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Land cover and land use change analysis: Its impacts on rangeland ecosystems in Kakooge County, Nakasongola district, Uganda.

James Mbaziira[1],*

Abstract · The paper presents and reviews the land cover and land use changes within a rangeland ecosystem and their impacts for a period of 18 years (1987–2005) in Nakasongola district, specifically, Kakooge County. The study used ArcGIS 10.2 data, field observations and community perceptions. Results showed a typical change in built areas, bush lands and subsistence farmlands expanded by 822.2% in 1987 and 61.7% in 2015, while commercial farmland, forest plantations, wetlands and woodland declined by 1.5%, 67.5%, 37.6% and 6.5% respectively. The changes in land cover and land uses originated from poverty, charcoal production, occurrence of drought, and introduction of pine plantations by 41%, 37%, 55% and 50%. Similarly, this resulted into frequent droughts, reduced soil productivity, food insecurity, and wood fuel crisis by 98%, 67%, 33%, and 36%, respectively. There was also general decline of land holding per household from 1.6ha to 1.5ha. Thus, such cumulative effects contribute to rangeland degradation calling for appropriate management measures like strengthening environmental monitoring and ecosystem conservation strategies, extending poverty alleviation programmes and integrating of tree planting into the farming system in a more collaborative way to halt the outpacing impacts.

Keywords · Rangelands · Landsat · Ecosystem · Land cover · Land use change.

Introduction

Rangelands relate to the world's most sensitive ecosystems adversely affected by inappropriate land uses (Zziwa *et al*., 2011). Globally, rangelands are under intense pressure from natural and human induced factors (Mbaziira, 2016; Tsegaye *et al*., 2012). Since 1950, about 10.7 million km^2 of the world lands occupied by grassland and woodland have been changed to farmlands (Kimiti *et al*., 2016). In Uganda, rangeland ecosystem decline is most pronounced in the dry corridor which stretches diagonally from the northeast through the central to the south western parts of the country covering a total land area of 84000km sq. (~ 40%), (NEMA, 2008; UNDP, 2009).

[1]Uganda Martyrs University, *jmbaziira@umu.ac.ug

The gradual increase in land cover and land use changes in rangelands of Kakooge, Nakasongola district emanates from a complex mixture of drivers, which have turned out to be a substantial problem for rangeland management. The state of the changes largely differ depending on the anthropogenic influences like increased demand for fuel wood from woodlands as the primary source of energy, and population pressure (Mbaziira, 2016; Muleneh, 2003; Lambin *et al.*, 2001). As such, the sustainability of rangelands services in Kakooge, is at stake (Zziwa *et al*., 2012,) calling for continuous monitoring as a way of understanding the dynamics and utilisation of the natural resources within the region (Mwavu and Witkowski., 2008). Such information is also very crucial in enhancing the formulation of informed policies to support sustainable rangeland management and rehabilitation practices for increased natural resource protection, resilience of rangelands to changing climates and pastoral livelihoods (Zziwa *et al*., 2012).

There is a limited linkage between land cover and land use changes with socio-economic surveys (Beza, 2011; Amanuel and Mulugeta, 2014). For instance, according to Kisamba-Mugerwa (2001) mapping spatial changes using remote sensing can only give quantitative descriptions than explaining the relationship of patterns of change and the driving forces. Therefore, understanding land cover and land use change implications on rangelands ecosystems is crucial for designing effective land use plans (Mbaziira, 2016). Therefore, it is essential to identify and assess the patterns and magnitudes of change and disaggregation of their causes using geospatial techniques, given "situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilisation of the landscape" (Sreenivasulu *et al*., 2014: 124). This facilitates the synoptic analyses of Earth - system functions, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localised ecological research and regional, national and international conservation and management of biological diversity (Sreenivasulu *et al*., 2014). Therefore, this study focused on analysing land cover and land use changes and their implications on rangeland ecosystems in Kakooge County from 1987 to 2005, their drivers and the related implications on the rangeland ecosystems in the area to support environmental planning.

Materials and methods

Description of the study area

The study was conducted within the rangelands of Kakooge county-Nakasongola corridor extending between 0^0 57' 44.89" to 1^0 40'42.76" North and 31^0 58'03.77" and 32^0 48' 00.29'' East longitude. The average altitude ranging between 3000 feet and 4550feet, with extensive uniform undulating plains panctuated by broad seasonal swamps with about 475km^2 of woodland and grassland ecosystems; and 32 km^2 open

water and wetlands and mean annual rainfall ranges between 500mm to 1000 mm per annum with mean annual temperature 26 ^{0}c (Nakasongola District Council (NDC), 2009).

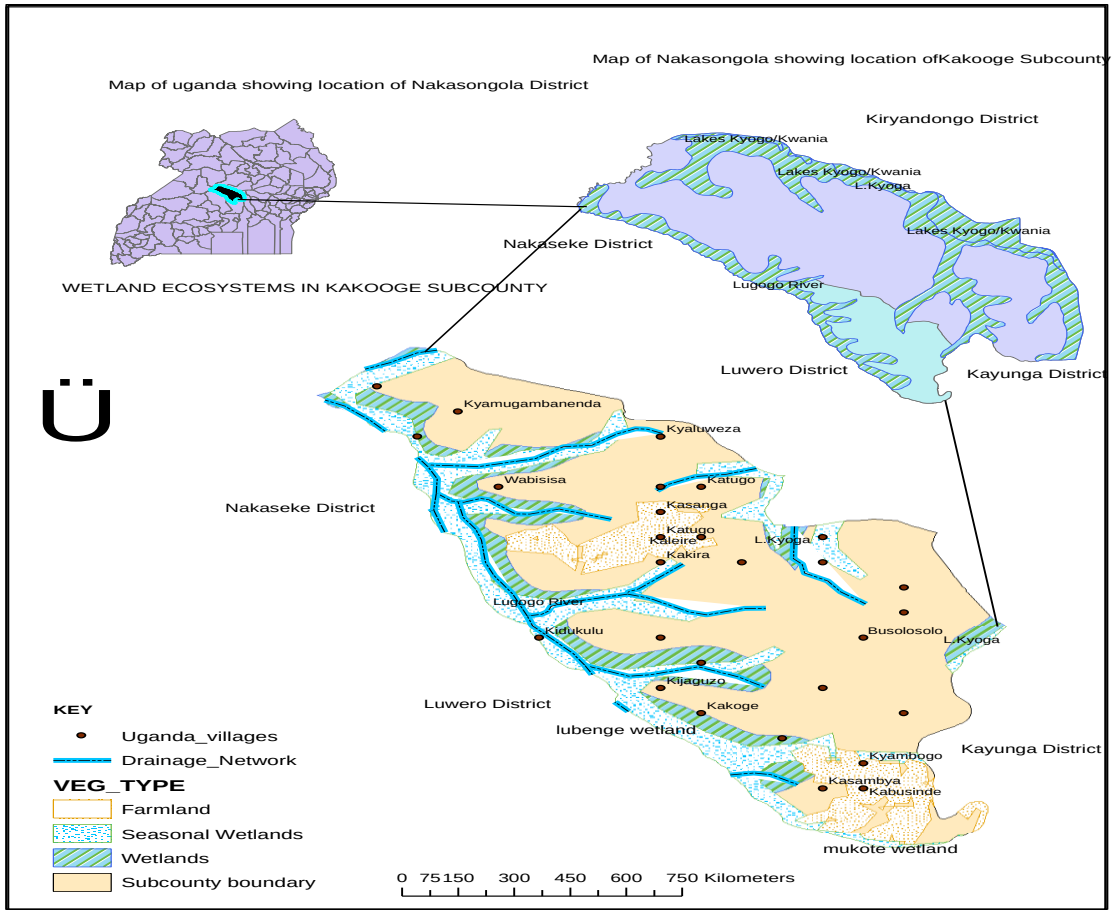

Figure 1**: Location of Kakooge County within Nakasongola District Corridor. Source: Arcmap 10.1, Uganda Administrative Boundaries shape files 2014.**

Data collection methods for land cover and land use changes

Satellite images of Landsat images obtained from the Global Land Cover Facility (GLCF), (2014) archive were analysed to study land cover and land use change. To obtain data for land cover and land use changes from 1987 to 2005, Thematic Mapper (5TM), and Enhanced Thematic Mapper plus (7 ETM+) of 30 metres resolution were used. These were cloud free and a topographical map (at scale 1:50,000 sheet 50/1 and 50/2 series Y732) which covers the entire area was obtained from the Department of

Mapping and survey at Entebbe and a Google earth map was used as supplementary ancillary data for classification and accuracy assessment in Figure 1.

Each image (1987 and 2005) was geo-referenced and ortho-corrected using the basic topographic maps and a generated Arc map of the study area in ArcGis 10.1 Software. The images were imported into the arcmap info 10.1 and transformed under the raster operations using the World Geodetic System 1984 datum (WGS 84) co-ordinate system. Using the land cover and land use map generated for the years studied, the land cover and land use changes analysis was performed using cross-tabulation, cross-classification; area losses and gains evaluation of each land cover and land use classes, and net change contribution and persistence analysis (using the land change modeller algorithm available in ArcGIS). To evaluate land cover and land use classes, about 44 Global Positioning Systems (GPS) ground truth data were collected from the field by consulting local people regarding the history of land cover and land use, their drivers and anticipated impacts on ecosystems.

The categories of land cover and land use classes for this study were adopted from the classification used by previous studies (Kafeero, 2007; Zziwa *et al*., 2011) in rangelands of eastern and central Uganda. For clarity, this categorisation was modified to generate eight classes as indicated in Table1.

Table 1. Land use and land cover class categorisation used in the study area

Class	Category	Descriptions
Class 1	Built area	Rural settlements that are associated with pastoral production systems, permanent houses and cultivated slots.
Class 2	Grasslands	Areas with permanent tall grass used for grazing but outside the tree canopy
Class 3	Wetlands	Primary, secondary and tertiary wetland ecosystems with numerous springs clustered trees, tall grass
Class 4	Subsistence farm lands	Areas used for rain fed cultivation practiced by agro-pastoralists with grassland
Class 5	Woodlands	Dense woodlands mixed with bushes and shrubs
Class 6	Forest plantations	Planted pines and eucalyptus with tall grass in between
Class 7	Bush lands	Thickets/shrubs scattered trees but bushy
Class 8	Commercial farmlands	Plantations for coffee, large scale maize gardens and enclosed ranches

Source: Ministry of water, Lands and Environment (2003)

Data analysis

Image classification and accuracy assessment

Unsupervised classification methods were employed to classify the image and produce the land cover and land use map. Unsupervised classification was also used to provide preliminary information about the potential spectral clusters to be assigned to thematic classes. Accuracy assessments of maps were determined using error matrix and Kappa

statistic (Congalton and Green, 2008). The validation for the classified maps of 1987 and 2005 were done using ground truth data of 44 points, which were gathered during the fieldwork. At each ground truth point, discussions were held with the local people who were familiar with land cover and land use classes to recall about their history covering the 1987and 2005 periods.

Land cover change analysis

After Landsat images of each year were classified and labelled independently, land cover and land use change was done using a post classification comparison method, and then a comparison was made using an overlay procedure (Egeru *et al*,. 2014; Mbaziira, 2016). Total Area (TA), Changed Area (CA), Change Extent (CE), and Annual Rate of Change (ACR) variables were used to determine the magnitudes of change in terms of Land Use Land Cover (LULC). The variables were calculated as follows

$CA = TA_{(t_2)} - TA_{(t_1)}$

$CE = (CA/TA_{(t_1)}) * 100$

$CR = CE/ (t_2 - t_1)$

Where t_1 and t_2 are the beginning and ending time of the land cover studies conducted. Change detection analysis was carried out using ArcGIS 10.1 by comparing two classified land cover maps; that is, land cover for 1987 and 2005. The summaries of the areas and percentages of land cover change are presented in Table 2

Socio-economic data

Qualitative data collected from field questionnaires and household interviews was gathered, organised and summarised using tables based on themes addressed during the study. This information was used to interpret and clarify land use land cover data collected from household interviews. The Statistical Package for the Social Sciences (SPSS v.20) was used to analyse data collected from semi-structured interviews. Descriptive statistics such as means and percentages were used to present the results.

Results and discussion

Extent of land cover and land use changes

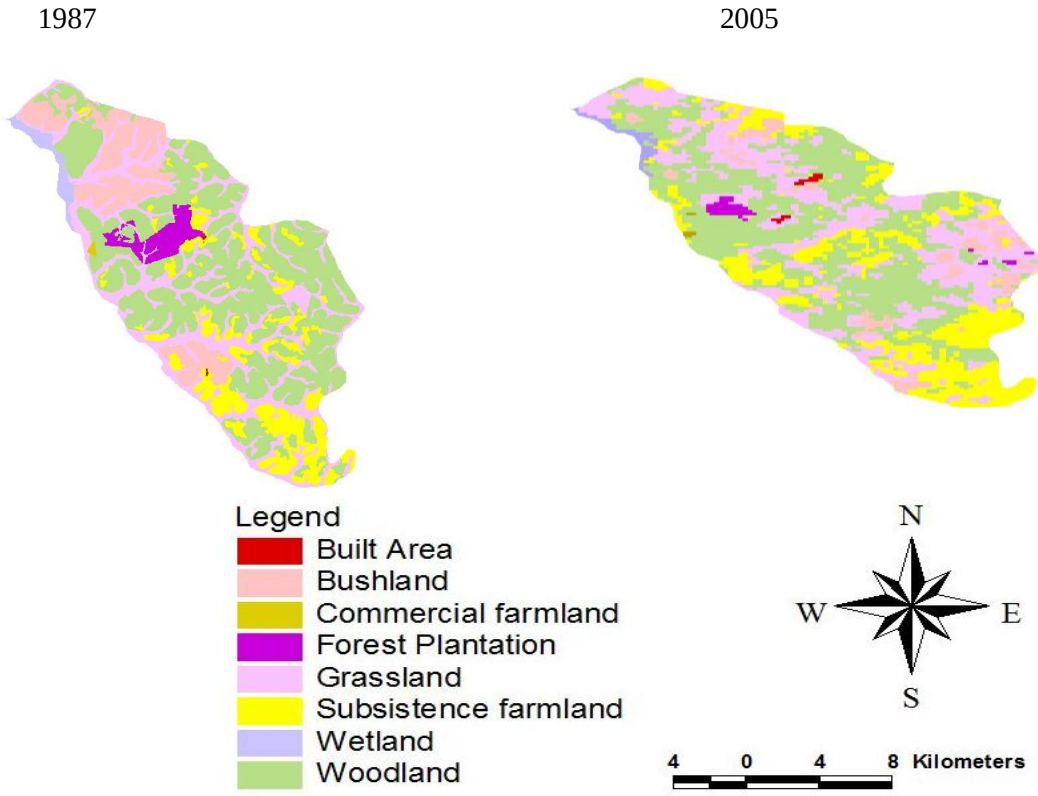

Figure 2. Land cover and land use change for Kakooge county between 1987 and 2005. Source: ArcMap 10.1 Landsat Images for 1987 and 2005

Table 2: The land cover and land use changes between 1987 and 2005

Land use/cover type	1987		2005		Change 1987-2005		
					CA	CE	CR
	Hectares	%	Hectares	%	Hectares	%	%
Built areas	18	0.0	166	0.3	148	822.2	1.8
Bushlands	6,431	12.1	2,919	5.5	-3512	-54.6	- 1.6
Commercial farmland	67	0.1	66	0.1	-1	-1.5	-150
Forest plantation	1,707	3.2	549	1.0	-1158	-67.8	-5.9
Grassland	12,929	24.3	15,236	28.7	2307	17.8	-0.8
Subsistence farmland	6,749	12.7	10,914	20.5	4165	61.7	1.5
Wetland	983	1.8	613	1.2	-370	-37.6	-10.2
Woodland	24,288	45.7	22,698	42.7	-1590	-6.5	-0.4

Source: Landsat Images for 1987 and 2005

Land cover and land use change analysis for the two study periods 1987 to 2005 showed that Kakooge rangeland ecosystems were subjected to considerable transformations (Table 2 and Figure 2). The study identified eight major land cover and land use classes, which included woodlands, built area, bush lands, forest plantations, subsistence farmlands, commercial farmlands, wetlands and grasslands as seen in Table 1. Results indicated that in the last eighteen years similar changes in land cover and land use were seen for all the land cover types except that of commercial farmlands (Table 2 and Figure 2).

Woodlands partly reduced by 6.5% for the years under analysis from 24,288 ha in 1987 to 22,698 ha in 2005 (Table 2). Overlay analysis showed that 88% of woodland was converted into other land cover types particularly built up areas, grasslands by 0.6% and subsistence farmland by 1.3% between 1987 and 2005. However, during the same period when woodland declined, other land uses also declined. For instance, bush lands declined by 2.4% whereas wetlands reduced by 1.4% between 1987 and 2005. This showed a greater diversity in their abundance of 2.0130 diversity indices (Mbaziira, 2016). This decline in woody vegetation was attributed to increased demand for charcoal production, firewood, construction poles and expansion of farmlands. This is also evident in most East African countries where areas under forest cover were converted into grazing land, farmland or used for charcoal production (Witkowski and Garner, 2008; Mbaziira, 2016). Similar trends have been observed in rangelands of Kakooge as valuable woody species are lost daily (Zziwa *et al.*, 2012) and we are losing the most important woody species from time to time (Abate and Angassa, 2016).

Results also indicate that the built-up area significantly increased by 822.2% with an average annual increment of 8.2ha per year (1987 to 2005). This resulted into a decrease in woodlands from 24,288ha in 1987 to 22,698 ha in 2005; wetlands reduced

to 835.4 ha (2005) at a rate of 15%, forest plantations by 9% between 1987 (1707ha) and 2005 (1559.4ha) while bush lands decreased by 2% as subsistence farmlands gained more areas by 2.2%, (Table 2). Dominantly the built-up areas have changed to bush lands and scrublands. Human settlements and establishments between 1987 induced this and 2005 since peace had returned into the area (Mbaziira, 2016).

Area under bush land tremendously decreased from 6,431ha in 1987 to 2,919ha in 2005 representing 5.5% reduction. The greatest decline in bush lands was observed between 1987 and 2005 as 3512ha; major conversions were into woodland, followed by grassland, subsistence farmland, built-up, wetland and forest plantations (Table 2 and Figure 2). This decline originated from excessive human burnings for new pastures, expansion of farmlands and over grazing (Olson *et al.*, 2006).

Forest plantation was an alien land use form in the area that was recognised in the satellite image of 1987. The area under pine plantations has steadily decreased from 1,707 ha in 1987 to 549ha in 2005, which represents a reduction of 67.8% (Table 2 and Figure 2). The analysis indicated that forest plantations had been established in areas formally under bush land, grasslands, farmlands and woodlands, but with the establishment of major settlements, this led to a 9% loss of forest plantation because of harvesting for poles and invasions by termites (Zziwa *et al*., 2012).

Grassland cover significantly increased by 2307ha from 12,929a in 1987 to 15,236ha in 2005 (Table 2). There was an increase of 17.8% in grasslands during the period of analysis. These changes ought to have resulted from the conversion of woodlands, where grasslands gained by cultivation, bush and woody encroachment are the major land cover types taking over grasslands in the area (Mbaziira, 2016; Zziwa *et al*, 2012).

However, the conversion of grasslands into bush and woodland is rather an ecological process that involves the interplay of several factors that include management, climatic and atmospheric composition with complex feedback mechanisms involved. Overstocking and grazing, limited or complete elimination of fire as a rangeland management tool, increasing termite activity, frequent and prolonged droughts, high ambient temperatures and elevated levels of atmospheric carbon dioxide concentration are notable factors that lead to encroachment of grasslands by woodlands (Kisamba-Mugerwa, 2001).

Subsistence farmlands substantially increased throughout the year from 6,749 hectares to 10,914 hectares between 1987 and 2005 making the generate rate of increase of 4165 hectares (Table 2 and Figure 2). Overlay analysis showed that subsistence farmlands encroached on all cover types but with severe infringement on woodlands, bush lands and grasslands. According to Lambin *et al*. (2003), expansion of agricultural land is associated with increasing number of immigrants; during the past 18 years, there were areas of high farmland expansion in Nakasongola due to settled communities.

Commercial farmlands are yet another interesting land cover that the area has adopted. By 1987, they were occupying 67 hectares; however, by 2005, it had

decreased to 66 hectares (Table 2 and Figure 2). This decrease was attributed to increased demand for cropland and invasion of tick making the area to longer support large herds leading to the annual rate of decline as 1.5%. As earlier noted, with human population increase and changes in climate, ranching land is largely at risk (Kisamba-Mugerwa, 2001).

Wetland cover form the dominant cover in the area covering over 80% of the total land area, though this was subjected to 370 hectares (37.6%) decline between 1987 and 2005, having been converted into built-up and farmland areas. These changes were a result of increase in built-up and cropland areas, however, according to Mbaziira, (2016); the greatest changes in wetlands were their conversion to croplands.

Drivers of land cover and land use change on the rangelands ecosystem

Table 3: Summary of the drivers of land cover and use change

Drivers	Frequency N=238	Percentage (%)
Socio-economic	98	41.2
Demographic	65	27.3
Ecological	55	23.1
Policy	20	8.4
Total	**238**	**100**

Source: Field data, 2017

Most respondents (41.2%) ranked socio-economic drivers as the major cause of the ever land cover and land use within the region. The prevalence of poverty forces people to turn to the natural environment as a source of livelihood, particularly, the production of charcoal as a source of fuel (Kisamba-Mugerwa, 2001; Zziwa *et al.*, 2012). It is a known fact that the high dependency on firewood and charcoal for cooking is one of the major causes of deforestation (Ezzati *et al*., 2001).

The variations in the land cover and land use are related to demographic drivers (27.3%) as reported by local inhabitants; such results are in tandem with findings elsewhere (UBOS, 2014; Mbaziira, 2016). Census data indicate that the population in Kakooge County increased from 20,622 in 2002 to 26,316 in 2014, implying that demographic expansion and consequent agricultural expansion are crucial towards land use and land cover change in any region. The study also identified ecological drivers (23.1%) in form of unreliable rainfall and drought. This is largely supported by Zziwa *et al.* (2011) that unreliable rainfall and temperature extremes contribute to woody encroachment. Furthermore, notable changes in Nakasongola woodlands between 1961 and 2010 were attributed to drought (Kigenyi, Gondo and Mugabe, 2002).

Management policies (8.4%), namely promotion of pine growing, ranching and land tenure system were identified as part of the contributers to land cover and land use changes. Division of ranches into small farms and individualisation of the land in 1994 in Nakasongola led to increased fencing and further subdivision of land into smaller patches, that could no longer support livestock grazing hence the adoption of crop production (Zziwa *et al.*, 2011). The ranching system restricts mobility of animals, which in turn leads to overstocking, thus limiting the regeneration of pastures/ bushes (Kisamba-Mugerwa, 2001).

Impacts of land cover and land use changes on rangelands ecosystems

Table 4: Impacts of land cover and land use changes on the rangelands ecosystem

Effect	Frequency	Percentages (%)
Frequent drought conditions	47	27
Reduced soil productivity	32	18
Food insecurity	29	17
Wood fuel crisis	28	16
Biodiversity depletion	20	12
Poor water quality and scarcity	12	7
Atmospheric pollution	6	3
Total	**174**	**100**

Source: Field data, 2017

Following discussions with the local people, a number of impacts of land cover and land use changes on the rangelands were indentified: frequent drought (27%), reduced soil productivity (18%), food insecurity (17%), wood fuel crisis (16%), and biodiversity loss (12%) among others. These findings are related to a study conducted in Nakasongola rangelands by Zziwa *et al.* (2011) who noted that socio-economic anthropogenic and ecological activities are the major factors causing degradation of rangelands.

According to the results obtained from this study's key informant interviews, woodlands, grasslands and wetlands were found to have declined by 1,590 hectares, 2,307 hectares and 370 hectares, respectively. The effects of such a decline are well illustrated by authors such as the Intergovernmental Panel on Climate Change (IPCC), (2007) and McCarthy (2002). These have demonstrated that land cover and use change contribute to regional and global changes in atmospheric composition, hence affecting the quality and quantity of primary production of livestock production; however, they also influence atrophic interactions that may accelerate further land use changes. Changes in the rangelands cover lead to rains, which are erratic, highly seasonal, and torrential in nature resulting into flooding (Zziwa *et al*., 2011). However, prior to the current trends in land use cover changes in most parts of the rangelands region, these regions used to significantly receive more rain (750mm) which allowed crop cultivation, (Kisamba-Mugerwa, 2001); the large-scale deforestation lead to reduced rainfall and increasing temperatures, (NEMA, 2009).

In most parts of the study area, the effects of drought tend to be very severe and are reflected in the less cloud cover, while accumulation of smoke from bush fires contributes to the build-up of atmospheric carbon dioxide and that contributes to global climate change (NDC, 2007; NEMA, 2009). Generally, global temperatures' average surface warming was to rise between 1.8°C and 4.0°C, by 2010 which was approximated to cause 20-30 % of plant and animal species to be at risk of extinction in the rangelands (Food and Agricultural Organisation (FAO), 2007).

The subsequent conversion of land cover patterns severely alters ecosystem functionality and shifts them to a different stable state as noted by Lambin *et al*. (2001), that biodiversity functionality is always low given increasing population pressure. Consequently, the livelihood of communities that depend on the integrity of natural ecosystems for products and services becomes increasingly threatened (IPCC, 2007). This can further be exemplified by a biomass study per district in Uganda, which revealed that the rate of timber/deforestation between 1990 and 2005 reduced total forest cover by 60% in Nakasongola District Council ((NDC), 2009). According to National Land use policy (2006), land use cover affected by over-grazing leads to bush encroachment and emergence of other obnoxious plants that in turn reduces the available pasture.

In most parts of the cattle corridor, the effects of drought tend to be very severe resulting into a rise in loss of animal, water scarcity and food shortages. This concurs with Kisamba-Mugerwa (2001) and FAO (2007) reports that temperature varies greatly in the cattle corridor depending on the rainfall seasons and the amount of cloud cover on the skies. Moreover, accumulation of smoke from bush fires contributes to the build-up of atmospheric carbon dioxide, which in turn contributes to global climate change (NDC, 2009; NEMA, 2009).

Continued conversion of forestland into agricultural land has induced deforestation (McCarthy, 2002) and soil degradation (Ezzati *et al*., 2001) in Nakasongola District, while the continued pastoral activities like seasonal bush burning expose land to other vagaries like water and wind erosion (NDC, 2009 and Muleneh, 2003).

Conclusion of key results

This research exhibits spatial and temporal dynamics in land cover and land use ecosystems observed at high scales from 1987 to 2005. Major expansions were witnessed among built-up areas by 822.2%, followed by subsistence farmlands 61.7% and grasslands 17.8%, and a fast shrinkage in forest plantation 67.5%, wetland 37.6%, woodland 6.5% and commercial farmland 1.5%.

Charcoal production, population pressure, poverty, drought and introduction of pine trees are major driving forces, which have had immense impacts on the rangelands' ecosystem resulting into frequent droughts, reduced soil productivity, food insecurity, and wood fuel crisis, destruction of crops by wind and poor water quality and scarcity. These call for immediate actions to secure the land cover within

the region by conducting scientific experimental investigations. These would establish the degradation threshold beyond which land uses like charcoal making and grazing become destructive to rangeland ecosystems. They would also encourage government to undertake land use monitoring as well as formulation of clear policies for communities to adopt to mitigate the losses originating from land use and land cover changes.

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Author Biography

James Mbaziira's career interests are spatial planning, landscape ecology, climate change, disaster risk reduction and rural sustainability with links to livelihood and community resilience and land use cover change analysis. He is a member of the International Geography Union, serves as the coordinator and teacher of geography for the Uganda Geographical Association and is currently a PhD Geography student at Makerere University. He is also the Head of Department and Lecturer of Geography in the Faculty of Education at Uganda Martyrs University.