JASEM ISSN 1119-8362

Full-text Available Online at
www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. December, 2010
Vol. 14 (4) 101 - 106

The Effect of Land use/cover change on Biomass Stock in Dryland Areas of Eastern Uganda. A case study of Olio Sub-county in Soroti District

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ABSTRACT: Drylands occupy 44% of Uganda's land surface and provide livelihood to a cross-section of both rural and urban folks. However in the face of population pressure, drylands are increasingly in the path of conversion and degradation. This study therefore, performed an assessment of the effect of land use/cover change on biomass stock in olio sub-county from 1973 to 2001. A series of systematically corrected Orthorectified Landsat imageries of 1973, 1986 and 2001 obtained from the Landsat website were used. The images were analysed using unsupervised approach in Integrated Land and Water Information System version 3.3 and validated using field observations and historic memories of village elders. Findings indicate that land use/cover change is driven by small-scale farming. Between 1973-1986 significant declines were identified among small-scale farming (23.2%), grasslands (8.7%) and large scale-farming (9.9%). Further, declines were also registered between 1986-2001 in Bushland (12.1%), woodlands (13.9%) and wetlands (8.2%) while dramatic gains were registered in small-scale farming by 19.4%. These declines led to losses in the available biomass stock by 2001 within bushlands, wetlands and woodlands loosing 29.1 million tons, 669.1 metric tons and 87.3 million tons respectively. We conclude that small-scale farming by resource poor farmers is rapidly transforming the vegetation landscape. Therefore, there is need for increased use of remote sensing and GIS to quantify change patterns at local scales for essential monitoring and assessment of land use and or/cover change effects and human interference on the landscape. @JASEM

Uganda's drylands cover 44% of the country (84,000 km^2). They are the second most fragile ecosystems in the country after the highlands (NEMA, 2007). These environments provide livelihood to both rural and urban folks and are very important food production zones. The current land use/cover change (LUCC) patterns are threatening the stability of these ecosystems; this is because LUCC that once required centuries now take place within a few decades. This is largely attributed to the dare dependence on primary resources (Ademiluyi *et al;* 2008). However, land use has been a component of human-driven global change that has been occurring for the longest period of time. Imperatively, land-cover change associated with agriculture has had an enormous impact on the structure and functioning of ecosystems (Paruelo *et al;* 2001). These changes have increased the rate of species extinction, not only by replacing natural eco-systems but also by changing the disturbance regime. Further LUCC have a potential of triggering local and regional consequences including loss of soil fertility, soil erosion, reduction of biological diversity, hydrological changes, climatic alteration and a modification of the atmospheric composition. These have all attracted attention in the recent past but one very basic effect of LUCC on biomass stock has eluded attention.

Historically, the driving force for most LUCC is population growth (Ramankutty *et al;* 2002b) although there are several other interacting factors involved (Lambin *et al;* 2001). LUCC detection at micro level allows for the identification of major processes of change (Fasona and Omojola, 2005) and can also facilitate quantification of change effects. The effects of LUCC are less well studied thus there is a need to understand LUCC and its effect on the overall ecosystems (Lambin *et al;* 2003). It is within this background that this study sought to determine the effect of LUCC on biomass stock.

MATERIALS AND METHODS

Olio sub-County is located in Eastern Uganda. It lies approximately on latitudes 1°33' and 2°23' North off the equator, 30°01' and 34°18' degrees East of Prime Meridian and is over 2,500 feet above sea level with isolated rock outcrops (Figure 1). The area is largely underlain by rocks of the basement complex pre-cambrian age which include; granites, mignalites, gneiss, schists, and quartzites with four major soil units; Serere and Amuria catena; Metu complex and Usuk series.

The vegetation is a mixture of woodlands, a wooded savanna, grass savannah, forests and riparian vegetation (DSER, 1997). Wooded savannah consists of moist *Acacia* savanna associated with *Hyparrhenia spp* and *combretum* associated with *Hyparrhenia ssp* while *Hyparrhenia spp, Themeda* and *Imperata cylindricum* are the dominant grass savannah (DSER, 2004). Expanses of riparian vegetation (Wetland vegetation) with scattered tree grasslands associated with *Setaria incrassate*

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Hyparrheria rufa, Accacia sayel Acaccia fistula, *Balanities aegyptica* and *Terminalia spp, Cyperus papyrus, Aeschynomen, Cyperus articulatus, Ulylectrum digitatum, Suddia sagitifolia* dominate. These wetlands are used as feeding areas by wading birds including; Fox Weaver (*Ploceus spekeoides*), Blue Quail (*Coturnix adansonii*), and Yellow-billed Ox-pecker (*Buphagus africanus*) and also do provide firewood (NEMA, 2006).

A Series of systematically corrected Orthorectified Landsat imageries for 1973, 1986 and 2001 were downloaded from the Landsat website. Three scenes were used; a Landsat MSS (1973) at a 57m X 57m spatial resolution; a Landsat TM (1986) at 28.5m X 28.5m and a Landsat ETM (2001) at a 28.5m X 28.5m spatial resolution. All image data had been obtained during the mature plant/vegetation period in the area. Resampling was performed to enable location of the study area and facilitate the scenes to be geometrically compatible. The projection was set at UTM Zone 36N, Ellipsoid WGS 84 and Datum WGS 1984. Road intersections, culvert points and administrative buildings and schools that were in existence before 1973 were used as control points for image geometric corrections. The images were analysed using unsupervised approach in Integrated Land and Water Information System (ILWIS) version 3.3. Preliminary land-use/cover maps were validated using field observations and historic memories of village elders. Validated maps were then processed in the land-use modeller integrated in ArcGIS 9.2.

Following the land use land cover (LULC) classification units produced for Uganda by the Forest Department of the Ministry of Water Lands and Environment (2003), thirteen (13) LULC units are listed including plantations hardwoods, plantations softwoods, THF-degraded, THF-normal, woodlands, bushlands, wetlands, subsistence farmlands, commercial farmlands, built-up areas, water and impediments. For this study, the classification units were reduced to eight (8) which were recoganisable in the area to include; built up areas, bushlands, grasslands, wetlands, impediments, woodlands, small-scale (subsistence farmlands) farming and large-scale (commercial farmlands) farming. The output of hectares from each of the LULC units was multiplied with NFA (2003) estimate of the mean standing stock in kilograms or approximate tons per hectare. In order to establish the socio-economic characteristics of the community, a household survey was conducted among 10% of the households (490 households) in the sub-county.

RESULTS AND DISCUSSION

Socio-economic characteristics: From the household survey over seventy percent of the households (70.8%) were male headed with an average age of 43 years. On average there were 6.8 persons in the household, this is above 5.6 persons' national average. About thirty seven percent (36.5%) of the household heads had attained formal primary education formal education, 23.9% had not, 22.2% had completed Secondary level of education and 17.3% had completed tertiary education, overall literacy stood at 76%. Over 94% of the households relied on crop cultivation for both food and income generation. On the other hand, 19.4 % of the household heads were engaged in fuelwood trade for income generation. Amidst these developments, 99.8% of the household heads observed that there were significant changes in vegetation cover in the last 10 years with 98.8% observing that there were fewer trees now.

Table 1: Estimated mean Standing Stock (tons) Per Land use/cover type (without sub-stratification)

Land use/cover type	1973	1986	2001	Total change 1973-86	Total change 1986-2001
Built up area	27736044	43877833.34	85173481	90507.2696	231725.9
Bushland	14,800,851	45403025.76	16,301,560	30,602,174.70	-29,101,466
Grasslands	37,384,431	24,956,837.90	32,059,437	-12,427,593	7,102,599
Impediments	N/A	N/A	N/A	N/A	N/A
Large-scale farming	6,143,023	0	2,070,139	-6,143,022.97	2,070,139
Small-scale-farming	75,097,024	29450024.22	67,581,226	-45,646,999.70	38,131,201
Wetlands	931,459.30	1169447.399	500,358.30	237,988.08	-669,089.10
Woodlands	238,786.20	87952923.15	693,617.10	87,714,136.90	-87,259,306

N/A = Not applicable

About 99% of the households use fuelwood in form of firewood for cooking and preserving food. This portrays the importance of traditional biomass energy in the households. The mean annual consumption was estimated at 3687.8 kilograms translating to 542.3 kilograms per capita thus giving a 10.4 kilogram weekly consumption average. This finding is however below the 629 kilograms capita wood consumption estimates reported by Buyinza and Teera (2008) for Hoima district Uganda and lowers than 687 kilograms for South Africa reported in Shackleton (1993). Comparatively this per capita wood consumption is higher than 485 kilograms per capita estimates for Nakasongola and Masindi districts of Uganda reported in Kalumian and Kisakye (2001).

Findings further reveal that 34.3% of the households occasionally used charcoal with a per capita annual demand of 231.6 kilograms which translates to 4.45 kilograms per week and approximately 0.64 kilograms per day. According to Ahmet *et al;* (2008) a high dependence of households on firewood illustrates that firewood is a necessity for the rural communities. The total reliance on firewood was attributed to it perceived availability (71%), cheapness (62%), efficiency in cooking (49%), it is a tradition to use firewood for cooking and the alternatives are expensive (30%). These findings reinforce Sikei *et al;* (2009) observations in Kakamega western Kenya. The traditional three cooking stones are still the dominant cooking facilities among 87% of the households, these facilities loose a lot of heat to the environment and therefore they are unsustainable. In Williams and Shackleton (2002) argument sustainable wood use can have positive economic benefits at household level.

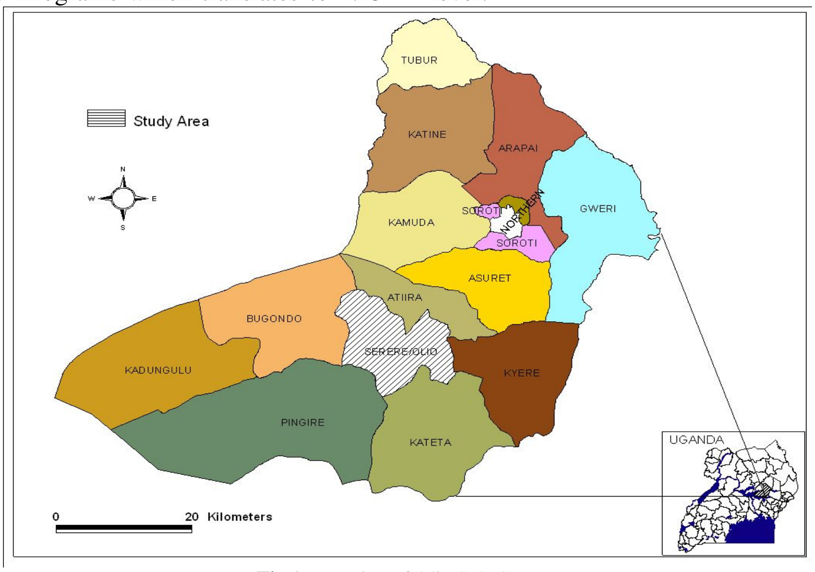

Fig 1: Location of Olio Sub-County

Land use/cover Change (LUCC): Olio Sub-county covers a total land area of 17,823 hectares. Findings indicate that small-scale farming was the dominant land use (38.17% hectares), grasslands vegetation (26.14% hectares) was the dominant vegetation cover unit (Table 1 and Figure 2). After a ten year period, small-scale farming had declined in hectares by 23.20% to 14.97% land utilization in 1986. The Government of Uganda Report (2007) pointed out that during this time about 78% of the populace in the area had limited access to land and 84% of the population depended on external food aid. As small-scale farming declined, other land cover units gained such as; wetlands (2.9%), woodlands (14.06%), bush lands (12.71%) and impediments to 8.21% (Figure 3). The gain in impediments specifically was attributed to bush burning as a method adopted by the population and the military to clear the bushes so as to deny insurgents camouflage; this left a number of the areas open and bear. In his exposition, Mushemeza (2008) pointed out that in a situation of conflict movement and other uses on land are restricted. The civil unrest the area was subjected led to tremendous declines in large scale farming (commercial farmlands) by 9.97 %. Okori *et al;* (2002) highlighted that the political unrest in Teso sub-region in the mid 1980's and early 1990's led to the collapse of production systems.

A 15 year interval was observed from 1986-2001; this phase was characterised with a number of new developments in the socio-political sphere of the country and the sub-region. Importantly, the ascendance of the National Resistance Movement (NRA) to power in 1986 transformed the geo-social political sphere of the country and the economic policies pursued thereafter. The recovery process saw a lot of encouragement for the population to return to their homesteads and embark on cultivation to secure necessary food requirements and a settled life. This therefore accounts for the upsurge in small-scale farming (subsistence farmlands) by 2001 to 34.4% land use utilization; an increase of 19.38 %. In their argument, Olson, *et al;* (2004) underscored that small holders are major actors in land use change due to agricultural intensification. The elders also attributed intensification of subsistence farmlands to the prevailing peace, an increase in the number of households and profitability of crop cultivation has encouraged opening of more land. These findings corroborate with the findings of Esikuri (1998); Anantha and Marlene, (2007) in Amboseli (Kenya) where the major factor determining land use change was the growth in agriculture, largely for the provision of food and fibre. The dominance of small-scale farming in changing vegetation cover implies that on average 34.35% hectares are under cultivation in a single season. This has deprived vegetation cover of its regeneration potential, exposed large hectares to direct insolation. Because of this, stronger storms are experienced in the area than in the past. Increase in sheet and rill erosion and decline in crop yields as fallow periods have been shortened were also observed as emerging consequences of LULC changes.

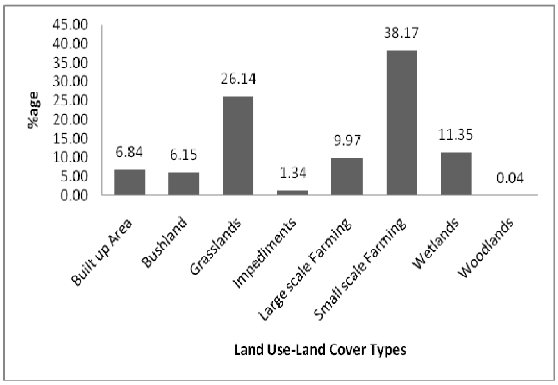

Fig 2: Land use/cover Types for Olio Sub-County (1973)

What is worrying is the nature of the land clearance methodologies in use. About 80% of respondents admitted to at least setting the bush on fire before felling down the trees during the land preparation phase, this is detrimental to land cover presence. According to Nkem *et al;* (2007) environmental researchers consider biomass burning as an important source of greenhouse gases and aerosols such as sulphur, nitrous oxide, methane and carbon dioxide. The National Environment Management Authority for Uganda in 2004 highlighted that significant amount of greenhouse gas emissions are released from the biomass burned for example, biomass burning for energy leads to the release of 13,763.000 CO_2 (Gg), agricultural waste burning (246.500 CO2 (Gg)), savanna burning (72,130.000 CO2 (Gg)), and grassland conversion (4.015 CO2 (Gg). Further, in a situation of management practices such continuous tillage, alterations in the population structure, reduction of key groups and species of soil fauna and a reduction in abundance of above ground and below ground biodiversity occurs Beare *et al;* (1997).

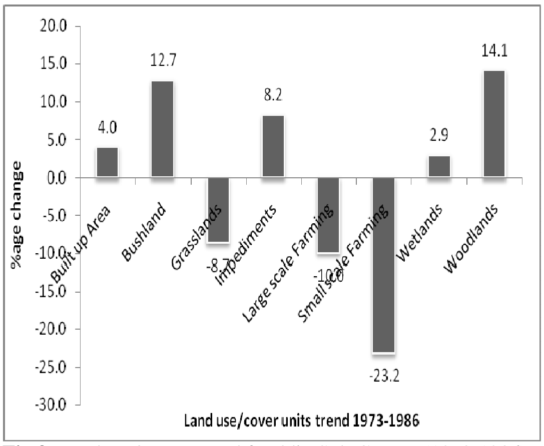

Fig 3: Land use/cover Trend for Olio Sub-County (1973-1986)

The gains in subsistence farmlands are also responsible for various significant losses in various land cover units between 1986-2001. For example, woodlands declined by 13.99% from 14.10% in 1986 to 0.11% in 2001, bushland experienced a loss of 12.09% in the same period from18.86% (1986) to 6.77% in 2001 and wetlands were neither spared declining from 14.25% (1986) to 6.10% (2001) a loss of 8.15% (Table 1 and Figure 4). Regarding wetlands, their decline is owed to the surge in the cultivation in wetland. This finding corroborates the findings of Kibwage *et al;* (2008) in which agricultural cultivation has affected the size and facilitated rapid resource declines from Lake Victoria basin wetlands.

Effect of Land use/cover change (LUCC) on Biomass stock: With the variations exhibited by different land-land cover units; declines and/or gains in hectares in each land use/cover unit influenced variations in the amount of biomass stock accordingly. Findings indicate that in 1986, woodlands had the highest amount of biomass stock approximately 88 million tons; this was followed by bushlands with approximately 45.4 million tons while large-scale farming had totally collapsed at this period. By 2001 small-scale farming (subsistence farmlands) had tremendously gained to approximately 67.6 million tons of biomass stock a gain of 38.1 million metric tons (Table 1). While small scale farming gained in standing biomass stock between 1986-2001; other land use/cover units declined tremendously for example bushlands lost 29.1 million tons, while woodlands lost approximately 87.3 million tons of standing biomass stock, this was the largest loss generated from the image analysis. Wetlands were equally affected losing approximately 669.1 metric tons of biomass stock. These changes in biomass stock have affected fuelwood supply leading to an increased distance (2±7 Km) travelled by firewood collectors especially women and young girls.

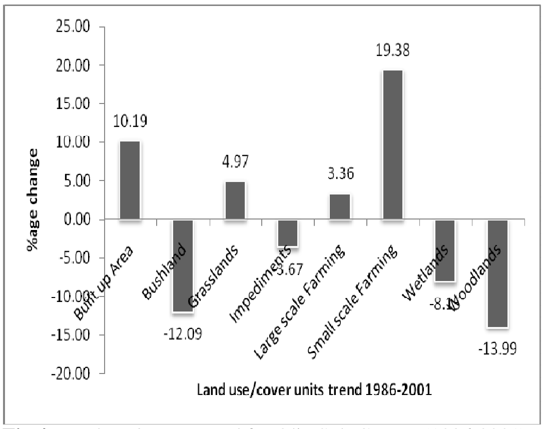

Fig 4: Land use/cover Trend for Olio Sub-County (1986-2001)

While biomass stock declines are occurring in various land cover units including grasslands, woodlands (which are nearly disappearing), and wetlands; 96.1% of the household heads have never directly planted a tree and advance a myriad of reasons including; lack of funds to purchase seedlings, lack of organizational structures and lack of motivation. Others argued that cattle owners tend to graze in their gardens and trample over seedlings, termites attack the young trees, trees do not bring immediate profits, and trees attract birds that destroy their crops. With these range of reasons one of the respondents concluded that "*trees have always been there, we found them here and they will be there, we did not plant and we do not need to plant, they grow alone.*" These according to Ayuke, *et al;* (2008) lead to a change in habitat structure and leads to reduction in range and abundance of food resources. However, with the increasing crop failures due to rainfall variability and flooding in Teso sub-region, rising food insecurity with a significant proportion of poverty stricken resource poor farmers; household heads, desperate to provide food to their families have turned to charcoal production. This is not only unsustainable due to wasteful charring methods but ecologically destructive.

Conclusion: This study has shown that drylands should not only be looked at as poor, remote and largely self-subsistent areas but should be brought at the fore front of the development agenda if some of the catastrophic effects of LUCC are to be minimized. Small-scale (subsistence farmlands) farming by resource poor farmers has been identified as the key driver of LUCC in the area along with biomass extraction for fuelwood. The dependence on subsistence farmlands is not a choice but a consequence of low incomes, limited non-farm income generating opportunities, a sequence of conflicts that have plunged the area, significantly reduced number of livestock due to civil unrest and cattle rustling in the 1980's. Additionally, it has been established that land cover conversion is unidirectional and no measurable area that has been converted to subsistence farmlands has been left to revert to its original land cover type and LUCC has a significant influence on biomass stock. This study has further shown that the use of remote sensing and GIS can help quantify LUCC at micro scale levels thereby giving greater details and precision. We therefore recommend for a focus on integrated soil fertility management and water conservation (ISFM), adoption of innovative platforms for development and a green revolution. These would make drylands to become central in sustainability strategies; it is only when resource poor farmers are certain of food security with significant crop yields that a call to environmental management and custodianship of environmental resources may be heeded.

Acknowledgement: The funding for this work came from the generous contribution from Regional University's Forum for Capacity Building in Agriculture (RUFORUM) and Agricultural Innovations in Dryland Africa (AIDA). Appreciation is further extended to those individuals whose works have been cited in this paper.

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