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Amos Nyirenda and Dr. Progress Nyanga

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Estimation of the Aboveground Carbon Stock in Kanonge Local Forest of Kaputa District in Northern Province, Zambia

Amos Nyirenda

Post Graduate Student: School of Natural Sciences, University of Zambia

*Corresponding Author's E-mail: amosn69@gmail.com

Dr. Progress Nyanga

Lecturer, School of Natural Sciences, Department of Geography and Environmental Studies, University of Zambia

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Abstract

Purpose: The majority of district-level carbon stock estimates for the local forests are obsolete and incomplete. Because of this, decisions made by policymakers have an impact on forest regions. This study establishes some baseline information for estimates of the above-ground carbon stocks in the nearby Kanonge forest.

Methodology: The use of a sequential explanatory design allowed the quantitative data to be collected and analysed first, and the qualitative data to be collected and analysed later to explain why the variables identified in the first phase are significant predictors of the aboveground carbon stocks. As a result, 15 sample plots were used in the forest, 286 households were sampled on villages within 5km radius to the forest, 8 key informants were sampled from Forestry Department, 8 from Ministry of Agriculture, 10 village head persons and 10 forest users. The quantitative data was collected using forest inventories and household surveys while qualitative data was collected using key informants' interviews. The allometric equations were used to analyse forest inventory data, logistic regression was used to analyse household survey data and the key informant interviews were analysed using thematic analysis.

Findings: The results show that, the above ground biomass and carbon stock were 276.19 ± 7.41 and 155.76 ± 4.18 t ha-1 respectively. The logistic regression results shows that Forest products use, farm size, household size and forest clearing where the significant predictors of the reduction of the aboveground carbon stocks. The results further reveals that there is inadequate intersectoral coordination at district and local level.

Unique Contribution to Theory, Practice and Policy: Further study should be done to find strategies to sustain carbon stocks in the forest while maintaining the use of the forest by the local communities. This study provides accurate estimates of forest and tree carbon stocks and supports in the development of the district integrated plan in accordance with decentralized policy. This information can therefore be used at the district and federal levels in various carbon programs like REDD+, offering the district the chance to participate in the fight against climate change and global warming.

Keywords: *Aboveground Biomass and Carbon Stock, Kanonge Local Forest, Anthropogenic Factors, Forest Policy, Household Survey*

INTRODUCTION

Biomass estimation for tropical forests has gotten a lot of attention in recent years since biomass change is thought to be a big part of climate change (Sun & Liu, 2020). Biomass is used to calculate the amount of carbon released as a result of deforestation, forest degradation, and conversion of natural forest lands. For a better understanding of the effects of deforestation and forest degradation on global warming and environmental degradation, accurate biomass estimation is required (Taghavi et al., 2011). Natural forests store a considerable amount of carbon, which is transformed to carbon dioxide and released into the atmosphere when they are removed (Williams et al., 2018). The accuracy of projecting forest ecosystem carbon stock has been a focus of research in the subject of global climate change.

The rate of carbon sequestration per hectare varies due to forest diversity, mostly in terms of structure and kind. Data such as tree size, species, growth rate, and age are used to estimate the amount of carbon stored in forest regions (Yelemfrhat, 2015). Carbon stock in forest ecosystems can be affected by a variety of causes, some of which fluctuate over time, such as climatic factors, pest or disease outbreaks as well as the anthropogenic factors. As a result, forest carbon stores can be conserved and increased through sustainable forest management, planting, and rehabilitation (Tamene et al., 2016).

Estimates and inventories of forest carbon have been produced using a variety of methods. Forest inventories are commonly employed as a preliminary step in estimating biomass and carbon storage in natural forests(Kambayi, 2017). Typically, biomass equations have been created using data from forest inventories (Hermhuk et al., 2020). Counting and measuring the diameter of trees at breast height and total height are common practices in forest inventories. Remote sensing is another helpful and relevant tool for better estimating forest carbon trends and changes over time. Remote sensing (RS) technology will increasingly be used in carbon storage estimation methodologies to give global, regional, and national coverage, as well as to update them quickly following disturbances (Kambayi, 2017).

Statement of the Problem

Above-ground biomass and carbon stocks, as well as their value for the area, are subject to inadequate knowledge and obsolete information in most of the land use change studies and climate change related studies at micro level. Integrated Land Use Assessment II – Report for Zambia, reported the most recent biomass and carbon estimations for all of Zambia, (Shakachite et al., 2016). The estimates were published per province as the sum of all of the province's districts, making it difficult to determine the biomass and carbon estimates of local forests at the district level. Similar studies with different objectives and conclusions have been conducted in other regions of the country by the following; (Kapinga et al., 2018) in Copperbelt Province, (Ngoma et al., 2018) in Zambezi and (Kaonga & Bayliss-Smith, 2010) in eastern province. However, this study is confined to northern region of Zambia particularly in Kaputa District where the knowledge of the spatial–temporal variations of carbon stock is lacking and hard to acquire.

This is a concern because the policy makers utilize the same information to formulate the policies and strategic guidance documents like the Integrated Development Plans for the districts in accordance to the decentralization policy. Furthermore, due to a lack of knowledge and information, policy-makers are making policies based on the obsolete data resulting in decisions that negatively impact the area's carbon pools especially at local levels like districts. Due to lack of evidence-based decisions making, cases of concession timber licenses have been assigned to local forests, settlements, and agricultural fields without regard for the amount of carbon stock released into the atmosphere.

The consequences of the above problem context are that the local areas or districts are destined to lose forest cover and face degradation, resulting from soil erosion, water insecurity, climate change effects and loss of forest-based livelihood support.

The real carbon stock estimations and the voices of the Kanonge Local Forest users are both lacking in empirical evidence or literature and discussions. As a result, there is a gap because previous research hasn't sufficiently described the mechanisms or context behind quantitative trends. Not only are quantitative data required, but they must also be explained in more depth, particularly in terms of detailed voices and local resident's viewpoints.

LITERATURE REVIEW

Carbon Stock Estimation Models

There is evidence that the miombo woodlands, the largest dry forests in the African biosphere, store a significant quantity of carbon (Kapinga et al., 2018). The most prevalent dry woods in the African biosphere are the miombo woodlands. Allometric relationships can be used to convert measurements of diameter at breast height (DBH) alone or in combination with tree height to estimate forest carbon reserves, according to (Gibbs et al., 2007) 's suggestion. Forest inventory surveys and direct assessment of aboveground biomass through disruptive harvesting should significantly improve the quantification of forest carbon stores. (Tamene et al., 2016) proposed that each model used measured diameter as an input in their investigation of Spatial Variation in Tree Density and Estimated Aboveground Carbon Stocks in Southern Africa.

Kapinga et al., (2018) considered three variables (DBH, ρ and H) as predictor variables, which were used to develop the models. Parameter estimates and performance criteria for all models with DBH as the sole predictor variable and in combination with basic wood density and height as independent variables are presented. Therefore, the combination of breast height diameter, basic wood density, and height explained significantly bigger variances in all species, but not a better fit. Sun & Liu, (2020), argued that in geostatistical modeling, forest inventory data is combined with topography, elevation, slope, aspect, and other environmental variables to produce statistical models that estimate forest biomass at regional scales. They added that, the three main types of information used to estimate vegetation carbon storage are optical remote sensing data, synthetic aperture radar satellite data (SAR), and Lidar data (LiDAR).

Factors Affecting Carbon Stock

Deforestation, especially the conversion of forestland to agricultural land, continues to be the principal factor negatively affecting tropical forest cover and services. According to Chinasho, (2015) research, selective harvesting significantly affects biomass and carbon stocks. The above- and below-ground carbon levels varied with height gradients because the size of a given species' trees (DBH and/or Height) varies with area. This indicates that clearing large trees, particularly in forests, lowers carbon stocks. According to Gebeyehu et al., (2019)'s hypothesis, the relationship between stem density and aboveground biomass carbon stocks (AGB CS) revealed that smaller size classes housed the majority of stems but only provided a tiny portion of the living AGB CS. This implies that felling enormous trees, especially those that are particularly large, is necessary.

According to (Lembani et al., 2020), the influence of forest disturbance on aboveground carbon stores in the Miombo woodlands is highlighted by field evidence of variations in tree size at different sites and the related spatial changes in AGLB. Xu, (2016), argued that, internal community-level mechanisms like as competition and natural succession, rather than external environmental factors, appear to be more important in driving forest biomass C variation at the regional scale. According to Taghavi et al., (2011), topography is one of the most important environmental gradients that affect biomass, stem size, stand density, and spatial heterogeneity of stems, and that the results revealed that slope and aspect have a significant relationship with biomass in forest areas due to interaction between solar radiation and soil properties (e.g. soil moisture, soil nutrient).

Tree density, biomass, and carbon stocks fluctuate dramatically among land uses and eco-zones in southern Africa, according to Tamene et al., (2016) this study, the tree densities and carbon stock appear to be lowest in sites with considerable anthropogenic disturbance (such as many in Malawi), whereas undisturbed woodlands and some grazing regions appear to have dense tree cover and carbon stock. Greater biomass C in huge trees can be attributed to increased stem density of larger trees as a result of shifting forest age structure, as well as large growth rates of gigantic trees due to improved availability to more resources such as light and water (Stephenson et al., 2014). The fact that massive trees in forests continue to grow rapidly means that there is plenty of opportunity for future biomass C development. In the old-growth forest of the Mid-Atlantic, most trees in the largest size class (50-70 cm DBH) are equivalent to only the intermediate size class in this study.

Factors Affecting Land-Use Change

A household's size is an important indicator of a population's environmental impact. According to Handavu et al., (2021), the size of the household had an impact on the collection and utilization of wild fruits and cattle feed. The findings also revealed a link between household size and the collection of construction poles, wild fruits, and thatching grass. Kouassi et al., (2021) in their study stated that, Agricultural operations were aided by the dramatic loss of forestlands (dense forests and degraded forests) in the landscape. They further stated that, forestlands were converted to agricultural lands for economic reasons.(Olorunfemi et al., 2022) argued that, the combined effects of rural population growth, increased subsistence and commercial farming, climate change, and uncertain economic and socio-political variables have resulted in land cover shifts in Sub-Saharan Africa. Phiri et al., (2019) claims that, population density in native forests, yield per hectare in secondary forests, and mean yield in plantation forests all played a role in forest decline.

According to Kouassi et al., (2021), local farmers saw agricultural development, logging, firewood gathering, charcoal manufacture, and settlements as major direct sources of deforestation, in addition to migration. Furthermore, population increase, migration, land misuse, a lack of education, a lack of law enforcement and inadequate regulations, and land tenure uncertainty all contributed to these factors. Handavu et al., (2019), posited that, rural inhabitants living near the forests have a strong affinity for forest products and services. Therefore, aside from agricultural items, many rural communities continue to rely on forests and other habitats to provide nutritious food for their families. Mushrooms, wild fruits, and firewood were the most important and used subsistence forest products, according to our respondents. Forest products are a source of income for rural areas, as evidenced by the fact that rural people continue to rely on them for income.

Forest Based Livelihoods

Kazungu et al., (2021) contended that, tropical and subtropical forest landscapes support the livelihoods of their inhabitants through subsistence use of goods and financial gain through product sales. Forest products provide for an average of 20.6 percent of total household income (subsistence and cash) at the eight sites studied, and are the second or first source of income in five of them. Forest-based activities including carpentry, beekeeping, and timber and rattan sales account for more than half of the average household's income. Forests are currently being destroyed, and it is critical to comprehend the consequences of this loss. (Jumbe et al., 2018), revealed that, forests are vital to rural communities because they provide a diverse range of products and services for both subsistence and financial revenue.

Deuteronomy et al., (2019), reported in their findings that wood products, fuel wood, market integration, and wild foods all have a favourable influence on the likelihood that a representative household will engage in commercial forest resource exploitation in the area. Schielein & Börner, (2018), pointed out that, the first high-resolution tree species distribution maps for trees of economic and livelihood value in Zambia are presented in this work.

According to the literature review, the discussion on aboveground carbon stocks is centred around carbon estimating methodologies, variables affecting carbon stocks, and factors affecting land use change as well as livelihoods reliant on forests. The literature study also focuses on the total provincial aboveground carbon stock estimations, such as those in the 2016 integrated land use assessment report. The baseline data for the aboveground biomass and carbon stocks at district local forests, where estimates are difficult to obtain, as well as the local forest's aboveground biomass and carbon at district levels, however, received little attention. Therefore, this research focuses on the creation of the baseline data in terms of the aboveground biomass and carbon stock estimates at district level and the anthropogenic factors that influence the aboveground carbon stocks as well as the how the forestry policy have contributed to the reduction in the aboveground carbon stocks as a result of challenges in the implementation.

MATERIAL AND METHODS

Research Design

The study used mixed methods procedures to answer the study research questions (Creswell & Clark, 2017), which is a procedure for collecting, analysing, and mixing or integrating both quantitative and qualitative data at some stage of the research process within a single study. Creswell, (2009) posited that, the reason for combining quantitative and qualitative data is that neither quantitative nor qualitative methods are sufficient in and of itself to capture the trend and details of situations like carbon stock assessment in the local forest. Quantitative and qualitative approaches complement each other and create a fuller picture of research problems when utilized together (Creswell & Clark, 2017).

As a result, a sequential explanatory mixed methods design was used in this study, with two distinct stages (Ivankova, 2014). The quantitative, numeric data was collected and analysed first, followed by the qualitative, text, data helped to explain or elaborate on the quantitative results achieved in the first phase. The quantitative data was used in this study to identify the possible prediction capacity of carbon stock variables, as well as to choose the informants for the second phase. Then, using a qualitative group discussion technique, we'll explain why specific factors that were examined in the first phase were important predictors of carbon stocks in the local forest. As a result, the quantitative data and results provided a broad picture of the research problem, while the qualitative data and analysis refined and explained those statistical results by delving deeper into the local residents' perspectives on the value of forest products and services to livelihoods as well as the challenges in the forestry policy implementation by the forest experts.

Data Collection Methods

Field Assessment

Forest inventories where use as field assessment for the study in which a total of 15 plots were sampled for the forest assessment in the study site. This covered an area of just over 15ha in which the DBH and total heights of all trees were measured. The protocol used in this research was based on the field manual prepared for the Integrated Land Use Assessment (ILUA) project of the Zambian Forestry Department (Vesa, 2013). Nested plots were designed in which a set of sub-plots of different sizes for different size (diameter) classes was accommodated (Asus, 2013). Furthermore, a reasonable plot size was suggested based on the stocking density of the stand.

Above ground biomass data was collected in all plots that was chosen. All trees with a DBH of larger than 10 cm within the plots (20m wide and 50m long) was sampled, with sampling consisting of measuring the height and diameter at breast height and recording the tree species (Republic of Zambia, 2021). A rectangular sub plot in the first 10 meters of the larger plot was used to measure trees with a DBH of 5 to 10 cm(Chidumayo, 2016). In a nested sub-plot within the rectangular sub-plot, regeneration trees with a DBH of less than 5 cm was measured. Each tree's height, DBH, and species was measured once more.

Dead-wood data was collected on all fallen dead logs and branches in the plot area that have a diameter of 10 cm or greater (regardless of where they originated). The length of dead wood to be measured was at least 1 meter. All pieces of fallen wood having a diameter more than or equal to 10 cm within the plot area had their length and diameter measured at both ends. According to (Chidumayo, 2012), the typical wood density of 619 kg/m3 was utilized to convert the volume estimations to biomass.

Household Surveys

Primary data on the variables affecting the tree biomass in terms of household use were gathered using semi-structured questionnaires. Individual questions in the questionnaire were orally translated into the respondents' native tongues (Bemba/Tabwa) while being administered to respondents. The questionnaire was written in English. The questionnaire included several sections covering the following areas: general household socio-economic data (demographics, assets and land-use) (Kamwi et al., 2015), level of dependence on forest products and income generating activities. Local community members who were familiar with the study sites were engaged to help with locating the selected farms/households. Upon location of the households and prior to administering the questionnaire, coordinates were taken using a hand-held Global Positioning System (GPS) equipment to ensure that only households within the 5-km buffer were captured.

Semi structured questionnaire provided links between the forest users and the factors that could have influenced the above ground biomass. Questionnaires developed by (Central Statistical Office, 2014) were adapted and expanded to suit the objectives of this study. These questionnaires have been widely used in developing countries to collect data on people’s dependence on natural resources. These questionnaires lasted an average of 50 minutes per household and were conducted in the local vernaculars (*Tabwa* and *Bemba*), in which the researcher was conversant.

Key Informant Interviews

In this study the provincial level interviews with respondents discussed policy goals in their respective sectors and policy implementation strategies. Interviewing key informants from various government offices at various governance levels provided insight into policy implementation at various levels and the horizontal relationships in policy implementation. Key informant interviews with local and international NGOs provided insight on policy implementation at local scales, and local peoples' concerns. Village level interviews with residents provided an opportunity to explore policy implementation at local level and underlying drivers of aboveground biomass and carbon stocks reduction as well as forest degradation as viewed by local people. Residents included traditional leaders and other elderly males and females who were knowledgeable on forest management issues. Interviews were carried out in English for all stakeholders except for local key informants who were interviewed using local languages (i.e., Bemba and Tabwa). A total of 51 interviews were performed, and according to (Neetij and Thapa, 2015), these interviews are primarily a discussion in which the interviewer establishes a broad direction for the conversation and pursues themes presented by the respondents.

Data Analysis Methods

Allometric Equations

As a result, this research relied on mathematical relationships, often known as allometric equations, to link the aboveground biomass of individual trees to other tree traits that are more easily assessed in the field. These characteristics include diameter at breast height (DBH), total height, and wood density (Chidumayo, 2012). The wood density (g/cm3) values were calculated using data from Handavu et al, (2021) and the ICRAF database www.worldagroforestry.org/wd/genus. The average wood density of the genus species was estimated for species that were not immediately recoded in the data sets. The best-fit models constructed by (Handavu et al., 2021) (($AGB = 0.093(\rho D^2H)^{0.97}$) was used to calculate above-ground biomass estimates. Then, using the mean tree C % value of 0.564, the tree biomass estimates were converted to C stock (Handavu et al., 2021)

Newton's formula was used to determine the volume of dead pieces of wood lying on the ground (> 10 cm mid-diameter) (Kershaw et al., 2017).

$$V = \frac{L}{6(Ab + 4Am + At)}$$

Where, V = Volume (m3), L = Length of log (m), *Ab* = Area at the base (m2), *Am* = area at the middle (m2), and *At* = Area at the top (m^2) of the wood lying on the ground.

This volume, along with the wood density and expansion factor of the sampled trees, was used to calculate the biomass of dead wood. $AGB = \frac{L}{6(Ab+4Am+At)}$ x SWD x *ExpF*

Statistical Analysis

The household survey data was analysed using the principal statistical techniques used to analyse the quantitative data were both descriptive and inferential statistical methods (Giliba et al., 2011; Pallant, 2020). Using descriptive statistics, such as frequency counts, and percentages of observed variables, it was possible to describe the demographic characteristics of the communities inside the 5-km buffer. The independent variables were analysed using logistic regression as part of an inferential data analysis. The binary dependent variable of this study was 'aboveground biomass and carbon stocks' which was assigned the value '1' if there is reduction in the local forest and '0' if it is not the case. The independent variables were forest product use, farm size, education, household size, forest clearing and period of residence. Logistic regression model presented in equation (1) was used: Yi=1/1+ez………………….……………………. (1) Where, Yi = is a binary variable with the value of 1 if the anthropogenic factors contribute to the reduction of the aboveground biomass and carbon stocks in the reserve and 0 if otherwise; Z = β0 +β1 X1 + β2 X2 + β3 X3 + ...+ βn Xn β0, β1 to βn = coefficients of independent variables showing marginal effect (positive or negative) of the unit change in the independent variables on the dependent variable; X1 to Xn = independent variables; e = natural logarithm base (2.718); i = 1, 2 …. n; where n is the total number of variables.

FINDINGS

Aboveground Biomass and Carbon Stocks

The result revealed that a total of 704 individuals, representing 22 species, were identified and measured in all the sample plots. The density of trees varied among all sample plots, ranging from 280 to 802 stem/ha. The stem diameter and height of individual trees varied among plots, with a mean of 22.67 ± 3 cm and 6.6 ± 0.8 m, respectively. The aboveground biomass (AGB) and carbon stocks varied greatly, reflecting a declining trend from the plot with the least number of trees and small diameter class (0.19 t/ha) to the highest number of trees per plot and big diameter classes (14.31 t/ha). The overall difference among all these sample plots was attributed to the presence of large stem diameter and height of species.

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Table 1: Shows the DBH, H, P, Above Ground Biomass Carbon Stocks and their Standard Error

Sample plot #	DBH (cm)	Tree height (m)	AGB(t/ha)	AGB t/ha (dead wood)	AGC (t/ha)	AGC t/ha (deadwood)	Stand density (trees /ha)
1	33.89	7.28	25.38	0.00	14.31	0.00	400.00
2	22.51	7.20	34.99	0.05	19.73	0.02	802.47
3	31.78	7.72	60.95	0.14	34.38	0.06	670.00
4	28.88	9.08	48.26	0.00	27.22	0.00	720.00
5	18.40	5.34	13.84	0.00	7.81	0.00	429.09
6	34.79	5.96	14.97	0.20	8.44	0.09	280.00
7	26.43	9.10	22.89	0.03	12.91	0.01	480.00
8	6.54	1.83	0.19	0.06	0.11	0.03	310.00
9	21.89	8.82	5.83	0.01	3.29	0.00	348.46
10	8.11	3.18	2.65	0.05	1.50	0.02	702.71
11	13.45	3.69	2.06	0.14	1.16	0.07	290.00
12	19.91	5.57	2.88	0.00	1.63	0.00	320.00
13	22.72	6.90	5.79	0.00	3.26	0.00	300.00
14	23.01	10.63	3.38	0.00	1.90	0.00	286.90
15	27.73	7.05	27.57	0.00	15.55	0.00	474.17
Total	340.04	99.36	271.62	0.68	153.20	0.32	6813.80
Mean	22.67	6.62	18.11	0.05	10.21	0.02	454.25
SD	8.53	2.42	18.50	0.07	10.43	0.03	182.04
SEM	2.70	0.76	5.85	0.02	3.30	0.01	57.57
Total AGB (t/ha)	**272.30 ± 6**						
Total AGC (t/ha)	**153.52 ± 3**						

Biomass and carbon stock estimates for the sampled Kanonge Local Forest 272.3 t/ha and 153.52t/ha of biomass and carbon, respectively.

Anthropogenic Factors Influencing the Above Ground Biomass Stocks in the Local Forest

Table 5 shows that Wald statistics are non-zero values, which implies that there is interaction between the dependent and independent variables. According to Pallant, (2020), the non-zero Wald statistic values indicate the presence of relationships between the dependent and explanatory variables. Therefore, the null hypothesis is rejected and accept the alternative hypothesis which states that the anthropogenic factors have a significant influence on the aboveground biomass and carbon stocks.

Table 2: Factors Influencing the Above Ground Biomass and Carbon Stocks in Kanonge Local Forest

Variables	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*95% C.I.for EXP(B)*	
							Lower	***Upper***
Forest product use	-0.562	0.209	7.263	1	0.007 *	0.57	0.379	0.858
Farm size	0.476	0.182	6.834	1	0.009 *	1.61	1.127	2.301
Education	-0.079	0.103	0.598	1	0.439 ns	0.924	0.755	1.13
Household size	-0.302	0.102	8.861	1	0.003 *	0.739	0.606	0.902
Forest clearing	0.174	0.091	3.653	1	0.056 *	1.19	0.996	1.421
Period of residence	0.122	0.165	0.546	1	0.46 ns	1.13	0.818	1.561
Constant	1.961	1.054	3.461	1	0.063	7.106		

Number of cases = 286, Model Chi-square= 33.9 (p=0.000), -2LL = 281.9; Overall percentage = 68.8%, Exp (β) **)** *= odds ratio (probability of success/probability of failure), SE= standard error of the estimate, *Statistically significant at 0.05 level of significance, ns = statistically non-significant at 0.05 level of significance, Sig = significance, β = regression coefficients which stand for the odds ratio of probability of success to the probability of failure and Wald statistics = β/ (SE)2, d.f = degree of freedom.*

Forest Products Use

The use of the forest products by the households in the study area have a negative regression coefficient (β) of -.562 with odds ratio (Exp β) of .570, meaning that a unit increase in forest products use will reduce the likelihood of reduction in the above ground biomass and carbon stocks of the local forest by a factor 0.57 and vice versa (Table 4). Figure 9 shows the forest products use by the households as identified in the study area. Like many places in rural areas, charcoal constitutes 47% of the forest products use in the study area, firewood (31.34%), wood poles (12.31%), industrial wood (4.8%) and wood carvings (4.48%) were the forest products use which entirely depend on the local forest.

Farm Size

Cultivated land size has positive regression coefficient (β) of 0.476 with odds ratio (Exp β) of 1.61 which was statistically significant at probability level of 5% (p = .009) (Table 4). In other words, increase in one hectare (ha) unit of cultivated land size, increases the likelihood of the reduction in the above ground biomass and carbon stocks in the local forest by a factor 1.61 and vice versa. Furthermore, most households in the study area cultivate in the local forest of which 46.64% had the farm size of 3 ha, 20.90% cultivated 2 ha, 16.42% cultivated 1 ha and 16.04 cultivated 4 ha respectively.

Education

Education has a negative regression coefficient (β) of -0.079 with odds ratio (Exp β) of 0.924. This implies that an increase in education, which was statistically insignificantly (p=0.439), decreases the likelihood of the reduction of the above ground biomass in the reserve by a factor of .924. That is, farmers who can read and write are most likely not to disturb the reserve than those who have not been to school. Education is an important issue in development of livelihood strategies as it determines which livelihood activities a household is involved. In the study area, 42.91% of the respondents have received no education at all, 33.21% for those that attended school from grade 1-4, 2.2% from grade 5-7, 14.18% attended grade 8-9 and 7.46% those that attended GCE O level.

Household Size

Household size has a negative regression coefficient (β) of -0.302 and the odds ratio (Exp β) of 0.739 (Table 5). This implies that an increase in the household size, which was statistically significantly at probability of 5% (p=.003), reduces the likelihood that the household will contribute to the reduction of the aboveground biomass in the reserve by a factor of 0.739.

Forest Clearing

Forest clearing has positive regression coefficient (β) of 0.174 with odds ratio (Exp β) of 1.19 which was statistically significant at probability level of 5% (p = .05) (Table 1). In other words, increase in one unit of forest clearing increases the likelihood of the reduction of the above ground biomass in the forest reserve by a factor 1.19 and vice versa. This implies that if a household has cleared a large piece of the forest, eventually there will be reduction in the above ground biomass in the local forest.

Period of Residence

Duration of residence in the area has a positive regression coefficient (β) of 0.122 with odds ratio of 1.13 which was statistically insignificant at probability level of 5% (p=0.42) (Table 4). This indicates that for a unit change in this variable, the risk of a drop in biomass in the forest reserve rises by a factor of 1.13. In other words, the likelihood that a home in a community next to a forest reserve may perceive a disturbance grows with the number of years the household has lived their increases. Families expand in size the longer they stay in a location. As a result, the reserve must supply more forest products, and more acreage is needed to accommodate the demands of the expanding population.

Challenges in the Implementation of the Forestry Policy

Perception of the Policy Actors on the Orientation Process

The forestry sector in Zambia has policies in place to fight deforestation and forest degradation, according to interviews with several policy actors at the province and local levels. However, it was made clear that there are gaps between the policies' content and actual execution, leading to implementation deficits. For instance, data on the ground demonstrated a lack of implementation despite the policies' overriding emphasis on minimizing the use of wood fuels through the promotion of efficient charcoal production and use as well as the use of other renewable energy sources. The absence of knowledge of alternative energy sources at the district and village levels was highlighted through interviews with district level government officials and local NGOs. The table below shows the responses of the participants regarding the orientation process.

DISCUSSION

Comparison of *Kanonge* AGB and AGC Levels with other Forests

The calculated AGB and AGC values for trees with a diameter of equal or greater than 1 cm across all plots in the analysed Kanonge Local Forest (closed canopy forest) were 275.85 ± 7.41 Mg ha-1 and 155.59 ± 4.18 Mg C ha-a, respectively. Lewis et al., (2013) estimated 395.7 Mg Ha-1 for the African closed canopy forests. The AGB values for the Amazonian Forest, which are predicted to be between 312 and 464 Mg Ha-1, likewise fall above the range. This figure is quite comparable to the value estimates of 279 Mg ha-1 and 260 Mg ha-1 made by (Baishya & Upadhaya, 2014) for an African moist tropical forest that Lung and (Lung & Espira, 2015) observed.

Factors Influencing the Above Ground Biomass Stocks in the Local Forest

Deuteronomy et al., (2019) says forests play a significant role in the life of local populations since they supply poles for construction, wood fuel for cooking, aid in soil erosion reduction, and provide a variety of foods and medicines owing to biodiversity. Forests are currently being destroyed, and it is critical to comprehend the consequences of this loss. (Jumbe et al., 2018) claimed that, the forest products provide for an average of 20.6 percent of total household income at the eight sites studied. High demands for charcoal also exist in urban centres Firewood use is concentrated in rural communities, where almost everyone (over 80% of households) uses it as their primary source of energy (Kalinda et al., 2008; Mulenga et al., 2011). Some of the variations attributed in study results are likely to reflect the methodology and context in which researchers performed their studies (Giliba et al., 2011).

Intersectoral Coordination and Policy Implementation

Zambia's agriculture policy interacts negatively with the forest policy, which compromises the efficacy of the forestry policy. The sustainable management of forests is seriously threatened by the inability of two or more actor groups to coordinate their conflicting interests. These results support research conducted in Cameroon by Dkamela et al.,(2014) that identified inconsistencies between sectoral policies and rivalry for forest resources as barriers to the implementation of forest sector policy. The sustainable management of forests is seriously threatened by the inability of two or more actor groups to coordinate their conflicting interests (Ongolo, 2015). In accordance with the national development plan, the agricultural strategy is focused on boosting agricultural productivity (i.e. Vision 2030).

CONCLUSION AND RECOMMENDATION

The study was conducted in Kanonge local forest and it was evident that the forest contains moderately diversified plant species. The above ground carbon stocks of Kanonge local forest were estimated at 155.79 t/ha. The projected values for total biomass and C stock are similar to those seen in other dry tropical forests in Africa. This demonstrates the capability of the woods to store CO_2. The forest product use, household size, forest clearing where significant predictors of the factors influencing the aboveground biomass and carbon stocks of Kanonge local forest. Inadequate intersectoral coordination at district and local level was identified as one of the barriers that hinders the policy implementation which in turns influences the biomass and carbon stocks of Kanonge local forest.

Recommendations

- Need to undertake annual forest inventories in order to update the biomass and carbon stock estimates.
- To ensure the effective management of biomass and carbon stocks, the forestry and agriculture policies must be revised to take into account estimates of the biomass carbon stock and the forest users.
- Need to Include household needs and environmental security in policy frameworks that call for including different use methods, like charcoal production into sustainable forest management

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