# Landscape Composition and Structure of River Sio Catcment

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## Abstract

Uganda's landscape is still under enormous threats from mainly anthropogenic activities. Therefore, the objective of this study was to assess the landscape composition and structure of River Sio catchment. The Sio catchment land use maps of 2004 and 2009 were analyzed using an ArcGIS 9.3 based Patch Analyst extension to assess the landscape composition and structure. At the landscape level, the sum of all land use/cover patches in River Sio catchment landscape was relatively high in 2004 (97%) compared to 3% in year 2009. Meanwhile, at class level in 2004, wetland and bushland patches reduced from 46%, 40% to 28% and 32% in year 2009 in the total patch area and individual numbers of patches in each class compared to small scale farming and woodlands patches which increased from 10%, 3.4% in 2004 to 24.2%, and 15.1% in year 2009 respectively.

**Keywords:** landscape level, class level, patches

## 1. Introduction

Landscape composition and structure can be attributed to both natural and anthropogenic factors which are responsible for the global environmental change (Meng& Zhang, 2008). By focusing on the relationships between landscape pattern and ecological processes, landscape ecology offers a useful framework for examining the factors affecting daily land use activities and how they may translate into overall landscape patterns (Coppolillo, 2009). The quantification of spatial pattern is necessary to link the effects of landscape heterogeneity with ecological function and using remotely sensed data is useful in the measure of changes in large spatial units (Turner*et al.,* 1987). In addition, Remote Sensing and Geographical Information Systems (GIS) technologies provide practical means for land use and land cover analysis which is critically important for landscape pattern and ecological studies (Guofan&Jianguo, 2008). The pattern of land use can give an insight into the factors that cause the land cover to change (Verburg&YouQi, 2009) and in particular, changes in the landscape structure are mainly as a result of complex interactions between physical, biological, economic, political and social factors (Kamusoko&Aniya, 2007). However, landscape pattern approaches are not limited to land, but are also applied in aquatic and marine ecosystems (Turner, 2005).

The ways in which humans use land are key drivers of landscape pattern (Mladenoff*et al*., 1993) for instance, in Dhaka Metropolitan (Bangladesh), the land use/cover changes and subsequent landscape fragmentation are governed by a combination of geographical, environmental and socio-economic factors such as the landscape diversity declined and urban dominance increased considerably in response to widespread urbanization (Ashraf *et al.,* 2010). Whereas in Costa Rica, the reduction in forest cover reflected historical land use processes in the Chorotega region and more especially during the period from 1960 to 1979, with an annual deforestation rate of 2.8% (Juan *et al.,* 2005). In Latin America, large-scale forest conversion and colonization for livestock based agriculture is prevalent, whereas cropland expansion by smallholders dominates especially in Africa and in Asia, intensified shifting agriculture, including migration into new areas, gradual change of existing areas toward more permanent agriculture, and logging explain most of the land cover clearances (Lambin*et al.,* 2003).

All across Sub-Saharan Africa, the increasing population pressures have led to increases in cultivation and grazing intensity which is responsible for the massive natural land cover clearances and conversion of natural habitats to farmlands and settlements which degrade the biodiversity and landscape (Olson *et al.,* 2004). The largest conversion of land use in East Africa over the last 50 years has been the expansion of agriculture at the expense of grazing land. Prior to 1950, semi-arid and sub-humid areas were predominantly pastoral with scattered settlement and cultivation. From the 1950s to the present there has been significant transformation of grazing land to mixed crop-livestock agriculture (Maitima*et al.,* 2010). And Uganda in particular, the changes in land use/cover between 1950 and 2009 in southwestern Uganda showed that small scale farming (non-uniform) farmlands patches covered 57% and 68% of the total land area (i.e. excluding lakes) in Kabale and Kisoro Districts respectively while natural forest patches covered only 2.0% of land in Kabale District and 16.3% of Kisoro District (National Biomass Study, 2003).The consequences of land fragmentation results into changes in both composition and configuration as landscape fragmentation may be characterized by a reduction in the total amount of habitat or land use/cover patches, and change in the spatial characteristics and configuration of remaining patches (Hansen *et al.,* 2001). However, most studies on landscape analysis have focused on a dominant driver rather than on the multiple drivers that together generate spatial pattern;

interactions among the varied drivers remain poorly understood, in part because they are not well documented (Turner, 2005).

Therefore, assessing the landscape composition and structure of River Sio was critical in understanding landscape dynamics and metrics which are not well documented. These are significant in quantifying the spatial diversity of landscape patches and land fragmentation and degradation characterization. The findings will also form a basis for monitoring changes in marginal areas for catchment conservation planning and evaluation of anthropogenic activities in the catchment.

## 2. Materials and Methods

### 2.1 Description of the study area

The study was carried out in River Sio catchment which is shared between Uganda and Kenya. The catchment is well endowed with both renewable and non-renewable resources. These include; minerals, forests, wetlands, soils, biodiversity, water resources and a good climate among others. Over 85% of the population is engaged in Agriculture (subsistence farming) as a major source of income as well as livelihood/subsistence. Agriculture is largely rain fed and production entirely depends on the use of crude implements (NBS, 2003).

### 2.2 Landscape composition and structure characterization

To characterize the Sio catchment landscape composition and structure, the study used ortho-rectified Landsat images of 2004 and 2009 (30m). These were processed using Idrisi 32 software for classification procedures. A hybrid unsupervised and supervised classification approaches were adopted for quantitative information extraction from the images, following a land use/cover classification system developed by the National Biomass Study (2003) for Uganda in the description of land use/cover landscape patches (small scale farming, woodlands, wetlands and bushlands). The classified images were analyzed using an ArcGIS 9.3 based Patch Analyst extension to assess the landscape structure and composition of Sio catchment. In analyzing the landscape composition and structure, the study followed an approach proposed by McGarigal and Marks (1994) in regards to quantifying the landscape structure at both landscape and class level. At the landscape level, Shannon's Diversity Index (SDI), Shannon's Evenness Index (SEI), Mean Patch Size (MPS), Mean Perimeter-Area Ratio (MPAR), Number of Patches (NumP), Landscape Area (TLA), and Class area (CA) were considered to determine both diversity and patch abundance and distribution whereas at class level, Mean Patch Size (MPS), Mean Perimeter-Area Ratio (MPAR), Number of Patches (NumP) and Class area (CA) were measured.

## 3. Results and Discussions

**Table 1:** Shows the landscape metrics of River Sio catchment

| **Indices** | **Year** | | | |
|---|---|---|---|---|
| **Landscape level analysis** | **2004** | | **2009** | |
| Shannon's Diversity Index (SDI) | 0.2 | | 2.0 | |
| Shannon's Evenness Index (SEI) | 0.1 | | 0.9 | |
| Mean Patch Size (MPS) | 21.2 | | 0.4 | |
| Mean Perimeter-Area Ratio (MPAR) | 1381 | | 1259 | |
| Number of Patches (NumP) | 21563 | | 41355 | |
| Landscape Area (TLA) | 4565965 (ha) | | 145013.2 (ha) | |
| Class area (CA) | 4565965 (ha) | | 145013.2 (ha) | |
| | | | | |
| **Class level analysis** | ***Land use/cover types (ha) year 2004*** | | | |
| **Indices** | *Woodlands* | *Farming* | *Wetlands* | *Bushlands* |
| Mean Patch Size (MPS) | 0.2 | 0.3 | 1.0 | 1.0 |
| Mean Perimeter-Area Ratio (MPAR) | 1451 | 1414 | 1369 | 1335 |
| Number of Patches (NumP) | 29575 | 53519 | 65969 | 66535 |
| Class area (CA) | 4973 | 13852 | 67008 | 59170 |
| | | | | |
| **Class level analysis** | ***Land use/cover types (ha) year 2009*** | | | |
| **Indices** | *Woodlands* | *Farming* | *Wetlands* | *Bushlands* |
| Mean Patch Size (MPS) | 0.2 | 0.3 | 0.3 | 0.3 |
| Mean Perimeter-Area Ratio (MPAR) | 1315 | 1224 | 1241 | 1252 |
| Number of Patches (NumP) | 10722 | 10001 | 94640 | 11105 |
| Class area (CA) | 17335 | 27775 | 33083 | 36816 |

At the landscape level, the sum of all land use/cover patches in River Sio catchment landscape was relatively high in 2004 with 97% compared to 3% in year 2009. The high sum of all patches in 2004 was due to the cohesiveness of areas covered by mainly natural land cover coupled with low population growth densities as compared to 2009 were the landscape had been fragmented to create cultivatable land. This was noted by FAO (2001) that the highest rates of natural land cover patch clearances occurred in areas with large growing populations such as the Lake Victoria basin area. The total number of landscape patches was relatively higher in 2009 with 66% than in 2004 with 34%. By 2009, the landscape had been subjected to intensive land fragmentation practices in the interest of creating more cultivatable fields for crop production. This reduced the areas covered by natural land cover patches at the expense of increasing agricultural patches. This is also similar with the findings made by Magunda*et al.,* (1998), Olson *et al.,* (2004), Bamutaze*et al.,* (2008) and Barasa*et al* (2011) in the Lake Victoria basin. However, it disagrees with the findings of Odada*et al.,* (2006) who argued that increased land fragmentation activities not only lead to land cover clearances but also lead to increased resource-use efficiency.

The increased land cover patch clearances for agricultural activities are responsible for the landscape shape complexities and numerous patch sizes which reduced from 1,381ha, 21.2ha in year 2004 to1,259ha, 0.4ha in 2009. The Shannon's Diversity Index showed that there were relatively fewer patch types (0.2) in 2004 compared to year 2009 where the numbers of patch types increased (2.0). Still at landscape level, the Shannon's Evenness Index showed that there was a relatively low distribution and abundance of patches in 2004 compared to 2009 were the distribution was higher. The fewer patches in 2004 were due to a higher land cover patch coverage compared to the scattered and integrated with agricultural patches in 2009.

Meanwhile, at class level, in 2004 wetland and bushland patches reduced from 46%, 40% to 28% and 32% in year 2009 with total patch area and individual numbers of patches in each class compared to small scale farming and woodlands patches which increased from 10%, 3.4% in 2004 to 24.2%, and 15.1% in year 2009 respectively. The patterns of land use/cover in the Lake Victoria basin are highly determined by variations of rainfall amounts and soil characteristics and these are entirely responsible for the conversion of primary land cover to cultivation practices replacing natural land cover with crops either planted as mixed cropping or planted and maintained as monoculture (Maitima*et al*., 2010).

The woodlands (1451ha) and small scale farming (1414ha) patch shape complexities were relatively large in 2004 compared to wetlands (1369ha) and bushland (1335ha) patches which were small while in 2009, the woodlands (1315ha) and bushlands (1252ha) had the biggest shape complexities than small scale farming (1224ha) and wetlands (1241ha) which had small complexities.

The large shape complexities in 2009 indicated higher human influences such as agricultural activities, charcoal burning and increased livestock grazing which shaped the landscape patterns. This was also attributed to increased land cover clearances which were responsible for dispersed land cover patches producing distinctive landscape patterns with high patch, edge density and shape complexities. This is similar to the findings of Turner (2005) who noted that the interactions between landownership and landscape position have emerged as strong determinants of land use/cover patterns and changes (Turner, 2005). Intensive agricultural activities and land cover clearances for firewood are the main landscape shaping activities.

The reduction in wetlands and bushlands noted is similar to the results of Elliott *et al.,* (2006) who argued that the principal patterns of landscape feature change in Zimbabwe in the course of resettlement have been an increase in cultivation land uses and a reduction in more 'natural' systems such as woodlands and woodland landscape classes, the actual dynamics of change need to be understood as varied and complex. This was also reported by Sivrikaya*et al.,* (2007) that habitat fragmentation and land cover clearances have been recognized as a major threat to ecosystems worldwide. However, Armenteras*et al.,* (2003) argued that the ecological consequences of fragmentation may differ depending on the patterns or spatial configuration imposed on a landscape and how it varies both temporally and spatially.

## 4. Conclusion

At the landscape level, the sum of all land use/cover patches in River Sio catchment landscape was relatively high in 2004 by 97% compared to 3% in year 2009. From the landscape ecology perspective, our results indicated a very fragmented landscape. The fragmentation was due to majorly human influences.

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