Estimation of the aboveground biomass in the trans-boundary River Sio Sub-catchment in Uganda

[1*]BARASA, B; MAJALIWA, M G J; [2]MAJALIWA, M G J; [3]LWASA, S; [4]OBANDO, J; [5]BAMUTAZE, Y

[1,2]Institute of Environment and Natural Resources, Makerere University, P. O. Box 7062, Kampala Uganda
[3,5]Department of Geography, Makerere University, P. O. Box 7062, Kampala Uganda
[4]Department of Geography, Kenyatta University, P. O. Box 43844, 00100 Nairobi, Kenya

ABSTRACT: The enormous land cover in Uganda is rapidly being depleted or encroached. To examine this, the study aimed at estimating the above-ground biomass in River Sio sub-catchment in Uganda. The study utilized an ortho-rectified Landsat TM/ETM image of 2004 which was classified using NDVI classification system for the aboveground biomass assessment in ILWIS 3.3 software. A total of 42 homogenous sampling sites were identified for biomass estimation along six laid transects measuring 500m long. The seven randomly selected sampling plots measured 50m X 50 m. The classification showed that Bushlands (0.17), wetlands (0.03) and small scale farming (-0.29-0.03) had relatively more medium and low biomass ranges compared to grasslands (-0.41/-0.29) which mainly comprised of bare land. The above ground biomass was relatively higher in bushlands (4.9 tons) and wetlands (4.7 tons) compared to non-uniform small scale farming (farmlands) with 3.9 tons and grasslands with 1.6 tons. The variation in biomass shows that the sub-catchment requires an urgent need for land use/cover planning and management to prevent further degradation of land cover. @JASEM

The estimation of aboveground biomass (AGB) is necessary for studying productivity, carbon cycles, nutrient allocation, and fuel accumulation in terrestrial ecosystems (Bannari *et al*, 2006). Biomass estimates take into account the differences in wood density, upper stem dimensions and crown morphology (Spetich & Parker, 1998). The use of Remote Sensing and Geographical Information System (RS &GIS) in the analysis of land cover is necessary because it analyzes spatial data especially the location and distribution of biological features and how the environment influences their functioning (Carol, 1998). The Normalized Difference Vegetation Index (NDVI) classification system is normally used to derive information about plant and land cover phenology (Hill & Graham, 2003). Important to note is that any remote sensing approach for biomass estimation as well depends on field measurements (Ravan, 1996 and Hans *et al*, 2009). Uganda still has considerable forest and biomass resources. However, these resources are being heavily 'mined' through rapid expansion for agricultural land (National Biomass Study, 2003). Overall, the agricultural sector in Uganda is responsible for 86–90% of the environmental degradation and also the forest cover, a major source of biomass and biodiversity, is declining at a rate of 55,000 ha year[-1](Isabirye *et al.,* 2008). In particular, agricultural activities in the Lake Victoria basin have expanded by 70% between 1958 and 2001, leaving only isolated pockets of land cover (Maitima *et al.,* 2004; Makalle *et al.,* 2008). Presently, the Sio sub-catchment (Uganda) biomass resources are still experiencing tremendous changes associated with the rapid expansion and intensification of agricultural activities. With the uncertainty about the catchment's biomass estimations, therefore this study addresses this knowledge gap and will provide accurate information on biomass estimations. This information is necessary for better understanding of deforestation impacts on the degradation of the sub-catchment's diverse natural resources.

MATERIALS AND METHODS

The study was carried out in the trans-boundary River Sio sub-catchment (downstream) on the Ugandan side. The River originates from Mt. Elgon and flows through Bungoma, Teso and Busia Districts into Berkeley Bay and drains into Lake Victoria in Uganda. Sixty five percent of the upper catchment is in Kenya, while the remaining portion is in Uganda. The sub-catchment vegetation consisted of; Wetlands comprising of *Papyrus reeds, Miscanthidium, Phragmites* , & *Acacia Siberiana* while bushlands comprised of *Ficus exasperata Vahl, Lantana Camara, Acacia, Maesopsis eminii, Euphorbia tirucalli* and *Teclea nobilis etc.*

Research Approach: An ortho-rectified Landsat TM/ETM image of 2004 was classified for the estimation of aboveground biomass ranges. The spatial resolution of 2004 image was 30 meters. The classified image was taken in January because the month marks the beginning of the dry season where spectral signatures of tree cover and that of undergrowth (grass, herbs) presents the highest contrast (Kiunsi & Meadow, 2006). The Integrated Land and Water Information Systems (ILWIS 3.3) Academic software was used for initial image classification procedures. The image was subjected to Normalized Difference Vegetation Index (NDVI)

E-mail: *benviromgt@yahoo.com   Tel: +256-712-712525*

classification approach. This approach was chosen because it generates a set of metrics that summarizes the phenology of vegetation (Hill & Graham, 2003) (Table I). This was calculated as: NDVI = (IR – R)/(IR + R); Where IR and R represent the remotely sensed response in the near-infrared (TM4) and red waveband (TM3), respectively. The preliminary map was validated and adjusted basing on ground truthed data. The classified image was further categorized into four land use/cover types.

A total of 42 homogenous sampling sites were identified for biomass estimation along the six laid transects measuring 500m long from the river floodplain. In each transect 7 sampling plots of 50m X 50 m were randomly selected for tree measurements. Trees were identified using both the scientific and local names. The height, crown and diameter of all trees greater than 1.3 m were measured. The tree height was measured using Suunto clinometers while the crown width and diameter at breast height (DBH) were estimated using a diameter and distance-tape measure. The analysis of single tree weights was based on Knut V. (1997) regression models developed from destructive sampling of trees for the prediction of single tree weights (as the dependent variable) and tree parameters (as independent variables) as shown in equations 1, 2 and 3 below: He recommended the use of tree size in intervals of 20cm diameter classes as a basis for grouping. Accordingly, he came up with the following;

dbh < 20cm: ln(W)=0.5*0.09937-0.909575+1.544561(ln d)+0.50663 (ln ht)+0.33346(ln cr); (1)

20cm < dbh < 60 cm: ln(W)=0.5*0.0892-1.795491+1.943912(ln d)+0.47371(ln ht)+0.245776(ln cr) (2)

dbh > 60cm: ln(W)=0.5*0.05222-2.192612+2.032931(ln d)+0.31292(ln ht)+0.436348(ln cr) (3)

The results from above (weight of single tree per plot) were summed up per plot and then converted to weight of trees. The study also utilized a Participatory Rural Appraisal method to assess the past and present trends of various tree species in Sio sub-catchment (Uganda). In particular, the focus group discussion method was adopted because they supplement the kind of attitudinal data (Morgan, 1996). Twelve focus group discussions were conducted in eight randomly selected locations at a village level comprising of 8-15 households who were also randomly selected from the local council member's list to acquire information regarding the past and present land use/cover types, tree species, their trend and historical management.

RESULTS AND DISCUSION

The image classification showed that Bushlands (0.17), wetlands (0.03) and small scale farming (-0.29-0.03) had relatively more medium and low biomass ranges compared to grasslands (-0.41/-0.29) which mainly comprised of bare land (figure I). The above ground biomass was relatively higher in bushlands (4.9 tons) and wetlands (4.7 tons) compared to small scale farming (farmlands) with 3.9 tons and grasslands with 1.6 tons. The trend of tree species showed that *Milicia excelsa* were the commonest trees species (19%) in the last 20 years followed by *Ficus exasperata Vahl* with 14%, *Ficus natalensis* (13%), *Markhamia lutea* (12%), *Ficus glumosa* (11%), *Lantana Camara* (10%), *Tamarindus indica* (9%), *Teclea nobilis* (7%) and lastly *Acacia sieberiana* with 5%. Whereas presently, *Musanga cecropioides* are the commonest trees species in Sio sub-catchment with 15% followed by *Maesopsis eminii* (13%), *Eucalyptus* (12%), *Carica papaya* (11%), *Moringa oleifera* (10%), *Euphorbia tirucalli* (9%), *Artocarpus heterophyllus* (8%), *Citrus limon* (7%), *Mangifera indica* (6%), *Citrus sinensis* (5%) and lastly Cyprus with (4%). For last 20 years, the disappearance of *Milicia excelsa* trees has been the highest with (40%), followed by *Ficus exasperata Vahl* (28%), *Ficus natalensis* (20%) and *Markhamia lutea* (11%) while *Musanga cecropioides* (43%) are the most commonly introduced tree species followed by *Eucalyptus* (24%), *Moringa oleifera* (19%), *Maesopsis eminii* (10%) and *Artocarpus heterophyllus with* 4% in Sio sub-catchment.

Table I: Shows the NDVI ranges and land use/cover types

NDVI	Land cover class	Description of the area
-0.41/-0.29	Bare land	Degraded land, fallow plots
0.03	Low biomass	Grasslands, annuals, scattered trees
0.17	Medium biomass	Shrubs and perennials with few tree density

The relatively more biomass in bushlands, wetlands and small scale farming compared to the grasslands is attributed to the intact vegetation (sedges) in the extensive wetland system and isolated pockets of bushlands. However, the vegetation is rapidly being cleared for agricultural expansions and human settlement. Similar observations were also made by Isabirye (2008) in the Lake Victoria basin. However,

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the low biomass levels in the plots under small scale farming were attributed to the presence of indigenous agro-forestry systems. The communities are also involved in planting trees purposely for shade provision, timber harvesting, attraction of rainfall and crops such as cassava and coffee. The agricultural expansions are also attributed to the decreasing cultivatable land (sub-divisions) caused by rapid population growth rates and extensive soil erosion effects (Makalle *et al.,* 2008). The impact of population growth on land cover, the National Biomass Study predicted that there will be a steady decline from 0.3 ha in 1991 to 0.1 ha per capita of

forest area by the year 2025 in Uganda (National Biomass Study, 2003). This also corresponds to the findings of Geist & Lambin (2001) who argued that agricultural expansion, overgrazing, charcoal burning and timber harvesting contributes to 37% of land cover clearances which is one third of the causal factors for land cover depletion/encroachment worldwide. However, Backeus (1992) also argued that the montane areas, especially of eastern Africa from South Africa to Ethiopia, human interference has created grasslands and bushlands over wide tracts of land.
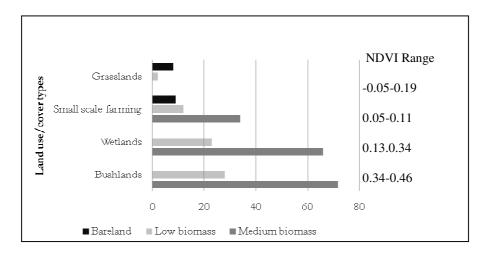

Fig 1. Shows the land use/cover types with the biomass classes

The local communities are also involved in small scale tree planting activities around their homesteads of certain tree species purposely for timber harvesting, rainfall attraction, control of soil erosion and medicinal purposes. Planting of shade trees was important for managing soil moisture, soil fertility and diseases in their farmlands. This also corresponds to the findings of Cornelis *et al,* (2002) who argued that land use change and tree planting projects that result in greater carbon storage in terrestrial ecosystems are widely seen as a low cost alternative to CO_2 emissions reduction for mitigating climate change and increased crop production worldwide.

Conclusion: Bushlands (0.17), wetlands (0.03) and small scale farming (-0.29-0.03) had relatively more medium and low biomass ranges compared to grasslands (-0.41/-0.29) which mainly comprised of bare land while the estimated above ground biomass was relatively higher in bushlands (4.9 tons) and wetlands (4.7 tons) compared to small scale farming

(farmlands) with 3.9 tons and grasslands with 1.6 tons. The variations in the tons of estimated biomass is crucial for vigorous vegetation protection or else by the year 2025, all the present land cover will be cleared as biomass from farmlands is set to increase.

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