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# ASSESSING WETLAND DEGRADATION USING LAND USE AND LAND COVER CHANGE IN LUKANGA WETLAND, ZAMBIA

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## Abstract

The main aim of this research was to estimate the proportional rate at which the lukanga catchment was being altered in terms of spatial and temporal scales, three objectives were answered. Extents and trends of land use and cover change were evaluated as well as estimating the rates of land use and cover change on wetland degradation in lukanga catchment from 1997-2017 as study objectives. Geographic information systems (ArcGIS 10.2.1 ) and remote sensing techniques methods were used, land cover datasets (Thematic mapper )TM, (Enhanced thematic mapper )ETM and (Operational land imager) OLI_TIRS images derived from Gloves between 1997 and 2017 were used to generate land cover map with a resolution of 30m x 30m based on supervised image classification methods using (ENVI 5.3) while considering only six land classes (forest, grassland, settlement, cultivated land, wetlands, water and bare soil), thereafter advanced mathematical models and descriptive statistics were used to determine the extents, trends and rates of change. The results indicated that though resource is fixed, between 1997 and 2017, settlements, cultivated land, grasslands, water and bare soil area (13,970.5 ha/year, 10,054.2 ha/year, 40,175.9 ha/year, 586.6 ha/year and 3,439.4 ha/year respectively) increased at high rates per hector per year while in the same periods forest land cover and wetlands area (-62,784.6 ha/year and -5441.9 ha/year respectively) decreased drastically over the 20 years period. Lukanga catchment for the period of 20 years (1997-2017) showed significant degradation rates on forests and wetlands areas.

## Keywords

Degradation, wetlands, land use cover change, remote sensing and GIS.

## INTRODUCTION

From ancient times, wetlands have been a center of human activity because of its limitless water supply, rich alluvial soils for producing root crops and cereals, and abundant natural resources such as vegetation, fish and wildlife (Kachali, 2007). Further Chabwela et al (2017) equally showed that wetlands are a source of fish, agricultural produce, livestock pasture fields, fuel wood and charcoal as well as space for habitat for humans. According to Schuyt (2005) wetland ecosystems services are categorized in, the provisional services, the cultural and the regulatory services.

Land refers to the physical and biological cover over the surface of the earth, including water, vegetation, bare soil, and or artificial structures (Ellis, 2010), Whereas, Land use refers to the intended use or, management of the land cover type by human beings according to (Lambin et al., 2006). Land use, is the purpose for which humans exploit the land cover or the manner in which human beings utilize the land and its resources; however, land use dynamics are important factors that affect ecosystem conditions and functions, Changes in land use and cover accelerate land degradation of ecosystems (Ellis, 2010). Land degradation is a worldwide problem that is essentially affecting all countries and communities in the world. Land degradation is reduction or loss of the biological or economical productivity (Kotze, 1994). Other studies raised serious concerns about change in the size and quality of Kafue catchment and its sub-catchments systems have being changing as more and more wetlands are been converted to agricultural or urban use and others uses by anthropogenic and natural factors like and drought (Munyati, 2000; Hunink et al., 2017; Chabwela et al., 2017). Degradation of watersheds in recent decades has brought the long-term reduction of the quantity and quality of land and water resources (Darghouth et al., 2008; Kamweneshe, 2002). Degradation of natural resources is considered the greatest constraint in most developing countries (Achouri et al., 2003). During the last few decades, degraded watersheds have posed serious problems to environment and people, both upstream and downstream. Degradation results from a range of natural and anthropogenic factors, including natural soil erosion, changes in farming systems, overgrazing, deforestation, and pollution. A combination of environmental costs and socioeconomic impacts has led to the development of watershed management approaches. Land use and land cover change by demographic dynamics contribute more than any other process to land cover changes from past few decades as one of primary factors responsible for wetland degradation that has seen wetlands and watersheds degrade from a global, regional and local perspective (Amare, 2015; Begg, 1987).

Many studied across the world have shown that land use and cover changes degrade the landscape; For example globally, in China, the loss and environmental degradation of wetlands in China caused mainly by economic developments and human activities where protection and management are a problematic issue (Bai et al., 2011). According to Begg (1987) regionally, for instance African wetlands in South Africa are among the most threatened aquatic habitats, with estimates of up to 50% having been lost countrywide. In Uganda, land use and land cover change is an environmental challenge (Mbogga et al., 2014; Townsend, 2011). The rate of land use and cover change was estimated at 7% in 1990 and now stands at 11% with eastern Uganda registering the highest rate of 20% (Mary et al., 2014). Awoja wetland and watershed in Kyoga Water Management Zone of eastern Uganda with an area of 10 km2 is a key watershed degradation hotspot with a perceived degradation rate of 76% as compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (NEMA, 2008; Nelson et al., 2016). And locally in Zambia, the Lukanga wetlands a Ramsar site, has in the past recorded wetland degradation through mainly anthropogenic activities that affect both quality and quantity of the wetlands through rapid urban expansion, rapid conversion of forests to agriculture lands, pollution (Kamweneshe, 2002; Hunink, et al & Chabwela, et al., 2017). Lukanga catchment was specifically selected for this study due to its position to the Kafue basin ecosystem and consequently considered part of the Kafue basin system.

The analysis of land use change revolves around two central and interrelated questions: what drives or causes land use and what are the environmental and socioeconomic impacts of land use change however, there are two main categories widely accepted: biophysical and socioeconomic drivers (Briassoulis, 2008; Lambin et al., 2003; Su et al., 2011). There are also five major types of driving forces of land use and land cover change namely socioeconomic, political, technological, natural, and cultural driving forces (Bürgi et al., 2004).

This study is centered on watershed approach, watershed is a terrestrial ecosystem consisting of intricately interacting biotic and abiotic components (Darghouth et al., 2008). The watershed is the logical unit for coordinated land-use planning, management, effective and sustainable resource and environmental management (UN-ESCAP, 1997). Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural and urban people (Wani et al., 2008).

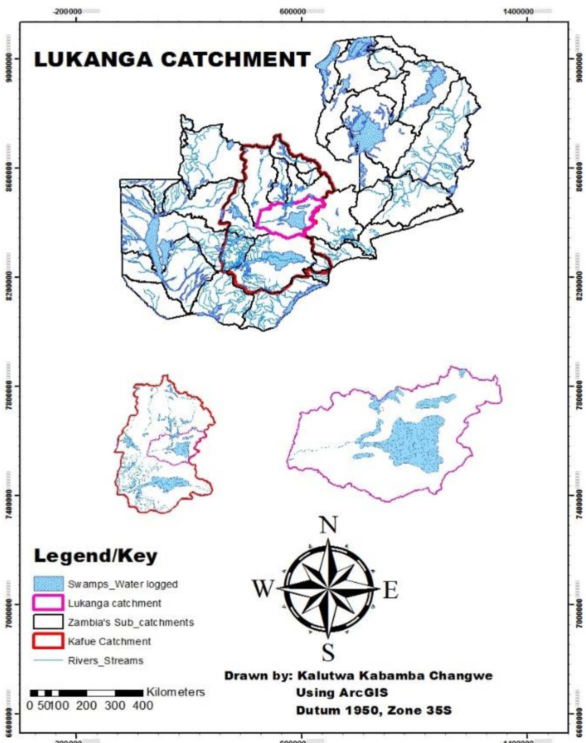
Watershed management is an approach that aims to reduce watershed degradation typically targeted for livelihood improvements and poverty reduction (FAO, 2006). However, in the present context, watershed management, not only for managing or conserving natural resources in a holistic manner, but also to involve local people for betterment of their lives (Achouri et al., 2003). Thus, modern watershed management is more people oriented and process based, unlike many of the programs in the past, which were physically target oriented.

To overcome the watershed degradation problems many developing countries have practiced different watershed management approaches from top-down and sectoral to bottom-up, participatory and integrated types (Tiwari et al., 2008). Thus, Watershed management is a landscape-based strategy that aims to implement natural resource management systems for improving livelihoods and promoting beneficial conservation, sustainable use, and management of natural resources (Chisholm et al., 2012).

## MATERIAL AND METHODS

### *Study area location*

Lukanga catchment covers an area of approximately 19,490 square kilometers with a permanent swamp of 2, 500 to 2,600 square kilometers (Chabwela, et al., 2017) during peak flooding, with a large shallow depression at 1090m amsl that extends over Kabwe, Chibombo, Kapiri-mposhi, and Mumbwa districts and a small part of the Copperbelt province as shown below (Figure 1). Chabwela et al (2017) stated that the large town of Kabwe is located 50 km west of the swamp. The Lukanga swamps are part of the greater Kafue system, the Kafue Basin that has a total catchment area of approximately 154,000 square kilometers and covers nearly one fifth of Zambia's total area (Chabwela, 1998).




*Source: Kalutwa Kabamba Changwe (2019)*
***Figure 1**. Location of Lukanga catchment*

## *Study area description*

From ancient times, the Lukanga Swamp has been a center of human activity because of its limitless water supply, rich alluvial soils for producing root crops and cereals, and abundant natural resources such as vegetation, fish and wildlife. By 2010, the estimated total population of the Lukanga catchment was 195, 993 individuals, with a rapid population growth rate of 3.5% per annum (CSO, 2010).

Most of the population has settled on the margins of the floodplains including elevated areas inside the swamps. Relatively few local people are engaged in fishing activities. However, most of the fishermen are migrants from Luapula and Western provinces. Local people are primarily engaged in subsistence agriculture, charcoal production, fuel woodcutting, and hunting, and harvest wetland resources such as papyrus and reeds to make mats and baskets. These resources, transported to urban markets for sale. The region is a transitional environment between the terrestrial and marine ecosystem. Therefore, the area contains highly diverse ecosystems, including wetlands, fishponds, croplands, forests and grasslands, (Environmental Council of Zambia, 2000).

Lukanga catchment has seasonally dependent water level, with depths ranging from 1.5 m to over 6.0 m in exceptionally high floods. The catchments main sources of water are rainfall, sub surface run off, the Lukanga River, the Kafue River and other channels that drain into the swamp from the catchment (Kamweneshe, 2002).

The climate of the Lukanga Swamp basin includes two distinct seasons, a 5-month wet season from November to March and a 7-month dry season from April to October. Mean annual rainfall over Lukanga Swamp is about 950 mm, but the inter-annual variation in rainfall is considerable. Maximum and minimum temperatures in the upper basin region range from about 19-36oC in October and 0-21o C in July (Kamweneshe, 2002).

The Vegetation in Lukanga catchment was classified in three broad categories palustrine, lacustrine, and riverine. Palustine wetland covers approximately 247,000 Hectors or 95% of the area. Chabwela et al (2017) showed that Lukanga swamp system, and includes permanent swamp, termitaria grasslands, and dambos. Permanent swamp covers an estimated 180,000 ha of the Lukanga basin, lacustrine wetland approximately 4000 ha or 1.5% of Lukanga basin is in permanent open water or lacustrine wetland, although the exact area of open water varies with season and flooding conditions. The swamp or basins have several lakes but only Lake Suye and Lake Chiposha exceed 10 hectares in size. Following the prolonged period of drought between 1986 to1995, most lakes in the Lukanga has overgrown with emergent and submergent vegetation. Riverine wetland (floodplain) Floodplains occurs along the fringes of the Lukanga and Mushingashi Rivers to the west of the swamp. Floodplain wetlands cover about 9100 ha on the other hand, 3.5% of the total Lukanga basin, and are seasonally flooded with characteristic levees, lagoons, and oxbow lakes.

## *Data collection*

The main aim of this study was to estimate the proportional rate at which the sub-watershed is altered in terms of spatial and temporal scales. To achieve this aim to the extents of land use and land cover over the study period were considered and the trends of land use and land cover changes were equally considered for the period of 20 years between every 5 years interval.

The main steps involved in this study included. Tesfa et al (2016) described the procedures and terms as follow; Catchment boundary identification and delineation (typically involved describing the study boundary and identification of the boundary), image identification and acquisition ( involved identifying the appropriate imagery datasets and obtaining the imagery from https://glovis.usgs.gov, as presented in Table 2, image processing (the process of merging imagery scenes and clipping the images respect to the catchment boundary delineated; as well as selecting suitable datum of projection of the image to Arc1950 UTM Zone 35S in ArcGIS 10.2.1), image enhancement and calibration (reducing the resolution difference of images using nearest neighbor resampling), preliminary image classification results( action of creating training sites and assigning signatures on the images of a particular land cover type), accuracy assessments for processed images results, actual supervised classification of the images (1997, 2002, 2007, 2013 and 2017) using Environment for Visualizing Images-ENVI 5.3 version.

***Table 1**. Sows the imagery data type and source used in this study*

| No. | Image type | Resolution | Sensor type | Path | Raw | Acquisition date | Source |
|---|---|---|---|---|---|---|---|
| 1. | Landsat5 | 30m*30m | TM | 172/173 | 070 | 23.05.1997 | https://glovis.usgs.gov |
| 2. | Landsat7 | 30m*30m | ETM | 172/173 | 070 | 20.10.2002 | https://glovis.usgs.gov |
| 3. | Landsat5 | 30m*30m | TM | 172/173 | 070 | 29.07.2007 | https://glovis.usgs.gov |
| 4. | Landsat8 | 30m*30m | OLI_TIRS | 172/173 | 070 | 14.08.2013 | https://glovis.usgs.gov |
| 5. | Landsat8 | 30m*30m | OLI_TIRS | 172/173 | 070 | 06.06.2017 | https://glovis.usgs.gov |

To detect changes of the images between the 5 years Interval, Google earth images were used to compare and verify classified results of the extents, trends, and rates of LULC changes, and finally conduct validation of results. Based on the procedures and steps involved in this study, direct observation was taken into account on environment or landscape to quantify the extents, trends and rates of change in the study area, therefore the study used a quantitative research method. Detailed picking of coordinates was done used for digitizing maps and images and acquiring online datasets to complete digitizing of the images.

## *Land cover classification system*

A classification system describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes as described in the table below (Table 2). Classification of image was entirely based on the classification system that is be clear, precise, possibly quantitative, and based upon objective criteria.

***Table 2**. Descriptions of land use land cover class.*

| No. | Land use land cover class | Description |
|---|---|---|
| 1. | Settlement | Scattered rural settlement closely associated with cultivated land and urban settlement. |
| 2 | Cultivated land | Land allotted for crop cultivation both annual and perennial crops. |
| 3. | Forest | Area covered with dense natural forest and plantation forest, it includes eucalyptus trees, junipers procera (Tid) and mixed indigenous bush and trees species. |
| 4. | Water body | An area having surface water. It includes pond water, streams, rivers, lakes, marshland and riverine trees found along riverbank and streams. |
| 5. | Bare soils | Area with very little or no vegetation cover on the surface of the land. It consists of vulnerable soil to erosion and degradation. It also includes bedrock, which is unable to support cultivation. |
| 6. | Wetlands | An area of land covered by thin film of waters flowing or stagnant. |
| 7 | Grasslands | An open area of land covered with grass especially one used for grazing. |

Source; Amare (2015); Tesfa et al (2016)

## *Data analysis*

Remote sensing (RS) techniques and geographic information system (GIS) was used in this study to digitize and analyze the images. The term RS refers to techniques used to analyze objects far away; for example, analyzing what these objects are or what states they are in (Engman et al., 1991). Whereas, GIS is a system which handles information referenced in terms of space-time coordinate values. GIS is a tool used for the measuring environmental variables, the mapping of features, monitoring of environmental changes and the modeling of plans or contingency plans (Sharma et al., 1993). GIS is a system in which map, along with various additional information, displayed and referenced using computers (Carroll, 1995). Therefore, Land Cover images, land cover datasets Landsat TM, ETM and OLI_TIRS images derived from Gloves earth explorer images of 1997 and 2017 were used to generate land cover map with a resolution of 30m. This study was limited to seven land cover types; the classes included agriculture or cultivated land, forest, grassland, wetland, water bodies, settlements or built environments and bare or barren land.

The analysis of changes of land cover type was accomplished using GIS techniques software and a third party application known Environment for Visualizing Images (ENVI 5.3 version). A cross detection method deployed to quantify the change in land cover type. The change for each land cover type in the study areas, calculated by the formula below:

**$\% \Delta A = [(AT2 - AT1)/AT1] \times 100$**

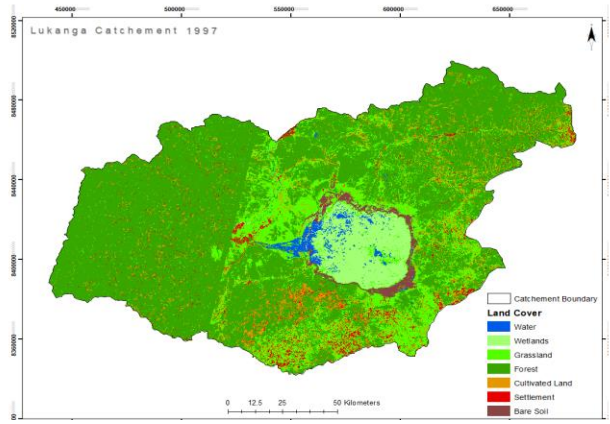
Where, **% ΔA** is percentage change in the area of land use and land cover class type $\mathbf{A_{T1}}$ = Area of land use and land cover type at initial time AT2 = Area of land use and land cover type at final time.

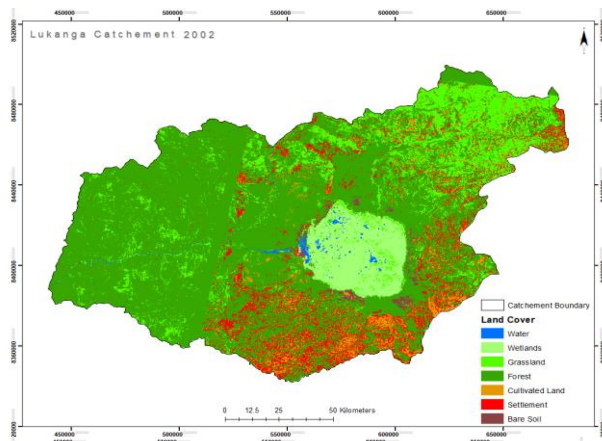
To compute the rate of change of land use and land cover type, the following formula was used.

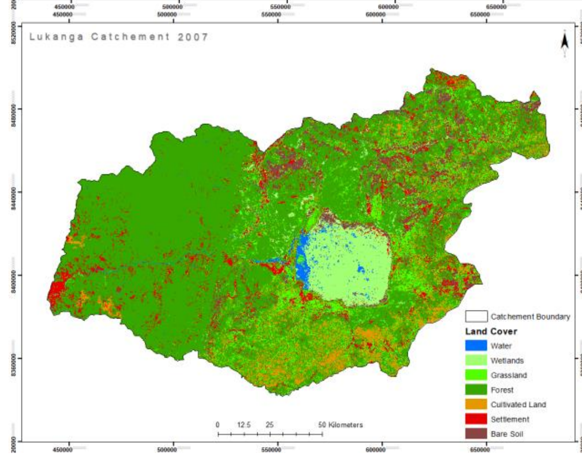
**$R\Delta$ (ha/year) = $(Z - X) / W$**

Where**, RΔ** = rate of change, **Z** = recent area of land use and land cover type in ha, **X** = previous area of land use land cover type in ha and, **W** = time interval between Z and X in years.

To confirm the results in this study area, use of Google images from Google earth application and use of numerous test sites in ENVI deployed after classifying the images and for validate the classified images.

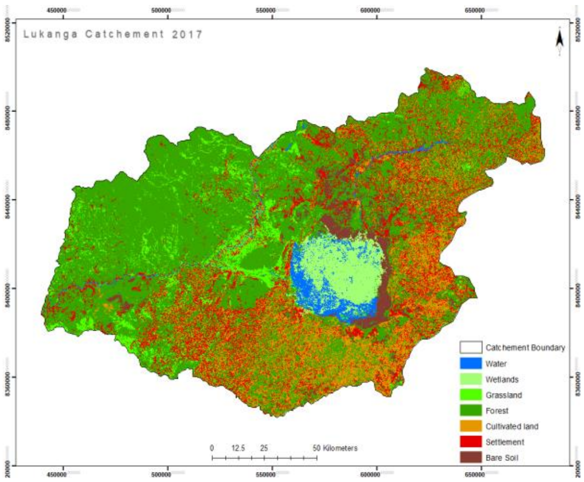



# FINDINGS AND DISCUSSION

This section presents findings for the assessment of land use and land cover change extents, trends and the overall results of the rate of land use and cover change on wetland degradation in Lukanga sub-watershed over the period of 20 years.



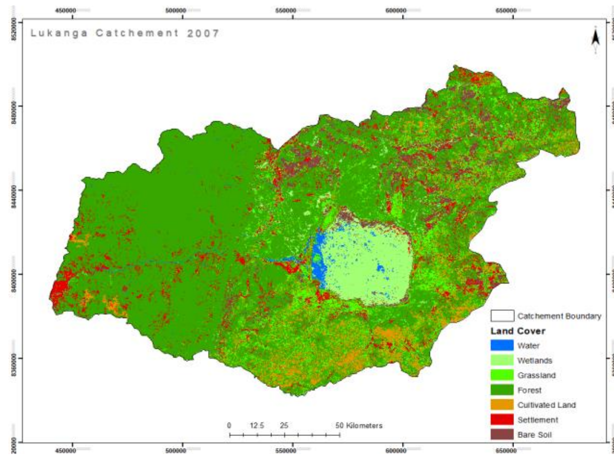




***Figure 2.*** *Classified land use and land cover maps for Lukanga (1997, 2002, 2007, 2013 and 2017)*

*5.1 The extent of land use and cover change*

***Table 3**. Area in hectors and percentage share of land use and land cover of Lukanga watershed from 1997 to 2017*

| **Year** | | **1997** | | **2002** | | **2007** | | **2013** | | **2017** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Land Class** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** |
| 1 | Forest | 1,419,532.7 | 64.1 | 1,416,136.5 | 64.6 | 1,367,999.6 | 62.8 | 1,441,192.6 | 65.8 | 163,841.6 | 7.5 |
| 2 | Grassland | 392,911.6 | 17.9 | 319,963.7 | 14.6 | 220,988.6 | 10.1 | 6,522.0 | 0.3 | 1,196,428.7 | 54.6 |
| 3 | Settlement | 72,589.4 | 3.3 | 151,383.8 | 6.9 | 228,357.6 | 10.4 | 262,948.5 | 12.0 | 352,000.1 | 16.1 |
| 4 | Cultivated land | 115,861.7 | 5.3 | 131,644.2 | 6.0 | 90,065.7 | 4.0 | 119,249.5 | 5.4 | 316,944.7 | 14.5 |
| 5 | Wetlands | 127,317.2 | 5.8 | 144,577.7 | 6.6 | 148,833.6 | 6.7 | 155,867.9 | 7.1 | 18,478.4 | 0.8 |
| 6 | Water | 29,218.1 | 1.3 | 11,981.4 | 0.5 | 25,162.5 | 1.1 | 27,567.1 | 1.3 | 40,949.2 | 1.9 |
| **7** | Bare Soil | 32,965.8 | 1.5 | 14,709.2 | 0.7 | 108,988.6 | 4.9 | 177,048.7 | 8.1 | 101,753.7 | 4.6 |
| | **Total** | **2,190,396.0** | **100** | **2,190,396.0** | **100** | **2,190,396.0** | **100** | **2,190,396.0** | **100** | **2,190,396.0** | **100** |

Table 3 and figure 3 shows the land classes in their respective areas and percentage share over the 20 years period disaggregated by the 5 years intervals and the marginal total areas of the study area. The results indicate that the extents of land uses and land cover change varied drastically over the period of study. Forests, grasslands, settlements, cultivated land, wetland areas, water bodies and bear soils areas all shows tremendous transition during the 20 years study period. All land uses and cover showed fluctuated throughout the period; however, area covered by grasslands during 2013 decreased to only 0.3% this because all other land cover classes had increased in size, around 2007 equally cultivated land decreased 4.0%, bear land area also decline to 0.7% in the year 2002 this is because forest cover and grasslands covered much of the catchment.

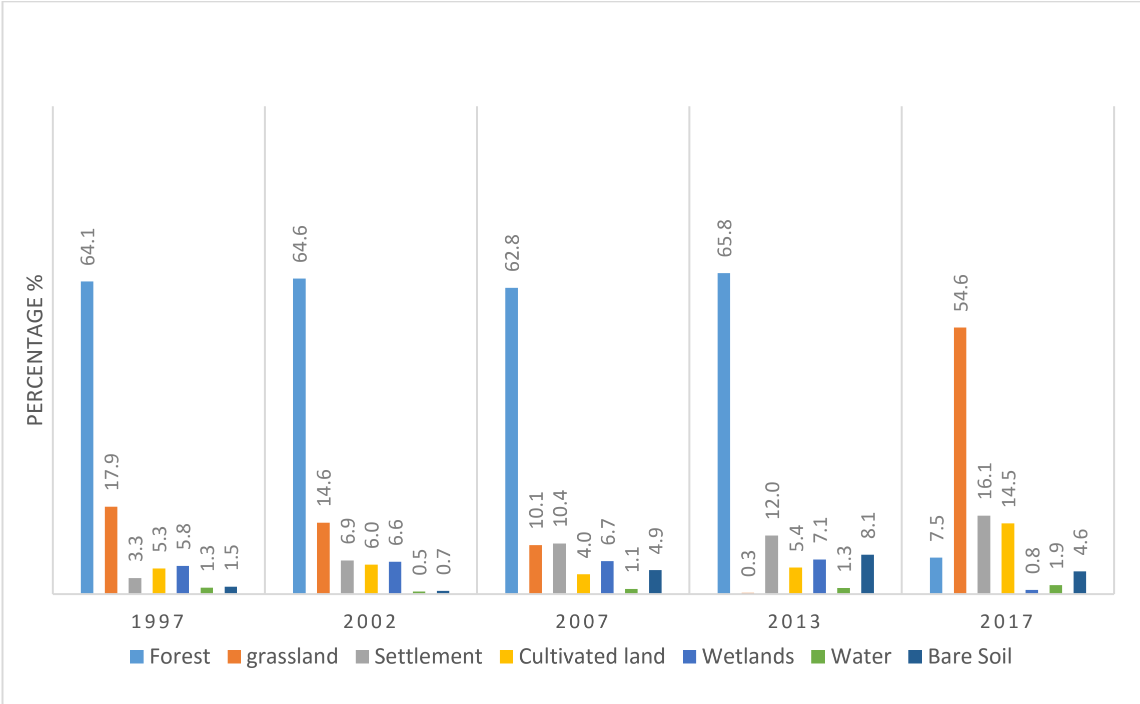



***Figure 3.*** *Actual Land use and land cover change by percentage from 1997-2017*

Table 3 and figure 3 show the current land use area of the classes considered had huge variations between each other, the general extents of the various land use and land cover classes have been fluctuating throughout the study period. However, in this section, only the overall extents of the study period was discussed and therefore detailed analysis of the extents refer to table above (Table 2). Forest cover dynamics over a period of 20 years (1997-2017) experienced huge transitions from a total of 64.1% of cover decline to only 7.5%. This extent of forest cover dynamics resulted from a number of anthropogenic activities (Chabwela, et al., 2017), result in alteration of the climate system in the region over the next few decades and reduced forest harvest and other forest based products. Grasslands emerged to be expanding throughout the period from only 17.9% to 54% during a 20 years period, the it was discovered that as much a forest cover declined the grasslands covered area became larger with time, this is because as forest cover was removed this converted and promoted extents of grasslands in the catchment. Another possible explanation for the rapid dynamics of forest cover change was due to rapid numbers of settlements recorded during this period of study, settlements continued to expand exponentially from 3.3% to 16.1%. Ancient economists predicted that population grows exponentially so as food production, this justifies the results obtained during the period 1997-2017, were cultivated land expanded exponentially from 5.3% to 14.5% of land use and land cover change. In 1997 wetlands covered area was approximately 5.8% and by the year 2017 only 0.8% of the total extent of study was for wetlands, this is due to rapid agriculture expansions and rapid increase of built environments and overall unregulated land uses in the basin. Water bodies' sizes increased throughout the period from 1.3% to 1.9%. Whereas, bare soils or barren land dynamics was positive due to rapid deforestation and migrations within the catchments for the search for more productive lands for agriculture, bare land extents from 1997 was 1.5% to 4.6%.

*5.2 Evaluating the trends of land use and cover change in Lukanga sub-watershed*

***Table 4.*** *Shows the trends of area in hectors and percentage share of land use and*

| year | land class | 1997-2002 | | 2002-2007 | | 2007-2013 | | 2013-2017 | |
|---|---|---|---|---|---|---|---|---|---|
| No. | | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** | **Area (ha)** | **% Share** |
| 1. | Forest | -3,396.2 | -0.2 | -48,136.8 | -3.4 | 73,193.0 | 5.4 | -1,277,351.0 | -88.6 |
| 2. | Grassland | -72,947.9 | -18.6 | -98,975.0 | -30.9 | -214,466.6 | -97.0 | 1,189,906.6 | 18244.4 |
| 3. | Settlement | 78,794.4 | 108.5 | 76,973.9 | 50.8 | 34,590.9 | 15.1 | 89,051.6 | 33.9 |
| 4. | Cultivated land | 15,782.5 | 13.6 | -41,578.4 | -31.6 | 29,183.8 | 32.4 | 197,695.2 | 165.8 |
| 5. | Wetlands | 17,260.5 | 13.6 | 42,55.9 | 2.9 | 7,034.2 | 4.7 | -137,389.4 | -88.1 |
| 6. | Water | -17,236.7 | -59.0 | 13,181.2 | 110.0 | 2,404.6 | 9.6 | 13,382.1 | 48.5 |
| 7. | Bare Soil | -18,256.6 | -55.4 | 94,279.4 | 641.0 | 68,060.1 | 62.4 | -75,295.0 | -42.5 |

The table above (table 4) shows the trends of the various land uses and land cover changes considered in this study over the 20 years period. Trends were analyzed and presented in intervals of 5 years, therefore forests, grasslands, settlements, cultivated land, wetland areas, water bodies and bear soils areas all produced fluctuating figures ranging from positive values to negatives though out the period

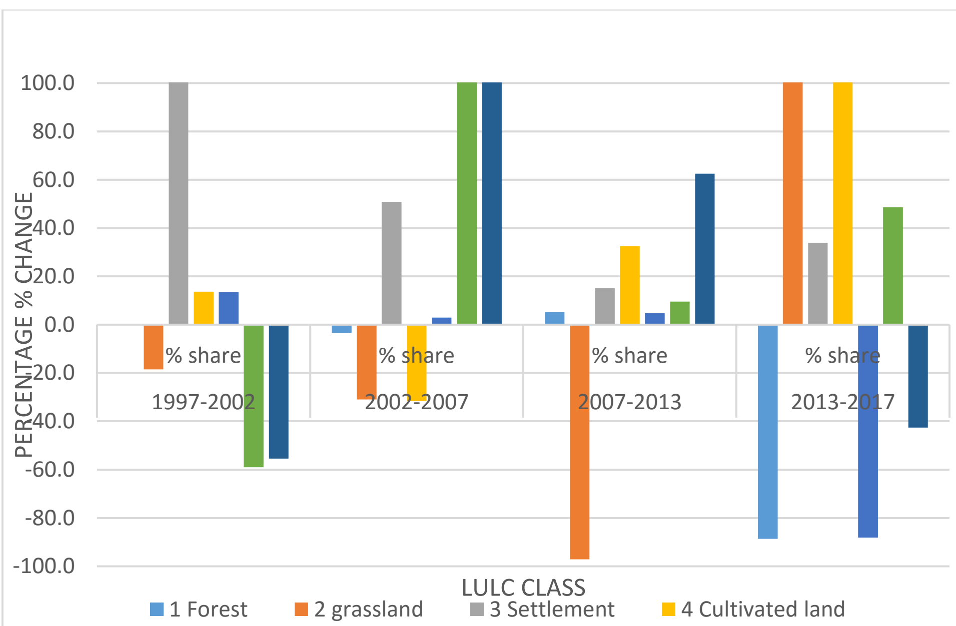



**Figure 4**. *Trend of percentage share of land use and land cover of Lukanga watershed from 1997-2017*

The change of land use and land cover class may not necessarily result in land degradation and soil erosion. However, if the change of land use land cover class is rapidly expanding into farm land, settlement land and barren land, fertile soil become more susceptible to massive erosion and degradation, particularly the land surface without dense forest as shown by (Tegene, 2002) and (Maitima et al., 2009). Table 3 and figure 4 both show that the trends for the land cover classes were all distinct within the periods (5 years' intervals) that were disaggregated during the study period, classes continued to fluctuate from time to time positively and others negatively (Munyati, 2000). Equally explained that the results indicate inconsistent trends in the changes of land cover classes, because of manipulation of the wetland by man through annual variations in the timing and magnitude of regulated flows into the wetland, as well as burning. Specifically, forest cover continued to decline in terms of area and percentage from 1997-2002 and 2002-2007 by -0.2% and -0.3% of the total area probably due to deforestation and demand for energy demand through charcoal production. Surprisingly forest cover increased by 5.4% during 2007-2013 which could have resulted from strong enforcement of policies and forest restoration intervention; however, this increment did not continue as forest cover again declined during 2013-2017 by (-1,277,351.0 ha) -88.6%.

Grasslands continued to decline from 1997-2013 by -18.6%, -30.9% and -97.0% (Table 3 and Figure 4). The decline in grasslands could have been due to intensive grazing of pasture by cattle. Nevertheless, during the last interval of study (2013-2017) the grasslands area increased drastically over 100% this was caused by rapid conversion of forest cover to grasslands. Settlements trend was positive throughout the study period, they Settlement increased by 108.5% during 1997-2002, 50.8% from 2002-2007, during the year 2007-2013 settlements equally increased by 15.1% and 33.9% this due to increased population and demand for land to settle on during their lifetime. As for the cultivated land trends illustrated both positive and negative throughout the period, 1997-2002 increased by 13.6%, during 2002-2007 it was surprising that the trends declined by -31.6 and finally during 2007-2013 and 2013-2017 cultivated land extent increased by 32.4 % and 165.8% respectively. Wetlands class continued to increase in size from 1997-2002, 2002-2007 and 2007-2013 by 13.6%, 2.9% and 4.7% respectively. However, between 2013 and 2017 wetlands covered areas drastically declined by -88.1%, possibly this might have been a result of rapid population 195, 993 individuals that have settled in the, increased cultivation in the catchment (Table 4.2).

Areas covered by water only declined during 1997-2002 by 59.0 less and continued to record positive trends for the rest of the period 2002-2007, 2007-2013 and 2013-2017 by 110.0%, 9.6 and 48.5% respectively, however the correlation between deforestation, agriculture expansion is quiet positive on water resources. Thus, the increase in areas covered by water could be resulting from the common over flows from the might Kafue River into Lukanga basin as shown by recent studies conducted by the nature conservancy in 2017 (Hunink et al., 2017). Finally, bare lands, accounted for -55.4% between 1997 and 2002 and continued to increase from 2002-2007 to 2007-2013 by 641.0% and 62.4% respectively, nevertheless this trend declined by 2013-2017 by 42.5%; Similarly, Tegene (2002) explained that rapid expansion of agricultural land into steeper slope aggravated for erosion and degradation. Amede et al (2001) equally, illustrated destruction of vegetative cover because of expansion of farming practice into steeper slopes particularly in the higher elevated lands without appropriate conservation practice resulted in (depletion of fertile soil) barren lands and less dense forests. This trend agrees with the results obtained by Munyati (2000) which showed that Sparse green vegetation is replacing the dense green vegetation in these upstream and downstream areas of the catchment.

*5.3 Estimating the rates of change*

***Table 5.*** *Shows the rate of change of land use and land cover between 1997-2017*

| No. | Land Class | Rate of change (ha/year) |
|---|---|---|
| | | Year 1997-2017 |
| 1. | Forest | -62,784.6 |
| 2. | Grassland | 40,175.9 |
| 3. | Settlement | 13,970.5 |
| 4. | Cultivated land | 10,054.2 |
| 5. | Wetlands | -5,441.9 |
| 6. | Water | 586.6 |
| 7. | Bare Soil | 3,439.4 |

Munyati (2000), also raised Concerns about change in the size, rate and quality of many of the Kafue catchment's wetland systems has been increasing as more and more wetlands are being converted to agricultural or urban use and by natural factors like and drought as identified in this study but did not estimate the rate of change for the catchment.

This study equally produced results of various rates of changes of the land classes, the rate of changes of farmland, grazing land, forestland, and water body barren land, settlement, wetlands and water area cover for the study watershed were already been presented above in the proceeding chapter. These result indicated that though resource is fixed, there was various rate of change in different land cover types. However, the rate of change of different land cover types was slightly variables among them. The analysis indicated that between 1997 and 2017, settlements, cultivated land, grasslands, water and bare soil area increased at a rate of 40,175.9 ha/year, 13,970.5 ha/year, 10,054.2 ha/year, 586.6 ha/year and 3,439.4 ha/year respectively caused for the outflow of grazing land, barren land and forest land (Table 4).

However, in the same periods forest land cover and wetlands area decreased at a rate of -62,784.6 ha/year and -5,441.9 respectively. Evidently, some of the causes in the reduction of wetlands have been due to over abstraction of water from the water bodies for irrigation practices in the watershed and another reason is that, wetlands in the catchment been occupied by settlements especially in urban areas where there is increasing population resulting in high demand for land for housing projects. Population increase also has caused encroachments of forest and reserved areas in the catchment resulting in an increase in the number of settlements as well as increased demand for energy demand might has resulted in rapid depletion of forest cover.

## CONCLUSION

Based on the land use and land cover change results, the study was concluded that Lukanga watershed over the period of 20 years (1997-2017) showed significant and drastic changes. The demand for land for cultivation and spaces for settlement for increasing population, led to rapid expansion of land for agriculture and habitation for communities respectively by clearing of forest in Lukanga watershed. A large extent of land was converted to farms and settlements, Forest cover showed deteriorating dynamics over a period of 20 years from whereas, grasslands expanded during a 20 years' period. Settlements continued to expand exponentially as well as cultivated land. Further, wetlands covered area declined due to rapid agriculture expansions and rapid increase of built environments. Water bodies' sizes increased significantly throughout while barren land areas also increased drastically in size except during 2002 period. Therefore, the study demonstrated that there was wetland degradation at high the rates of change in the catchment over the study period.

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