Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 2, No. 5, p. 61-73, 2012
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

The dynamics of land use and land cover change in Nakasongola district

Emmanuel Zziwa[1,2], Geoffrey Kironchi[1], Charles Gachene[1], Swidiq Mugerwa[1,3], Denis Mpairwe[2*]

1Department of Land Resource Management and Agricultural Technology, P. O. Box 30197, University of Nairobi, Kenya

2 Department of Agricultural Production, College of Agricultural and Environmental Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda

3National Livestock Resources Research Institute, P. O. Box 96, Tororo, Uganda

Received: 11 April 2012
Revised: 04 May 2012
Accepted: 05 May 2012

Key words: Grassland, magnitude, patterns, woody encroachment.

Abstract

Landsat (TM) of 1986 and 1990 and Landsat (ETM+) of 2000 and 2004 for Nakasongola district were obtained and analyzed using the ILWIS 3.6 software using unsupervised classification. An overlay analysis of satellite images was conducted in order to understand the patterns of land use and cover change. Cultivation, coniferous plantations, bush and woody encroachment were the most pervasive land use and cover types encroaching on grasslands. The area covered by grassland decreased by 13.1% between 1986 and 2004. Between 1986 and 1990, much of the grasslands were converted to bushland (38,608 ha), woodland (19,659 ha) and cropland (9,159 ha) while between 1990 and 2000 were converted to woodland (21,838 ha), cropland (5,912 ha) and bushland (4,506 ha) and between 2000 and 2004, 33,354, ha were converted to woodland, 12,029 ha to bushland and 6,114 ha to cropland. Bush and woody encroachment engulfed 65%, 50% and 54% of grasslands in the periods of 1986 – 1990, 1990 – 2000 and 2000 – 2004 respectively. The rate at which grassland is lost to other land use/cover types is greater than the rate of grassland expansion meaning that grasslands are at the verge of disappearing if no conservation measures are instated to protect them.

***Corresponding Author:** Denis Mpairwe ✉ dmpairwe@agric.mak.ac.ug

Introduction

Changes in land cover (the vegetational and artificial constructions covering the land surface) and land use (human purpose or intent applied to the biophysical attributes of the earth's surface) are significant human alternation of the earth's surface (Lambin *et al.,* 1999). Land use and cover change directly affect biotic diversity (Andrieu *et al.,* 2007; Seabrook *et al.,* 2007), contribute to global climate warming (IPCC, 2007), local and regional climate change and variability (IPCC, 2001) and is a primary source of soil degradation (Ruysschaert *et al.,* 2007). Land use and cover change also contributes to regional and global changes in atmospheric composition (IPCC, 2007) thus affecting the quality and quantity of primary production (Lindroth *et al.,* 2009). Changes in atmospheric composition directs new forms of plant growth and chemical composition that not only affect livestock production, but also influence trophic interactions that may accelerate further land use changes. The subsequent conversion of land cover types may alter ecosystems dynamics and functionality so greatly and shift them to a different stable state. Consequently, the livelihood of communities that depend on the integrity of natural ecosystems for products and services become increasingly threatened.

In the rangelands of Uganda, forms of land use and cover change include the conversion of natural ecosystems (forests, wetlands and rangelands) to cultivation, gradual intensification of agriculture on land already cultivated, bush/woody encroachment on grasslands as well clearing of woodlands for grazing (Sabiiti and Wein, 1987; NEMA, 2007; Owoyesigire *et al.,* 2008). Earlier surveys of vegetation cover in the rangelands of Uganda described them as open grassland savannas with occasional woody plants in the range of 5 – 20% (Langdale-Brown *et al.,* 1964; Sabiiti and Wein, 1987). This description greatly differs from what is observed today, with major transition from grass to woody dominated components of ecosystem vegetation (Mugasi *et al.,* 2000; Owoyesigire *et al.,* 2008).

One major challenge in the management of rangeland ecosystems of Uganda is the perceived wide spread encroachment of woody species, which reduce grazing area, suppress palatable grass species and increases production costs (Mugasi *et al.,* 2000; Byenkya, 2004). Woody encroachment is often associated with alteration of above and below ground productivity, litter quality, altered hydrology, changes in microclimate and earth's surface albedo among others (Chapin *et al.,* 2005; Huxman *et al.,* 2005; Weintraub and Schimel, 2005; Hughes *et al.,* 2006). Alteration of ecosystem characteristics due to woody plant encroachment in previously herbaceous dominated ecosystems can greatly affect the energy balance, carbon dynamics and storage potential and thus impact climate at local, regional and global scale through feedback interactions (Schlesinger *et al.,* 1990; Ojima *et al.,* 1999; Asner *et al.,* 2004). In order to protect rangelands from pervasive land use and cover changes, prevent major impacts on ecological and economical systems as well as the livelihood of pastoral communities, detailed studies on the extent and patterns of change and their drivers are needed.

Rangelands are regarded as the second most fragile ecosystem in Uganda after the highlands but limited basic research has been put in place to address the threats to rangelands (NEMA, 2007). Extensive review of literature revealed that no previous study has been conducted to produce a comprehensive estimate of land use and cover change as well as the patterns of change for the rangelands of Uganda over time. The few existing studies on land use and cover changes in the rangelands have reported bush and woody encroachment into grazing lands of between 25 to 75% (Mugasi *et al.,* 2000; Byenkya, 2004; Owoyesigire *et al.,* 2008). Although many factors; cultivation, grazing, fire, charcoal burning, population increase, political instability and climatic variations are cited among the notable drivers of land use and cover changes (Odada *et al.,* 2009; Maitima *et al.,* 2010; Ebanyat *et al.,* 2010), authentic assessments of the patterns and magnitudes of change and disaggregation of their causes are still elusive in the rangelands of Uganda. There is therefore a need to obtain detailed understanding of the patterns of land use and cover change as a fundamental precept for development of coherent strategies that promote sustainable management and utilization of fragile ecosystems. This study will therefore reap from the vast availability of remote sensing data to monitor the changes in land use and cover in the semi-arid rangelands of Nakasongola district in Uganda.

Materials and methods

The study was conducted in Nakasongola district of Uganda. The district covers an area of 4,909 km^2 and is located between 0^o 57' 44.89" to 1^o 40' 42.76" North latitude and between 31^o 58' 03.77" and 32^o 48' 00.29" East longitude. The area receives a bi-modal rainfall regime with the first rainy season occurring in the months of March–May while the second in September-November. The mean annual rainfall ranges between 500 mm and 1600 mm with seasonal variations and prolonged droughts at an interval of 8 – 12 years. The mean daily minimum temperature ranges between 15.0^{o}C and 20.9^{o}C while the mean daily maximum temperature ranges between 25.4^{o}C and 33.7^{o}C. Average humidity ranges from 80% in the morning to 56% in the afternoon. The potential evapotranspiration remains high through the year (~130 mm/month and ~1586 mm/annum) and shows less variability unlike the rainfall.

The study area was covered by Landsat images consisting of two scenes of path/row 171/059 and 172/059. The Landsat (TM) and ETM+ images used had a resolution of 30m (Table 1) and were composed of seven spectral bands. ILWIS 3.6 software was used for image processing and GIS analysis. The images were imported into the ILWIS 3.6 and transformed under the raster operation using the World Geodetic System 1984 datum (WGS 84) co-ordinate system. Un supervised classification (Heckbert, 1982; Richards, 1993) of images was conducted using the clustering functions of ILWIS. A total of 15 clusters were derived from the images similar to ones used by the National Biomas Unit of Uganda in mapping Land use/cover of Uganda in 1986. Eight land cover classes were obtained for the study area through digitizing, polygonising segments and labeling the polygons (Geneletti and Gorte, 2003) based on ground reference points and focus group discussions. To determine the patterns of land cover change, a land cover change detection (Singh, 1989) was conducted in ILWIS 3.6 to identify the differences in the state of land cover over years using a post-classification change detection method (Yuan et al., 2005). Overlay of two raster maps was performed using the cross operation to compare pixels on the same positions. A cross table showing the combinations of input values, classes, number of pixels that occur for each combination and the area for each combination was obtained after ignoring all undefined values.

Results

Built-up area

This category also includes un-vegetated/bare areas because it was particularly difficult to treat them as a separate land cover type. Built-up area was covering a relatively small area in 1986, but increased steadily to the year 2004 (Table 2). Greatest increment in built-up areas occurred in the period between 2000 and 2004 with an average annual increment of 3200 ha, approximately 59% increase annually. Land cover change detection showed that built-up/un-vegetated areas developed from former bush land, grassland and woodlands with major recruitments from bush lands. On the other hand, some built-up/un-vegetated areas were converted to bush land, grassland, cultivation and woodland (Table 3, 4 and 5).

Bushland

Generally, the area under bush decreased from 51,613 ha in 1986 to 35, 684 ha in 2004 respresenting 31% decline in bushland cover. However, there was an increase in area covered by bush between 1986 and 1990 from 14.68% to 39.57% respectively (Table 2). This was then followed by a drastic decline in bushland to cover 44,500 ha (12.66%) and 35,684 ha (10.15%) of the total area in 2000 and 2004 respectively. The greatest decline (68%) in bushland was observed between 1990 and 2000. Overlay analysis showed that between the year 1990 and 2000 when most bushland disappeared, major conversions were into woodland, followed by grassland, crop land, built-up, wetland and coniferous plantations (Table 4).

Table 1. Satellite data used for digital image processing.

Date of acquisition	Type of satellite image	Spatial Resolution
10/1/1986	Landsat-5 Thematic Mapper (TM)	30m
18/5/1990	Landsat-5 Thematic Mapper (TM)	30m
23/5/2000	Landsat-7 Enhanced Thematic Mapper plus (ETM+)	30m
27/5/2004	Landsat-7 Enhanced Thematic Mapper plus (ETM+)	30m

Table 2. Land cover types of Nakasongola district in 1986, 1990, 2000 and 2004.

Land cover	1986		1990		2000		2004	
	Area (Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Built-up	1264	0.36	1161	0.33	5464	1.55	18263.1	5.2
Bush	51613	14.7	139056	39.57	44500	12.66	35684	10.2
Coniferous	0	0	2339	0.67	5110	1.46	6150.9	1.75
Grassland	90020	25.6	53228	15.15	84408	24.02	78199	22.3
SSF	13149	3.74	41327	11.76	40914	11.64	54709	15.6
Water	26156	7.44	25620	7.29	27437	7.81	24555	6.99
Wetland	14495	4.13	13503	3.84	17581	5	14986	4.26
Woodland	154742	44.03	75205	21.39	126025	35.86	118892	33.8

SSF (Small scale farming)

Table 3. The change detection matrix for Nakasongola showing the patterns of land cover changes between 1986 and 1990.

Cover type	Built-up	Bush	Coniferous	Grass land	SSF	Water	Wet land	wood land	**Totals 1990**
Built-up	1	620	0	331	3	0	0	206	**1161**
Bush	588	26567	0	38608	2865	1373	1333	67722	**139056**
Coniferous	0	0	0	1768	0	0	0	571	**2339**
Grassland	207	4426	0	19218	2715	1200	1407	24055	**53228**
SSF	289	4383	0	9159	4556	391	1416	21133	**41327**
Water	0	1967	0	105	330	20727	2374	117	**25620**
Wetland	13	1131	0	1175	464	1808	6726	2186	**13503**
Woodland	166	12519	0	19656	2216	657	1239	38752	**75205**
Totals 1986	**1264**	**51613**	**0**	**90020**	**13149**	**26156**	**14495**	**154742**	

SSF (small scale farming). Rows represent gains while columns represent losses from one cover type to another

Table 4. The change detection matrix for Nakasongola showing the patterns of land cover changes between 1990 and 2000.

Cover type	Built-up	Bush	Coniferous	Grass land	Small scale farming	Water	Wet land	wood land	**Totals 2000**
Built-up	266	3810	72	279	157	0	5	875	**5464**
Bush	45	23610	15	4506	3544	0	55	12725	**44500**
Coniferous	0	1596	1468	1066	734	0	0	246	**5110**
Grassland	551	42079	313	18421	8167	0	877	14000	**84408**
SSF	131	14941	0	5912	12605	0	235	7090	**40914**
Water	0	231	0	4	1716	24376	1093	17	**27437**
Wetland	0	2666	0	1202	1217	1244	9787	1465	**17581**
Woodland	168	50123	471	21838	13187	0	1451	38787	**126025**
Totals 1990	**1161**	**139056**	**2339**	**53228**	**41327**	**25620**	**13503**	**75205**	

SSF (small scale farming). Rows present gains while columns represent losses from one cover type to another

Table 5. The change detection matrix for Nakasongola showing the patterns of land cover changes between 2000 and 2004.

Cover type	Built-up	Bush	Coniferous	Grass land	SSF	Water	Wet land	wood land	**Totals 2004**
Built-up	1816	11433	0	3628	879	0	0	507	**18263.1**
Bush	103	11979	370	12029	276	0	1910	9017	**35684**
Coniferous	0	146.9	2339	2267	307	0	105	986	**6150.9**
Grassland	2217	8309	0	26826	15121	0	3207	22519	**78199**
Small scale farming	416	2519	607	6114	18733	67	2570	23683	**54709**
Water	0	0	0	0	0	24388	167	0	**24555**
Wetland	0	318	0	190	608	2982	8945	1943	**14986**
Woodland	912	9795	1794	33354	4990	0	677	67370	**118892**
Totals 2000	**5464**	**44500**	**5110**	**84408**	**40914**	**27437**	**17581**	**126025**	

Rows present gains while columns represent losses from one cover type to another

Coniferous plantation

This is an alien land use form in the area that was first recognized in the satelite image of 1990 in Katugo forest reserve. From then, the area under pine plantations has steadily increased from 2,339 ha in 1990 to 5,110 ha in 2000 and 6,150.9 ha in 2004 (Table 2). Overlay analysis indicated that coniferous plantations have been established in areas formally under bushland, grasslands, croplands and woodlands but with major establishments on grasslands (Table 3 – 5).

Grassland

The area covered by grassland decreased by 13.1% from 90,020 ha in 1986 to 78,199 ha in 2004 (Table 2). There was a decline of 41% and 7.4% in grasslands during the period of 1986 -1990 and 2000 - 2004 respectively. However, there was an increase in grasslands of 58.6% between between 1990 and 2000. Between 1986 and 1990, much of the grasslands were converted into bush land (38,608 ha), woodland (19,659 ha) and cropland (9,159 ha) (Table 3) while between 1990 and 2000, 21,838 ha of grassland were converted to woodland, 5,912 ha to cropland and 4,506 ha to bush land (Table 4) and between 2000 and 2004, 33,354 ha were converted to woodland, 12,029 ha to bush land and 6,114 to crop land (Table 5). In general, bush and woody encroachment engulfed approximately 65%, 50% and 54% of grasslands in the periods of 1986 – 1990, 1990 – 2000 and 2000 – 2004 respectively.

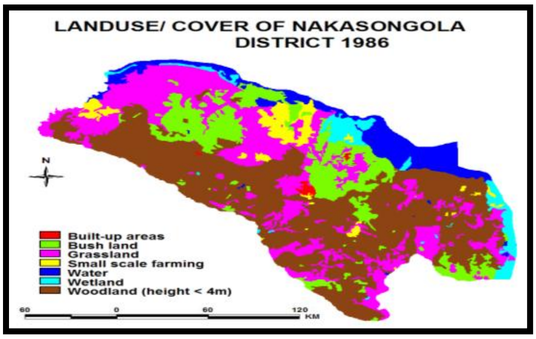

Fig. 1. Land use/cover map of 1986.

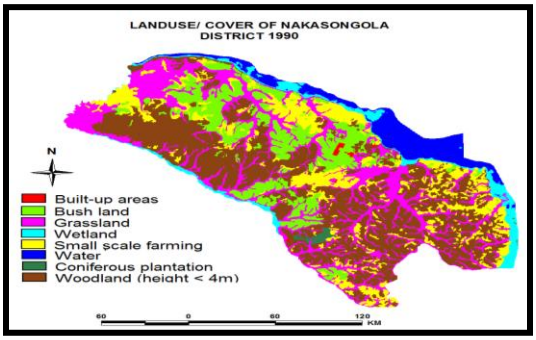

Fig. 2. Land use/cover map of 1990.

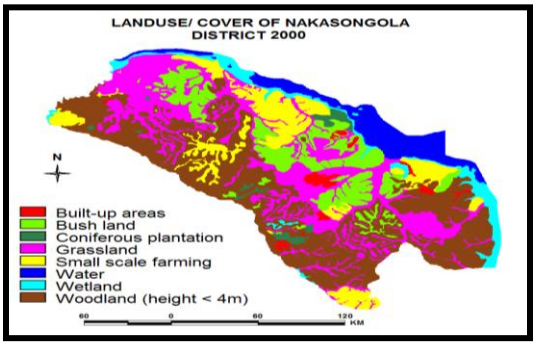

Fig. 3. Land use/cover map of 2000.

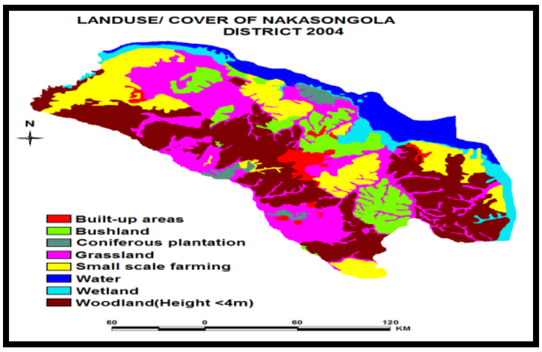

Fig. 4. Land use/cover map of 2004.

Small scale farming

This category includes rural villages (dispersed settlements) and homesteads. Generally, the area under small scale farming increased by 41,560 ha between 1986 and 2004. overlay analysis showed that small scale farming (cropping and settlements) encroached on all cover types but with severe infringement on woodlands, bushlands and grasslands. Between 1986 and 1990, woodlands lost 21,133 ha to farming, grasslands lost 9,159 ha while bushland lost 4,383 ha to farming (Table 3). Between 1990 and 2000, woodlands lost 7,090 ha, grassland 5,912 ha and bushland 14,941 ha to farming (Table 4), while between 2000 and 2004, woodland lost 23,683 ha, grassland 6,114 ha and bushland 2,519 ha to farming (Table 5).

Water

There was a 6% decrease in the area covered by water bodies between 1986 and 2004 from 26,156 ha to 24,555 ha (Table 2). There was a 2% decrease in the area covered by water between 1986 and 1990, an increase of 7.1% between 1990 and 2000, and finally a decrease of 10.5% between 2000 and 2004. A notable change in area covered by water was the presence of many small sized water bodies (valley dams) in 1986 which completely disappeared on the map of 2004 (Figures 1 – 4). Overlay analysis showed that may major land use and cover types encroaching on water areas were wetland, small scale farming and grassland (Tables 3 – 5).

Wetland

There was a 6% decrease in the area covered by wetland between 1986 and 1990, an increase of 30.2% between 1990 and 2000 and a decrease of 14.8% between 2000 and 2004 (Table 2). Overall, the area covered by wetlands increased by 3.4% between 1986 and 2004. Between 1986 and 1990; 7,769 ha of wetland were converted to other land cover type with the majority being inundated by water and encroached on by cultivation (Table 3). Between 1990 and 2000, wetland lost 3,716 ha but gained 7,795 ha in the same period causing a net increase of 4,078 ha in wetlands (Table 3). Between 2000 and 2004, wetland lost 8,636 ha (mainly to small scale farming, grassland and bush land) and gained 6,041 ha (mainly from water, small scale farming and woodland) leading to a net decrease of 2,595 ha (Table 5).

Woodland

There was a 23% decline in the area covered by woodlands over an eighteen year period from 154,742 ha in 1986 to 118,892 ha in 2004 (Table 2). There was a 51.4% decline in area covered by woodland between 1986 and 1990, with an annual decline of 12.9%. There was an increase in woodland between 1990 and 2000 of 67% and a decline of 5.7% between 2000 and 2004. Overlay analysis showed that 115,990 ha of woodland were converted into other land cover types particularly bushland (67,722 ha), grassland (24,055 ha) and cultivation (21,133 ha) between 1986 and 1990 (Table 3). However during the same period 19,656 ha of grassland and 12,519 ha of bushland were converted into woodland (Table 3). 87,238 ha and 36,418 ha of woodland were gained and lost respectively between 1990 and 2000, with woodlands encroaching on 21,838 ha of grasslands and 50,123 ha of bushland (Table 4). Between 2000 and 2004, woodlands expanded by 51,522 ha while 58,655 ha were converted to other land cover types (Table 5).

Discussion

Land cover changes in Nakasongola district are reflected in both temporal and spatial scales. Spatial changes in land cover changes include expansion of cultivated lands in natural vegetation types (grasslands, bush land, wetland and woodland), expansion of grasslands into bush land and woodlands, introduction and expansion of pine plantations into woodlands, bush lands and grasslands, encroachment of bushes and woodlands into grasslands and increase in bare ground, while temporal scales include the regeneration of woodlands on the same piece of land after some years of clearing. With the exception of bush and woody encroachment into grasslands all other spatial changes are driven by direct alteration of man on natural vegetation for food production, economic and social gains (Odada et al., 2009; Ebanyat et al., 2010; Maitima et al., 2010).

Built-up area

Human settlements and establishments account for this land cover between 1986 and 1990. The restoration of peace in this area after the bush war that ended in 1986 led to emigration of people that had immigrated into Nakasongola from other parts of the country hence leading to a decrease in the area covered by built-up area. The partition of formally natural grazing lands into small ranches followed by restricted mobility of livestock in 1994 led to overstocking in several places that limited the regeneration of pastures. This coupled with termite activity and charcoal burning exacerbated the land degradation problem that created bare patches of land hence explaining the immense increases in built-up/open areas from 1990 up to 2004. Anecdotal information from this area also suggests that land degradation, intensified termite damage and charcoal burning became problems in Nakasongola district around 1996 and 1998 and have led to the creation of large patches of bare land.

Bushland

The increasing human population, demand for food and increased cultivation in Nakasongola districts are major factors explaining the gradual decline in the area covered by bushlands. In most areas, bush has occurred as a transitional succession stage leading to establishment of woodlands in the area. The reduction in livestock populations in the area after the 1986 insurgency meant that the few remaining animals could not effectively graze and browse the entire area and this promoted the growth of shrubs leading to their increment in 1990. This therefore explains why immense areas formerly covered by grassland were converted into bush land. Overgrazing of land has often led into reduced soil fertility and exposure to soil erosion which results into failure of grasses to grow but does not affect the growth of deep rooted shrubs which recruit and suppress grasses. Because low input agriculture is practiced in the area with no fertilizers use, the soils loose fertility quickly and cultivators shift to new areas hence leaving former cultivated areas to furrow into bushland. Also, the increased cutting down of trees for wood and charcoal eliminates the intra-species competition between woody species and their saplings. This results into recruitment of hundreds of saplings into mature trees that first appear as shrubs before eventually becoming trees. Increase in woody cover has been earlier reported to reduce grazing space and increase production costs through bush clearing hence compromising pastoral incomes (Mugasi *et al.,* 2004)

Grassland

Cultivation, bush and woody encroachment are the major land cover types taking over grasslands in Nakasongola district. Increased conversion of grasslands into crop farming is basically an anthropogenic activity driven by the increasing human population and demand for food especially by immigrants from high potential areas that carry with them their former land use practices. However, the conversion of grasslands into bush and woodland is rather an ecological process that involves 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

Small scale farming

Conspicuous land cultivation for food production started around 1990 in Nakasongola district following the increased settlement of people with crop production background. The division of ranches into small farms and individualization of land in 1994 led to increased fencing and further sub-division of land into smaller patches that could no longer support livestock grazing hence the adoption of crop production as the most appropriate land use form for such bitty land holdings. However, because of the limited potential of soils in this area to support crop growth as earlier reported by Radwanski (1960) and the practice of low input agricultural production with no fertilizer use, farmers often open up new areas in search of fertile soils on an annual basis. In this regard, woodland, bushland, grassland and wetland are greatly encroached on by cultivators. Cultivation and the associated fencing of land to protect destruction from animals not only reduce livestock grazing resources but also restrict animal movements in search for water and forage especially during dry season. This leads to increased overgrazing of the remaining land thus accelerating degradation of grasslands. Overgrazing also means that animals eat most of the available plant material, both fresh and dry in the struggle to survive. In this situation, the deposition of litter which is a major source of food for the majority of termite species in Nakasongola is restricted. The litter feeding termites resort to fresh vegetation, competing with livestock and therefore increasing the pressure on grasslands resulting into unprecedented levels of land degradation and creation of immense patches of bare soil. Termite damage is unequivocal in both grasslands and croplands since they resort to feeding on fresh vegetation due to scarcity of dry materials and are thus regarded as a major threat to forage availability in Nakasongola district (Mugerwa et al., 2011a; 2011b). Because crop residues are not utilized in livestock feeding to lift the burden of overgrazing from grasslands during the dry season, the introduction and intensification of crop production in pastoral rangeland communities has no linkage with livestock production and therefore greatly contributed to the presently high levels of land degradation and decrease in livestock grazing areas.

Water and wetland

Changes in the area covered by water and wetlands follow the same pattern and are attributed to changes in the amount of rainfall received as well as the droughts experienced in the area. Increase in water levels as a result of high rainfall amounts result into a corresponding increase in wetlands due to inundation of nearby areas. Conversely, long dry spells reduce the area under water and wetland coverage. The area experienced long dry spells between 1983 and 1989 which led to the reduction in water levels and drying up of valley dams and tanks hence reducing the area under water in 1990 as well as increased cultivation in wetlands hence reducing their coverage. The increment in water and wetland cover in 2000 was attributed to relatively high rainfall years 1995, 1997 and 2000 while their decline in 2004 was attributed to long droughts of between 2001 and 2004. Imageries show that the area had many small water bodies (valley dams and tanks) in 1986 which contributed to high water coverage in this year. However, high rates of land degradation following the division of ranches and the resultant overgrazing increased soil erosion and deposition of silt in valley dams and tanks which led to a reduction in their volume and complete disappearance of most of these surface water reservoirs.

Woodlands

The continued decrease in area covered by woodlands from 1986 to 2004 is basically attributed to increased anthropogenic activities that include cutting down trees for cultivation, plantation forests, grasslands and charcoal production as has been the case elsewhere in the world (Lambin et al., 1999; 2001; Mwavu and Witkowski, 2008; Ebanyati et al., 2010; Maitima et al., 2010). However the increase of woodland in grasslands takes a rather more complex process with many contributing factors. Some of the forces driving reductions in woodland area have a positive feedback mechanism that drives more woody growth in the same area. The indiscriminative cutting down of sparse savanna trees often results into a dense stand of woodlands due to elimination of intra-species competition between tree saplings that gives an equal chance of all tree saplings to recruit into trees. Such forces therefore contribute to temporal and spatial variations in the area covered by woodlands.

The encroachment of bush and woody species in grassland ecosystem involves a sequence of ecological events and is driven by a complex of factors involving changes in management practices, climate and atmospheric composition (Archer et al., 1995; van Auken, 2000; Asner et al., 2004) which may act singly or in combination. Overgrazing, suppression of active fires and increase in termite activity are primary factors that led to alterations in tree-grass competition, reduction in herbaceous layer and consequently to a reduction in fire frequencies. There exist a feedback mechanism between these factors; for example, suppression of annual active fires is believed to have contributed to increased activity of termites in the rangelands. The scotching fires were a natural control over soft bodied ants and termites killing them even several centimeters below the ground. As herbaceous biomass declined and the frequency and intensity of fires decreased, termites populations started to build destroying more grass.

Reduction in herbaceous layer and fire frequencies shifted the competition between grasses and woody plants in the favour of trees, leading to increased recruitment of saplings into mature trees and increased density of woody vegetation in former grass dominated systems. Similar findings were reported by Brown and Archer (1999), Kraaij and Ward (2006) and van Auken and Bush (1997) who noted that the co-existence of grasses and trees in the savanna ecosystem is as a result of competition for resources and that alteration in the competition to favour one of the components leads to its dominance in the system.

Trees, being C_3 plants are known to have a more efficient photosynthetic process under elevated carbon dioxide conditions compared to grasses (C_4

plants). On this basis, the global increase in atmospheric carbon dioxide concentration above the upper safety limit (350 ppm) in 1988 is believed to have had a significant contribution on the increased woody encroachment in the savanna ecosystems in Nakasongola. Since farmers started noticing woody encroachment in 1990 and consequently becoming a rangeland management problem from 1994 (NEMA, 1996), the elevated CO_2 levels must have contributed to the increased dominancy of woody species into grasslands of Nakasongola rangelands as earlier observed in other regions by Knapp (1993), Polley *et al.* (1992) and Johnson *et al.* (1993).

Rainfall and temperature are among the climatic forces that might be contributing to woody encroachment in grassland ecosystems. There have been notable changes in the rainfall of Nakasongola between 1961 and 2010 and these must have strong bearing on woody encroachment since water is a major resource that determines tree – grass existence in savanna ecosystem (Knoop and Walker, 1985; Smith and Goodman, 1986; Kraaij and Ward, 2006). The years in which woody encroachment became a problem (1990 – 2004) are consistent with the years when droughts became more frequent and prolonged in the area. Since droughts lead to evaporation of all water in the grass root zone and subsequently leading to death of shallow rooted grasses, deep rooted trees recruit in numbers at the expense of grasses and thus become more dominant as observed by (Skarpe, 1990; Scholes and Archer, 1997; Scanlon *et al.,* 2005). From 1990, the area has received high temperatures above a 50 year mean. At high temperatures, the evapotranspiration rates of grasses reduce due to stomata closure. This reduces photosynthesis in grasses resulting into decreased performance of the grass component. The water stored in the soil therefore become accessible to only trees. This coupled with elevated carbon dioxide increases the performance and dominance of trees over grasses as suggested by Knapp (1993).

Conclusion

Cultivation, pine establishment, bush and woody encroachment are the most pervasive land use and cover changes with detrimental effects on the sustainability of grassland ecosystems in the rangelands of Nakasongola district. The findings of this study indicate that sustainable rangeland management practices such as discriminative tree cutting, use of fire as a rangeland management tool, and controlled cultivation in livestock movement areas need to be adopted to curtail the conversion of grasslands to other cover types. Intensification of cropping systems and transformation from low input to high input farming should be practiced to reduce the opening up of new land every season in search for fertile soils. The need to develop a rangeland policy for Uganda based on scientific evidence is envisaged to anchor the practice of strategies recommended from this study.

Acknowledgement

We acknowledge financial support from RUFORUM (Regional Universities Forum for Capacity Building in Agriculture), IFS (international Foundation for Science) and FSC (Food Security Centre) and the technical assistance from Makerere University, University of Nairobi and Bulindi Zonal Agricultural Research and Development Institute.

References

Andrieu N, Josien E, Duru M. 2007. Relationship between diversity of grassland vegetation, field characteristicts and land use management practices assessed at the farm level. Journal of Agriculture Ecosystems and Environment **120,** 359 – 369.

Archer S, Schimel DS, Holland EA. 1995. Mechanisms of shrubland expansion: land use, climate or Carbon dioxide. Climate change **29,** 91-99.

Asner GP, Elmore AJ, Olander LP, Martin RE, Harris AT. 2004. Grazing systems, ecosystem responses and global change. Annual Review, Environmental Resources **29,** 261-299.

Brown JR, Archer S. 1999. Shrub invasion of grassland: recruitment is continuous and not regulated by herbaceous biomass or density. Ecology **80,** 2385–2396.

Byenkya GS. 2004. Impact of undesirable plant communities on the carrying capacity and livestock performance in pastoral systems of South-Western Uganda. PhD. Thesis Texas A & M University, USA.

Chapin FS, Sturm M, Serreze M, McFadden J, Key J. 2005. Role of land-surface changes in arctic summer warming. Science **310,** 657–660.

Ebanyat P, Nico de Ridder, Andre de Jager, Delve DJ, Bekunda AM, Giller KE. 2010. Drivers of land use change and household determinants of sustainability in smallholder farming systems of Eastern Uganda. Journal of Population and Environment **31,** 474–506.

Foley JA, Kutzbach JE, Coe MT, Levis S. 1994. Feedbacks between climate and boreal forests during the Holocene epoch. Nature **371,** 52–54.

Geneletti D, Gorte BGH. 2003. A method for object-oriented land cover classification combining Landsat TM data and aerial photographs. Int. J. Remote Sensing **24,** 1273 – 1286.

Heckbert P. 1982. Color image quantization for frame buffer display. Computer Graphics **16,** 297-307.

Hughes RF, Archer S, Asner GP, Wessman CA, McMurtry C, Nelson J. 2006. Changes in aboveground primary production and carbon and nitrogen pools accompanying woody plant encroachment in a temperate savanna. Global Change Biol. **12,** 1733–1747.

Huxman T, Wilcox B, Breshears D, Scott R, Snyder K. 2005. Ecohydrological implications of woody plant encroachment. Ecology **86,** 308–319.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate Change 2001, Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the IPCC Third Assessment Report (TAR). Cambridge University Press, Cambridge, UK.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Report of the working Group II. Cambridge University Press, UK, pp. 973.

Johnson HB, Polley HW, Mayeux HS. 1993. Increasing Carbon dioxide and plant-plant interactions: effects on natural vegetation. Vegetation **105,** 157–70.

Knapp AK. 1993. Gas exchange dynamics in C3 and C4 grasses: consequences of differences in stomatal conductance. Ecology **74,** 113-123.

Knoop WT, Walker BH. 1985. Interactions of woody and herbaceous vegetation in a southern African savanna. Journal of Ecology **73,** 235-253.

Kraaij T, Ward D. 2006. Effects of rain, nitrogen, fire and grazing on tree recruitment and early survival in bush-encroached savanna, South Africa. Plant Ecology **186,** 235–246.

Lambin EF, Turner BL, Helmut JG, Agbola SB, Angelsen A. 2001. The causes of land-use and land cover change: moving beyond the myths. Journal of Global Environmental Change **11,** 261 – 269.

Lambin EF, Baulies X, Bockstael N, Fischer G, Krug T. 1999. Land-use and land-cover change (LUCC):Implementation strategy. IGBP Report No. 48, IHDP Report No. 10, Stockholm, Bonn.

Langdale-Brown I, Osmaston HA, Wilson JG. 1964. The vegetation of Uganda and its bearing on land-use. CABI direct. P. 147.

Maitima JM, Olson JM, Mugatha SM, Mugisha S, Mutie IT. 2010. Land use changes, impacts and options for sustaining productivity and livelihoods in the basin of lake Victoria. Journal of Sustainable Development in Africa **12,** 189 – 207.

Mugasi SK, Sabiiti EN, Tayebwa M. 2000. The economic implications of bush encroachment on livestock farming in rangelands of Uganda. African Journal of Range and Forage Science **17,** 64 – 69.

Mugerwa S, Nyangito M, Mpairwe D, Bakuneeta C, Nderitu J, Zziwa E. 2011a. Farmers' ethno-ecological knowledge of the termite problem in semi-arid Nakasongola. African Journal of Agricultural Research **6(13),** 3183-3191

Mugerwa S, Nyangito M, Mpairwe D, Bakuneeta C, Nderitu J, Zziwa E. 2011b. Termite assemblage structure on Grazing lands in Semi-arid Nakasongola. Agric. Biol. J. N. Am. **2(5),** 848-859.

Mwavu EN, Witkowski ETF. 2008. Land-use and cover changes (1988–2002) around Budongo forest reserve, NW Uganda: Implications for forest and woodland sustainability. Journal of Land degradation and development **19,** 606–622.

NEMA (National Environment Management Authority). 1996. The State of the Environment Report, 1996. Kampala, Uganda

NEMA (National Environmental Management Authority). 2007. The need for sustainable utilization and management of Uganda rangeland resources. 4(20).

Odada EO, Ochola WO, Olago DO. 2009. Drivers of ecosystem change and their impacts on human well-being in Lake Victoria basin. African Journal of Ecology **47 (Suppl.1),** 46 – 54.

Ojima DS, Kittel TGF, Rosswall T, Walker BH. 1999. Critical issues for understanding global change effects on terrestrial ecosystems. Ecol. Applic. **1,** 316–325.

Owoyesigire B, Mpairwe D, Bernard B, Mutetika D, Kiwuwa G, Peden D. 2008. Socioeconomic factors affecting livestock water productivity in rain fed pastoral production systems. Proceeding of second International Forum on Water and Food. 10th – 16th November 2008, Addis Ababa, Ethiopia. Volume II – IFWF2 Science Session papers p. 75 – 78.

Polley HW, Johnson HB, Mayeux HS. 1992. Carbon dioxide and water fluxes of C3 annuals and C3 and C4 perennials at subambient Carbon dioxide concentrations. Funct. Ecol. **6,** 693–703.

Radwanski SA. 1960. The soils and land use of Buganda. A reconnaissance survey. In the Memoirs of the research division, series 1 – Soils, Number 4. 631.44 (676.1) UGA. P. 1 – 133.

Richards JA. 1993. Remote Sensing Digital Image Analysis: An Introduction. 2nd edition, Springer-Verlag, New York, p. 340.

Ruysschaert G, Poesen J, Verstraeten G, Govers G. 2007. Soil loss due to harvesting of various crop types in contasting agro-ecological environments. Journal of Agriculture, Ecosystems and Environment **120,** 153 – 165.

Sabiiti EN, Wein RW. 1987. Fire and acacia seeds: a hypothesis of colonization success. Journal of Ecology **74,** 937-946.

Scanlon TM, Caylor KK, Manfreda S, Levin SA, Rodriguez-Iturbe I. 2005. Dynamic response of grass cover to rainfall variability: implications for the function and persistence of savanna ecosystems. Advances in Water Resources **28,** 291–302.

Schlesinger WH, Reynolds JE, Cunningham GL, Huenneke LF, Jarrell WM, Virginia RA, Whitford WG. 1990. Biological feedbacks in global desertification. Science **247,** 1043–1048.

Scholes RJ, Archer SR. 1997. Tree-grass interactions in savannas. Annual Reviews of Ecological Systems **28,** 517–544.

Seabrook L, McAlpine C, Fensham R. 2007. Spatial and temporal analysis of vegetation change in agricultural landscapes: A case study of two brigalow (Acacia harpophylla landscapes in Queensland, Australia. Journal of Agriculture Ecosystems and Environment **120,** 211 – 228.

Skarpe C. 1990. Shrub layer dynamics under different herbivore densities in an arid savanna, Botswana Journal of Applied Ecology **27,** 873-885.

Smith TM, Goodman PS. 1986. The effect of competition on the structure and dynamics of Acacia savannas in Southern Africa. Journal of Ecology **74,** 1013-1044.

van Auken OW, Bush JK. 1997. Growth of Prosopis glandulosa in response to changes in above ground and belowground interference. Ecology **78,** 1222–1229.

van Auken OW. 2000. Shrub invasions of North American semiarid grasslands. Annual Review of Ecology and Systematics **31,** 197–215.

Weintraub MN, Schimel JP. 2005. Nitrogen cycling and the spread of shrubs control changes in the carbon balance of arctic tundra ecosystems. Bioscience **55,** 408–415.

Yuan F, Sawaya KE, Loeffelholz BC, Bauer ME. 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Remote Sensing of Environment **98,** 317 – 328.