Diversity And Biomass Variation In Masinde Muliro University Of Science And Technology

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ABSTRACT

Tree biomass determination has always tended towards a forest centric approach ignoring trees outside forests. They have begun to receive much attention recently. In this study, we sought to determine tree diversity and tree biomass within Masinde Muliro University of Science and Technology (MMUST). 8 quadrats measuring 100m^2 were randomly laid in the proposed site for the Botanical Garden. Within each quadrat, the number and species of trees were recorded. Diameter at Breast height (DBH) was measured at 1.3m from the ground. This data was fitted in allometric equations to determine aboveground and below ground biomass. Tree diversity was determined by use of Shannon Weiner index. Correlations between tree species and tree biomass were done to ascertain whether there was a significant relationship. A total of 20 species were identified with *Eucalyptus grandis* being the most dominant (39.97%). Total tree biomass recorded in the study area cumulatively was 10,977.37kg cumulatively for the 8 quadrats. Tree biomass correlated positively with species diversity ($\mathbf{R}^2$=0.78, $\mathbf{P}$<0.001), richness ($\mathbf{R}^2$=0.72, $\mathbf{P}$<0.003) and evenness ($\mathbf{R}^2$ =0.75, $\mathbf{P}$<0.001) within the quadrats. Tree diversity was exhibited within the study site and biomass estimation revealed variation with richness and diversity.

Key words: Tree diversity, Tree biomass, Allometric equations, Diameter at breast height

1. INTRODUCTION

Trees are a critical component of the global carbon (C) cycle because of their ability to convert atmospheric carbon dioxide to plant biomass and therefore act as carbon sink (Kuyah and Rosenstock, 2014). Plant biomass can be partitioned into aboveground biomass (AGB) which is biomass in plants above the soils surface and below ground biomass (BGB) which is biomass below the soil surface within the roots. The roots according to (Mokany *et al*., 2006: Kuyah *et al.,* 2012) hold significant amounts of biomass, estimated at 20% of the total tree biomass (Cairns *et al*., 1997). Primary attention has been skewed towards forests, which account for 45% of terrestrial carbon stocks and are responsible for 17% of annual radiative forcing through deforestation (IPCC 2007: Kuyah and Rosenstock, 2014).Trees in other land use systems such as farmlands appear to have greater potential for emission or sequestration because of their spatial extent. A recent global survey has shown that over 45% of agricultural lands globally have more than 10% tree-cover (Zomer *et al*., 2009) and biomass carbon stocks ranges between 3–18 t C ha^{-1} (Nair and Nair, 2014). Although the aboveground C stocks found in trees on farms are less than forests, the aggregate C pool is presumably significant due to the spatial extent of farmland with tree cover (Zomer *et al*. 2009). Furthermore, increasing the area and density of trees on farm accumulates more C in biomass and is an important climate change mitigation strategy (Verchot *et al.,* 2007). The relationship between tree species diversity and biomass carbon sequestration is of great concern among land managers interested in sequestering maximum amounts of carbon in the short-term. The question of whether diversity increases biomass productivity is therefore pertinent to current efforts to increase carbon stocks while ensuring the maintenance and enhancement of biological diversity (Kirby and Potvin, 2007; Liang *et al*., 2007). Efforts to quantify tree biomass carbon stocks has always focused on forests and selected plantations. The role of trees on agricultural lands and other land use systems outside forests has received much attention recently. There is however, paucity of data on C and biomass stored in trees outside forests (de foresta et *al*., 2013; Kuyah and Rosenstock, 2014). The stock of aboveground biomass (AGB; in kg of oven-dry matter) held in vegetation is usually inferred from ground census data. Tree biometric measurements are converted into biomass values using empirical allometric model/equations (Brown, 1997; Chave *et al*., 2014). These equations express tree biomass as a function of easy-to-measure parameters such as diameter at breast height (DBH), height, or wood density, or a combination of these (Brown, 2002; Chave *et al*., 2005; West, 2009). However, diameter at breast height (DBH) is commonly used for aboveground biomass (AGB) estimation because it can easily be measured with high accuracy, repetitively and generally follows commonly acknowledged forestry conventions (Husch *et al*., 2003). According to Henri *et al*., (2011), (2009) and Basuki *et al*., (2010), the complexities and potential errors in measuring other parameters (i.e. sloped topography or dense foliage when measuring height), the need for specialised tools (e.g hypsometer or clinometer for height) or destructive measurements (e.g. wood density), the use of DBH alone appears cost effective and robust for most purpose. In this study, we sought to (1) determine tree diversity in Masinde Muliro University of Science and Technology (MMUST) and (2) determine biomass of the tree species. Since the trees are outside the forest, our findings will help to increase the volume and quality of data for trees on farms that is vital for individuals, projects, and communities that may benefit from emerging climate change mitigation opportunities (e.g. Nationally Appropriate Mitigation Actions) and timber markets by growing trees. The same can be replicated in other areas with different ecological, climatic and edaphic conditions.

2. MATERIALS AND METHODS

2.1 STUDY SITE

The study was conducted within the proposed site for the Botanical Garden in Masinde Muliro University of Science and Technology (MMUST) (N 00°22'12.5; 34°57'26.5'E; altitude 1561m a.s.l) (figure 1). Soils in this region have been classified as dystro-mollic Nitisols (FAO, 1974; Rota *et al*., 2006). The garden is bordered by students hostel, a sewerage system and laboratory science block. Within the garden passes several paths used by students and villagers who come to cut grass for their livestock. The garden is part of the University with trees compared to other areas within the campus where trees have been cleared to pave way for infrastructural development.

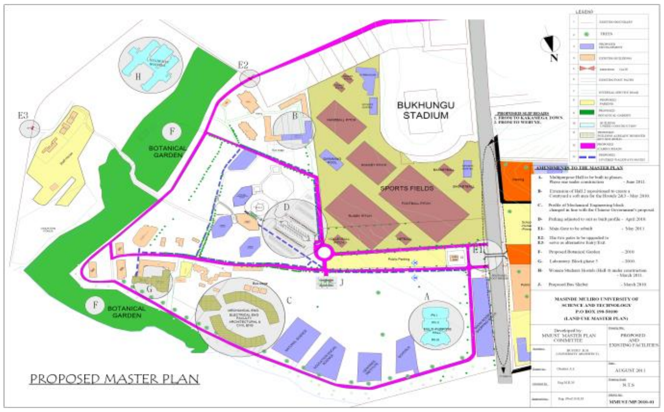


Figure 1: Master plan of the University with botanical garden shaded in green as part of the stud area. Courtesy of the university architect.

2.2 DETERMINATION OF TREE SPECIES DIVERSITY AND DENSITY

A total of 8 quadrats measuring 10m×10m were randomly laid within the Botanical Garden. Within each quadrat, the total number of trees and species were counted and recorded in a data sheet. Tree circumference at breast height (CBH) was measured using a measuring tape at 1.3m from the ground and recorded in the data sheet. Circumference at Breast height was then converted to diameter at breast height using the formula

$C = \pi d$……………………………….equation (1)

Where C- circumference, d- diameter and π-3.142

2.3 DETERMINATION OF TREE BIOMASS

Tree biomass was determined through non-destructive methods by use of allometric equations. The equations in the form of $y=ax^b$ were used where y is the biomass, x is tree DBH and a, b coefficients. Locally developed equations by Kuyah *et al.* (2012a, b) for agricultural lands in western region were used for both above ground biomass and below ground biomass according to equation 2 and equation 3 respectively. The choice of locally developed equations is supported by Henri *et al.*, (2009), who have cautioned that trees vary in characteristics among ecological conditions and particularly agricultural landscapes. The study site is also within the Western region of Kenya which has similar ecological and climatic conditions as to the ones from where the adopted equations were developed.

$AGB = 0.091 \times (DBH)^{2.472}$…………………………… (2)

Where AGB -Above Ground Biomass, DBH-Diameter at breast height

$BGB = 0.048 \times (DBH)^{2.302}$……………………….. ………... (3)

Where BGB - Belowground Biomass, DBH-Diameter at breast height

Total tree Biomass (TB) per quadrat/plot level ($mg100^{-2}$) was obtained by adding aboveground biomass (AGB) to below ground biomass (BGB) as (TB= AGB+ BGB). This was then extrapolated to $mgha^{-1}$.

3. DATA ANALYSIS

Data management was done using Microsoft excel and data analysis was done with using SAS 9.1 software (SAS Institute Inc.) at $p < 0.05$ confidence level. Tree species diversity was determined using Shannon Wiener index as per equation 4. This index is preferred because it is commonly used in carbon sequestration projects. It also gives both tree species richness and evenness.

$$H' = -\sum\left[\left(\frac{n_i}{N}\right)\times\ln\left(\frac{n_i}{N}\right)\right] \quad \text{...} \quad (4)$$

Where: n_i = number of individuals or amount (e.g., biomass or density) of each species (the i^{th} species) N = total number of individuals (or amount) for the site, and ln = the natural log of the number. Species density was determined by dividing the total number of trees per unit area. One-way ANOVA was performed to determine significant difference between the variables. Pearson's correlation analysis was used to explore the relationship between species diversity (species richness and Shannon diversity) and tree biomass. Regression analysis was used to examine the relationship between variation in biomass carbon density and tree species richness and Shannon diversity.

4. RESULTS

4.1 SPECIES ABUNDANCE, RICHNESS AND DIVERSITY

A total of (N=218) trees were sampled in the study area spread within the 8 quadrats. There was a highly significant relationship between species richness and diversity ($\mathbf{R^2}$=0.93, **P**<0.001), richness and evenness ($\mathbf{R^2}$=0.93, **P**<0.003) and diversity and evenness ($\mathbf{R^2}$=0.99, **P**<0.000) within the quadrats. Pearson correlation between species richness and species density was low but significant ($\mathbf{R^2}$=0.34, **P**<0.001). However as evenness of the species increased, there was a decrease in the species density resulting in a negative correlation ($\mathbf{R^2}$=-0.52, **P**<0.001). *Eucalyptus grandis* was the most dominant at 33.94% (n=74) (table 1). There was one invasive species (*Psidium guajava*) whose total abundance was 5.9% (n=13). Species with lowest human disturbance had the highest abundance (table 2). Quadrat 7 recorded the highest abundance of 17.89% (n=39) followed by quadrat 2 at 14.68% (n=32). Quadrat 6 had the least species abundance of 10.09% (n=25). Total species richness in all the quadrats within the study area was 20 (table 1). However, their distribution within the quadrats was not even (table 2). Quadrat 5 and 6 had the highest species richness at 11. Species richness within quadrat 7 and 8 was the lowest at 1. Although quadrat 5 and 6 had the same number of species, they were not evenly spread. Quadrat 6 recorded the highest species diversity at 3.4 then followed by quadrat 5 at 2.19.

Table 1: Total species abundance within the 8 quadrats within Masinde Muliro University of Science and Technology (N=218)

S/N	Scientific name	Family	Abundance	%Abundance
1	*Acacia abyssinica*	Fabaceae	1	0.458715596
2	*Afzelia quanzensis*	Fabaceae	1	0.458715596
3	*Albizia gummifera*	Fabaceae	3	1.376146789
4	*Bischofia javanica*	Phylianthaceae	9	4.128440367
5	*Bridelia micrantha*	Euphorbiaceae	26	11.9266055
6	*Croton macrostachyus*	Euphorbiaceae	16	7.339449541
7	*Croton megalocarpus*	Euphorbiaceae	1	0.458715596
8	*Cupressus lustanica*	Cupressaceae	6	2.752293578
9	*Eucalyptus grandis*	Myrtaceae	74	33.94495413
10	*Ficus benjamina*	Moraceae	1	0.458715596
11	*Grevilia robusta*	Proteaceae	29	13.30275229
12	*Harungana madagascariensis*	Hypericaceae	27	12.3853211
13	*Polycias fulva*	Araliaceae	3	1.376146789
14	*Psidium guajava*	Myrtaceae	13	5.963302752
15	*Senna spectabilis*	Fabaceae	1	0.458715596
16	*Sesbania sesban*	Fabaceae	1	0.458715596
17	*Shirakiopsis indica*	Euphorbiaceae	1	0.458715596
18	*Solanum incanum*	Solanaceae	1	0.458715596
19	*Vernonia amygdalina*	Asteraceae	1	0.458715596
20	*Xanthoxylum gilletti*	Rutaceae	3	1.376146789
	Total (N)		218	100

Quadrat 7 and 8 that had Eucalyptus grandis only, had a species diversity index of 0.

Table 2: Distribution of species within the eight quadrats and their diversities

Quadrat Number	Species richness	Abundance	%age abundance	Evenness	Diversity
Quadrat 1	6	11	5.05	2.06	1.60
Quadrat 2	7	32	14.68	1.93	1.64
Quadrat 3	9	30	13.76	1.93	1.82
Quadrat 4	6	25	11.47	2.04	1.59
Quadrat 5	11	28	12.84	2.11	2.19
Quadrat 6	11	22	10.09	3.27	3.40
Quadrat 7	1	39	17.89	0.00	0.00
Quadrat 8	1	31	14.22	0.00	0.00

Figure 2 shows the plot of the species distribution against accumulative area for all the quadrats. The plot gives the species area curve with equation $S=CA^{Z}$ (figure 2). Where S is the number of species, A is the area/cumulative area, z is the slope and C is a constant.

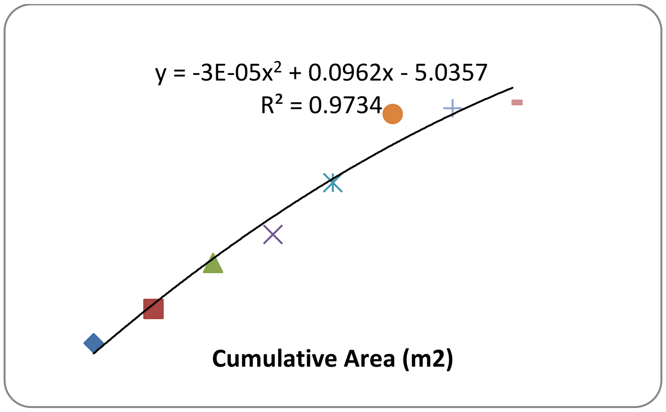


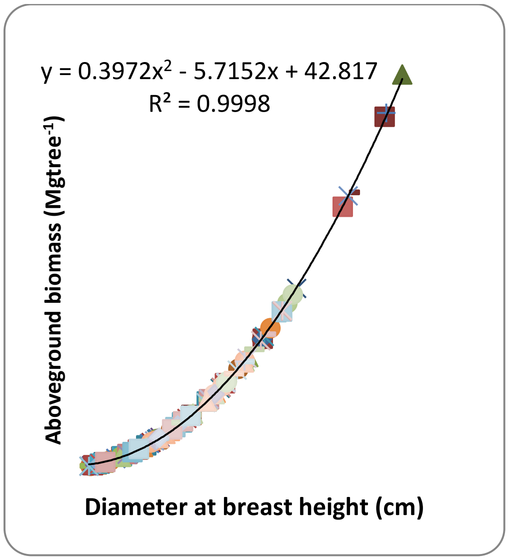
Figure 2: Cumulative species area curve for 8 the quadrats in (m^2)

It is clear from figure 2 as the area increases, ecological space increase that can accommodate more species.

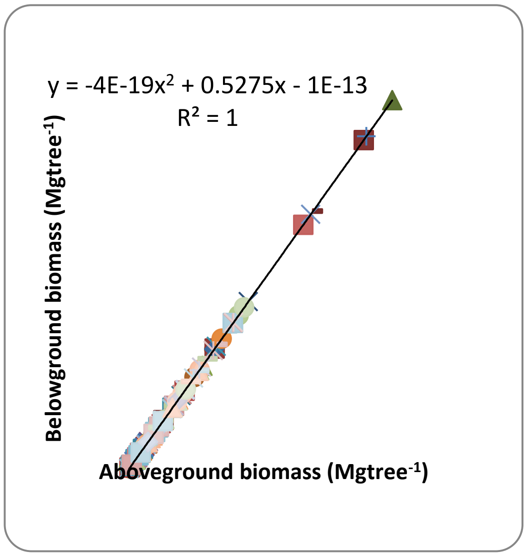
4.2 TREE BIOMASS WITHIN THE QUADRATS

Total tree biomass recorded in the study area was 109773.7kg for the 8 quadrats. Extrapolated per hectare measurements it translates to 1372171.7kgha^{-1}. (Quadrat 7 with the highest abundance of species (table 2) recorded the highest tree biomass (21705.13kgtree^{-1}). This was followed by quadrat 8 at 20391.28kgtree^{-1}. Although quadrat 4 had slightly higher species abundance (n=25) as compared to quadrat 6 (n=22), it had lower total tree biomass 7133kgtree^{-1} and 8355kgtree^{-1} respectively.

A scatter plot of aboveground biomass against DBH and aboveground biomass and belowground biomass for the 218 trees sampled at the study site is shown in figure 3. Diameter at breast height significantly correlated with above ground biomass (**R^2**=0.99, **P**<0.001) (figure 3a). Below ground biomass showed a linear correlation with aboveground biomass (figure 3b).



a)



b)

Figure 3: A scatter plot of aboveground biomass against diameter at breast height for the 218 trees within Masinde Muliro University of Science and technology compound

Relationship between tree biomass and species diversity, richness and evenness was highly significant (Table 3). Tree biomass correlated positively with species diversity (**R^2**=0.78, **P**<0.001), richness (**R^2**=0.72, **P**<0.003) and evenness (**R^2** =0.75, **P**<0.001) within the quadrats. As tree species diversity and richness increases within the quadrat, study site or a habitat it results to an increase in the total tree biomass within the place.

Table 3: Regression analysis showing relationship between tree biomass in relationship to diversity, richness and evenness

Variable	R^2	df	P value
Diversity vs richness	0.93	7	0.001
Diversity vs Biomass	0.78	7	0.001
Biomass vs richness	0.72	7	0.003
Biomass vs evenness	0.75	7	0.001

5. DISCUSSIONS

Species diversity within quadrat 1, 2, and 4 were slightly lower as compared to 5 and 6 (table 2). Quadrats 1 to 4 were laid in upper part of the botanical garden that was exposed in a way with paths passing through the garden, grazing of the animals, traces of grass harvesting evident. Grazing trambles young seedlings making them unable to establish themselves (Tsingalia, 2009). Some tree stumps were observed, a sign there was some felling that had been done. These could have been the factors that led to low species diversity within the quadrats. Tree diversity can be increased by enhancing conditions that favour increased birds' diversity. Birds will then enhance dispersal of tree species like *Bridelia micrantha* (Tsingalia and Kassilly (2010). Quadrat 5 and 6 had high species diversity as the area had minimum human interference. As species abundance evenness and diversity increased, it led to a decrease in species density as more species were being added per unit area hence the negative correlation. Quadrat 7 and 8 did not show any diversity as it only contained one tree species of *Eucalyptus grandis*. They are established as woodlots in a section of the university compound, part of the proposed botanical garden. *Eucalyptus spp*. are usually established woodlots to maintain the benefit and minimize negative interaction with crops or on other trees vulnerable to the effects of eucalyptus (Sinclair and Joshi, 2000; Smith Dumont et *al*., 2014). Both exotic and indigenous trees were sampled during the study. Most indigenous trees were mature trees that had been there for years. That is based on their DBH values Based on the age of the trees and proximity to Kakamega Forest, a tropical rain forest; there is a possibility that the compound under which the university stands could have been an extension to where the forest stood. But due to increased human population and need for land led to clearing part of the forest and part of which the university now stands. Due to human settlement around and a path that community passes on through the university together with presence of birds could be the source of invasive species like *Psidium guajava* in the study area. However, care should be taken in regard to its spread because of its invasive characteristics on the native species as noted by (Kawawa *et al*., (2016). Cumulative area curve (figure 2) showed an increase in area results to an increase in the species abundance however towards the end the line almost flattens an indication species area density has decreased and cannot accommodate more species. Species area curve relationship is a good model in designing nature reserves and botanical gardens and would be ideal in ensuring that the garden is well stocked and hence diversity being maintained. This will also affect productivity of the trees. Biomass storage capacity increases with increased area due to high abundance and diversity of trees. This reduces the concentration of carbon dioxide in the atmosphere hence mitigating effects of climate change. The use of DBH alone in the (equation 2) estimation tree aboveground biomass (AGB) provided a satisfactory estimation of biomass since the total variation explained by the relationship is high (R^2 =0.99). The results indicate that DBH is a strong indicator of aboveground biomass. The findings agree within studies in Western Kenya by (Kuyah *et al*., 2012a, Kuyah *et al*., 2012b). Total tree biomass results found here also varied slightly from other studies done using equation (2 and 3). Quadrat 4 with abundance of (n= 22) had total tree biomass of 7133.75kg/100m^{-2} while quadrat 6 with abundance of 22 recorded 8355.78kg100m^{-2}. This could be attributed to the size of the tree in relation to DBH. Tree with large DBH indicates mature trees and have higher biomass as compared to trees with smaller DBH. However, this only is applicable to medium aged trees. Very mature trees on the other hand reduce their productivity rate and hence less biomass stored in them. Quadrat 4 could be having high species richness but of which are younger trees. Quadrat 7 and 8 that were laid in *Eucalyptus spp* plantations had high total tree biomass due to greater abundance in the individuals. Eucalyptus species have the potential to contribute a significant amount of carbon sequestered in Western Kenya's agricultural landscapes since they constitute 59% of all trees encountered in agricultural landscapes (Kuyah *et al*., 2012; Kuyah *et al*., 2013). This dominance has been observed for decades (Senelwa, K, and Sims REH, 1998). There was a strong and highly significant correlation between tree species diversity and tree biomass (table 3). Increased diversity is a reflection of increased tree species richness and evenness. Cumulatively this will increase plant productivity and hence increased biomass. The introduction of more species in a production system due to increased area generally entails more complete utilization of soil nutrients, aboveground space and light and the system becomes more productive (Kirby and Potvin, 2007, Islam *et al*., 2015).

6. CONCLUSION

Tree diversity was evident at the study site and varied with site. DBH was the only variable that was used to determine tree biomass. Tree biomass varied within quadrats and highly correlated with tree diversity. The study recommends that allometric equations be used only used DBH as a predictor, it would be ideal for further studies using a different set of allometric equations that combine tree wood density and height or species specific equations suited for a particular tree species to accurately conclude that the tree biomass found was accurate.

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