 2020, the district boundary shapefile was used as the vector dataset. The images considered were those with the least amount of cloud cover.
LANDSAT 4-5 TM

LANDSAT 7 ETM

LANDSAT 8

DISTRICT SHAPEFILES

1990

2000

2010

2020

Clipping

BAND RATIO

NDVI

NDBI

NDWI

BAND RATIO

Is Classification Accuracy >80%

No


Bare Land: 1990, 2000, 2010, 2020

Computation of Landscape Matrices

Landscape Matrices That Show Different Ecological Processes
Data Acquisition

The United States Geological Survey (USGS) website provided access to a sequence of Landsat imagery from 1990 to 2020, with ten-year intervals. One Landsat-4/5 Thematic Mapper (TM) image dated 1990, two Landsat 7 ETM+ images of 2000 and 2010, and one Landsat 8 OLI image dated 2020 were chosen for this research.

Table 1: Landsat Images used for the study

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Data/sensor</th>
<th>Scale/Resolution</th>
<th>Path/Row</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landsat 4 (TM)</td>
<td>30m</td>
<td>172/060</td>
<td>22/12/1990</td>
</tr>
<tr>
<td>2</td>
<td>Landsat 7 ETM+</td>
<td>30m</td>
<td>172/060</td>
<td>12/02/2000</td>
</tr>
<tr>
<td>3</td>
<td>Landsat 7 ETM+</td>
<td>30m</td>
<td>172/060</td>
<td>30/11/2010</td>
</tr>
<tr>
<td>4</td>
<td>Landsat 8 OLI</td>
<td>30m</td>
<td>172/059</td>
<td>14/01/2020</td>
</tr>
</tbody>
</table>

Results and Discussions

4.1. Urban Growth Change Detection.

A supervised maximum likelihood classification was performed on the four images for the years 1990, 2000, 2010, and 2020. Five different land use/Land cover classes were identified namely: Wetlands, Primarily Vegetated, Built Up, Bare soils, and water. Figure 3 shows the land use/land cover types of the built-up areas of Masaka during the study periods.
Figure 2: Land Cover Maps of the Urbanized Areas of Masaka District in 1990, 2000, 2010, 2020
Table 2: Table showing Changes in landscapes.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (Sq KM)</td>
<td>%</td>
<td>Area (Sq KM)</td>
</tr>
<tr>
<td>Water</td>
<td>2213.986</td>
<td>10.47%</td>
<td>1347.6908</td>
</tr>
<tr>
<td>Wetland</td>
<td>5763.567</td>
<td>27.27%</td>
<td>4956.7628</td>
</tr>
<tr>
<td>Primarily Vegetated</td>
<td>7930.726</td>
<td>37.52%</td>
<td>7823.726</td>
</tr>
<tr>
<td>Built Up</td>
<td>3853.98</td>
<td>18.23%</td>
<td>5406.5668</td>
</tr>
<tr>
<td>Bare Land</td>
<td>1376.283</td>
<td>6.51%</td>
<td>1603.5998</td>
</tr>
<tr>
<td>Total</td>
<td>21138.542</td>
<td></td>
<td>21138.3462</td>
</tr>
</tbody>
</table>
The table above shows how different classes investigated have been changing over time, and it can be observed that among the greatly affected classes include the vegetated areas which most of the classes have been transformed to built up, for the water class, it disappeared during the time between the years 2000 – 2010, this can be attributed to many factors that include the wetlands growing over the water among others.

**Landscape Matrices**

Among the parameters considered for the analysis included Class area (CA), Number of Patches (NP), total core area (TCA), core area percent of landscape (CPLAND), Splitting Index (SPLIT) and Landscape Division Index (DIVISION)

**Class area (CA)**

*Table 3: A Table showing the Class area (CA).*

![Image of a bar chart showing Class area percentages for different classes over years: Vegetation, Built Up, Swamp, Water, Bare land.]

The class area shows how the different classes change, it can be observed that the class area (area of vegetated class) is reducing over the years hence this is having a negative effect on the habitats that are within the vegetated places, and the class area for the built up is observed to be increasing within the landscape. For the swamp, its slowly increasing in area and this can be attributed to the possibility of the wetlands taking over the open waters and also the fact that it was observed that the built up had a very minimal effect on the class of wetland, for the water class, it was all covered by the wetland between 2000 – 2010.
Number of Patches

The number of patches is a great sign of fragmentation, it is observed that the vegetated class is having an increase in the number of patches hence there is fragmentation happening to this class (this is not good as it reduces the core area for the habitat patches). The built up shows an increase in the number of patches between 1990 and 2000, and a decrease between 2000 – 2020, this means that the number of patches are significantly getting aggregated, the swamp also gets aggregated between 1990 – 2000, and a slight increase in the number of patched from 2000 – 2020.

Total core area (TCA)

Table 4: A table showing the Total Core Areas
This is the total area of a patch minus the area covered by the edge depth, a decrease in the TCA in the vegetated class shows a sign of fragmentation and a great loss of connectivity, this makes it hard for the animals to move through different patches of the same class, for the built up, the class didn’t have any core area by 1990, and there has been a significant increase mostly between 2010 – 2020, this means more aggregation and better connectivity.

Core area percent of landscape (CPLAND)

This is similar to the TCA, and shows the same conclusion but now this expressed as a percentage of the total landscape.
Splitting Index (SPLIT)

This is the probability of a particular patch to split up. It is observed that for the vegetated class, its probability of getting split up gets on increasing from 1990 – 2020, this is not a good sign mostly if it deals with conserving the vegetated class, it means that its chance of getting fragmented is raising which is contrary to the built up which is having its chances of getting split getting lower and lower with time, it getting more aggregated. The water class showed a higher chance of getting split up by the year 2000, and by 2010, it was no more, so more care needs to be taken on protecting the vegetated areas.
This is a probability that two animals placed at the different ends of a patch can actually meet, this can be seen that the vegetated class, the probability is getting higher throughout the study period, which is not the case to the built up areas where the probability is getting lower and lower.
Chapter Five: Conclusions and recommendations

5.1. Conclusion
The intent of this research was to get find out the impact of urbanization on the ecosystem with the use of GIS and landscape matrices, it was found that for the urban areas converged between 1990 and 2020 contributed greatly to the fragmentation of mostly the primarily vegetated areas of the study area, the core areas of different habitat has been lost.

5.2. Recommendations
Precise metrics of these spatial changes are required for long-term decision making regarding regional planning and the conservation of important native, core habitats.
References.


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