Population status, Phenological characteristics and Fruit yield potential of *Adansonia digitata L.*fruit trees in North West lowland area of Ethiopia

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Abstract

Adansonia digitata is one of the wild edible trees that have ecological and socio-economic significance in the low land areas. In Ethiopia, Baobab trees are found in sparsely scattered pattern. Despite its importance, the information on its current status and distribution is scanty. The survey was conducted in northwestern part of Ethiopia to determine the population structure and density of *A.digitata* in different land-use types. Six plots with a size of 1000m*100m and five plots having a size of 500 m*100 m were established. Sub-plots (25 m X 25 m) and sub-sub plots (5 m X 5 m) were established to record coexisting woody plants and regenerations respectively. Treediameter, height and crown diameter data were recorded. Density and structure of *A.digitata* trees was analyzed using SPSS software.The survey result showed that homestead, agricultural and forest land-use type had 2.24, 1.57 and 0.32$\pm$0.41 trees/ha respectively in Quara woreda. In homestead, open shrub land and riverine forest land uses of Kafta humera and Maytsebry woredas 0.95, 1.65 and 3 trees/ha were found respectively. However, the density difference among sites was not statistically significant. *A. digitata* had a very low importance value index; therefore, it needs sound management and conservation strategies. According to our result, variability in fruit yield was observed within different diameter classes especially within diameter class of 100 – 199.9 cm and 200 – 299.9 cm. This variability could be due to age, health status, human and animals factors.

Keywords: *Adansonia digitata*, survey, density, distribution, fruit, yiel

Introduction

Tropical regions of the Earth have more fruit plant species than any other region of the world. It is endowed with great diversity of fruit tree species that provide humans with basic food and nourishment for ages since the domestication of beneficial wild plants (Rathore, 2003). Tropical continents of the world possess rich variety of fruit trees with about 1000 species identified in Americas, 1200 species in Africa and 500 species in Asia (Paull and Duarte, 2011; Sthapit *et al*., 2012). Even though only relatively few fraction of these diversities are marketed worldwide, the diversities are nature's inestimable assets for the livelihoods of local people throughout the tropical regions.

Like that of Asia and Americas, the continent of Africa is blessed with a rich tropical flora. Many of the 50,000 or so plants that evolved within its forests and savannas ripen fruits to the many wild creatures into spreading their seeds. Including both indigenous and introduced naturalized ones, tropical Africa has 477 edible fruit and nut species grown across its landscape (Siemonsma *et al*., 2004).

Ethiopia is endowed with 370 indigenous food plants from 70 families and out of that, 182 species (40 families) are trees/shrubs with edible fruits/seeds (Asfaw and Mesfin, 2001). Out of the above mentioned edible fruits, 25 of the species have marketable fruits/seeds: 21 are marketable in local markets, 2 are reported national and 2 species are internationally marketable (Bashir, 2006).

The rural populations have a wide knowledge, tradition and opportunity of using wild edible plants(Amare Getahun, 1974; Getachew Addis *et al*., 2005).Wild edible plants are relevant to household food security and dietary diversification as well as income generation in some rural areas, particularly in the dry lands, to supplement the staple food, to fill the gap of seasonal food shortages and as emergency food during famine, prolonged drought or social unrest (Amare Getahun, 1974; Zemede Asfaw and Mesfin Tadesse, 2001). Plant partslikeleaves, stems, fruits, flowers, tubers, barks, seeds and roots are consumed in many communities around the globe.

Adansonia digitata (African baobab) is one of the most important wild edible forest products and a key species that has ecological and socio-economic significance in the lowland area (Venter & Witkowski, 2010). It is one of the eight species of baobabs in the genus of

*Adansonia (*family Malvaceae, subfamily Bombacoideae). Six species occur in Madagascar, one in Australia and one in mainland Africa (Baum, 1995b).

African baobab is a very long-lived tree and thought that some trees are over 1000 years old (Sidibe and Williams, 2002). It is characterized by swollen trunks and palmately compound leaves. The trunks consist of soft, fibrous wood that can store water. The leaves of juvenile trees are simple and gradually change to 5-7 foliate compound leaves as the tree gets older. Flowers are borne in the axils of leaves and comprise a single, large, odoriferous white flower made up of both male and female reproductive parts. The fruits are large, ovoid, and covered in a yellow/green velvety indumentum. The pericarp is woody and indehiscent. Seeds are reniform, embedded in a soft dry matrix (Baum, 1995b).

African baobabs are indigenous and widely distributed throughout the savannas and woodlands of sub-Saharan Africa where it is found in areas of South Africa, Botswana, Namibia, Mozambique, Zimbabwe and other tropical African countries where suitable habitat occurs (Sidibé& Williams, 2002). It is restricted to hot, dry woodland on stoney, well-drained soils and in frost-free areas that receive low rainfall (Curtis &Mannheimer, 2005).

Mostly found in the drier plant communities of the Sudano- Zambesian lowlands where annual rainfall is 200-800 mm annually (Wickens, 1982). In Ethiopia, baobab trees are found in sparsely scattered pattern in Tigray, Amhara and Benshangul Gumuz regions and rarely in Gambela region. *A. digitata* L.trees grow on sandy soil over granite, rocky outcrops and riverbanks and its roots are deep-rooted, drought resistant and prefer a high water table (Azene Bekele, 2007).

A. digitata L. is mostly regarded as a multipurpose fruit-bearing tree used for medicine, food, fibers, clothing and soil protection from various plant parts (Sidibe and Williams, 2002; Galizia et al., 2005). It is a typical tree that has been given attention by the local people due to multiple benefits derived from it and important for humans and animals in sub-Sahara and other dry areas of Africa (Galizia et al., 2005). Baobabs have developed structures that are able to withstand and survive harsh environmental conditions in savannas. Due to human induced factors, *A.digitata L.* tree species population is declining. Limited works carried out so far on *A.digitata L.* in Eastern Africa (North et al., 2014; Gebauer and Luedeling, 2013;

Gebauer et al., 2002; Melkamu et al., 2014) have shown different types of population structures. Therefore, proper attention need to be given to manage the remanant populations and develop different schemes to develop plantations, domesticate, and promote the species.

Objective of the study

The overall objective of this study was to generate information on the distribution, abundance, phenological characteristics and fruit yield of *A.digitata L.* Specific objectives include:

- To examine the abundance and population structure of *A.digitata L.* and associated species along different landuse types
- To determine phenological characteristics of flowering and fruiting period
- To determine the fruit yield potential of *A.digitata L.*

Methodology

Description of the study sites

This study was conducted in the lowland woodlands of Quara woreda of Amhara region and Kafta hummera and Maytsebry woredas of Tigray region. Both are located in the north western and northern Ethiopia, respectively as indicated in the figure (1).The two regions are adjacent to each other and the three woredas are found in relatively similar agro ecological zone with similar altitude, temperature and rainfall. Quara town is found at about 1049 km from Addis Ababa and Humera town is located at about 1200 km in North West direction from Addis Ababa town.

Vegetation of the study sites are known as the *Combretum-Terminalia* woodland vegetation (Friss et al.,2010;Teketay,2000; Eshete et al., 2011). Such woodlands are often found in shallow soils and sandy river valleys (Fichtl and Admasu,1994; Teketay, 2000). The rainfall distribution of all study sites ranges from 400 to 1200 mm. The mean annual temprature of Quara woreda ranges from 25 to 42 ^{o}C and that of Kafta humera and Maytsebry ranges from17.5 - 41.7 ^{o}C. The rainy season of the study areas are from June to September. The remaining 8-9 months between October and May is dry and hot. Temperature reaches its maximum range in the three woredas in April and May, and minimum temperature is in

August and July. Parent materials of the area are dominated by volcanic felsic and metamorphic pre-cambrian basements, and in some parts, limestone. Leptosols and vertisol are the pre dominant prevailing soil types in the area.

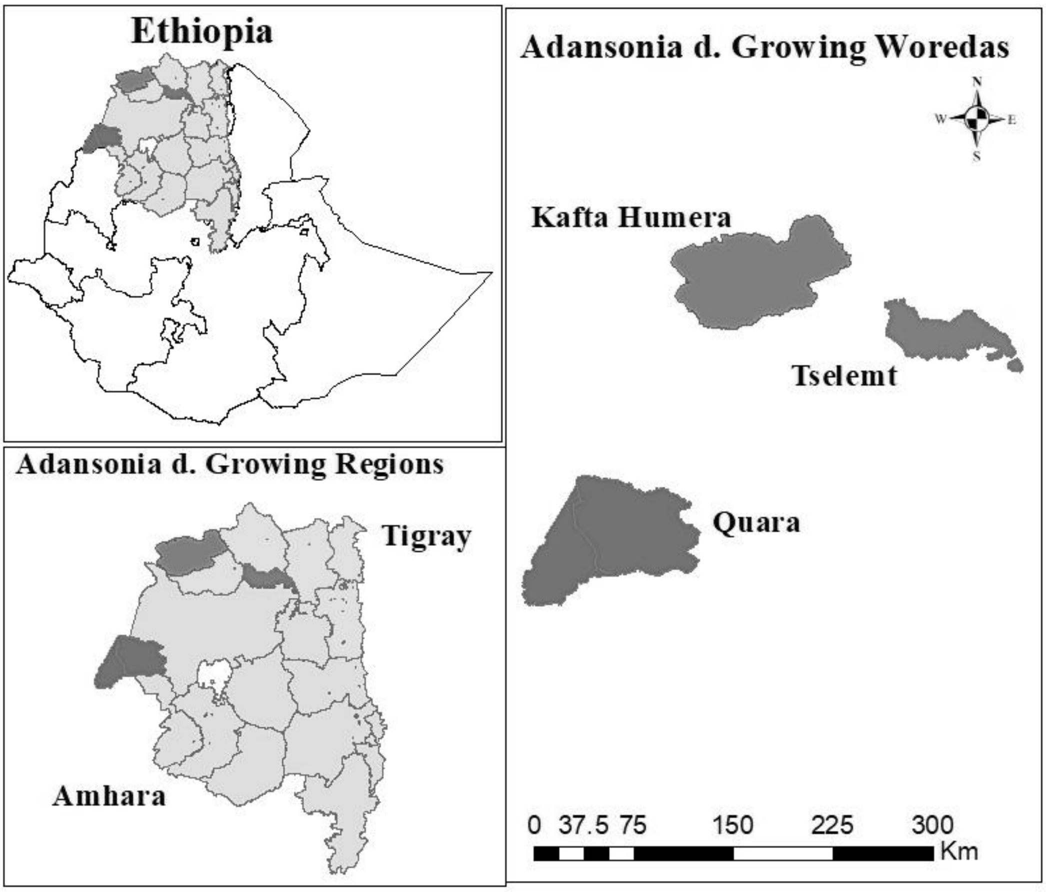


Figure 2: Map showing *A. digitata* study sites in Amhara and Tigray regions

Research design and parameters

This activity was started in assessing information about the location of the potential growing area of *A. digitata L.*tree species. Quick reconnaissance surveys were conducted to assess the range and degree of occurrence of the species and representative sites that harbor the species.The assessments were conducted in Quara woreda at Gelegu kebele, in Kafta Humeraand Maytsebry woreda at Dima and Senasil kebele respectively. Distribution, abundance, and structure of the species were studied in different land-use types such as homestead, agricultural, forest and open shrub and riverine forestland. The forest, open shrub, agricultural and riverine land-use areas were subdivided into 1 km*100 m main plots, and also homestead land-use or around settlements were sub-divided into 0.5 km*100 m main plots following the methods used by Venter and Witkowski, (2010).Ten percent intensity of the total plots in each land-use type was employed as a sample plot. In each plot, all matured trees including target fruit species and regeneration and saplings were considered to collect different tree parameters, such as diameter at breast height, total height, crown diameter and number of main branches per tree. Ten reproductively matured trees with easily visible crowns were selected and marked and a continuous observation and data recording on their flowering and fruiting phenology was recorded based on observation made at intervals of 15 days for three years. The yield traits: number of branch per tree, crown depth and diameter, number of fruits per branch, number of fruit per tree and total fruit mass/weight per tree was measured.

Data analysis

Population status of *A.digitata L.* and associated woody plant species were determined by computing density, abundance, frequency, dominance, importance value index (IVI) and population structure.

Density, which refers to the total number of individuals per hectare, in different land-use types was calculated by summing up all the stems across all sample plots (abundance) and translates to hectare base for the species encounter in the study plots (Abeje *et al.*,2011).

Size class distributions of tree species in different land-use types were analyzed and compared using analysis of variance (ANOVA), correlation and regression analysis.

Heterogeneity of the dry land species in different land use types were determined using Shannon-Weiner diversity indices. Shannon-Wiener's diversity index (H) was calculated as follows (Adefires, 2006).

$H' = -\sum_{i=1}^{s} pi \ln pi$ Where,

Where, H'=Shannon diversity index; S =the number of species; pi= the proportion of individuals or the abundance of the ith species expressed as a proportion of total cover; ln=natural logarithm.

Evenness which refers to the unique representation of a given species against a hypothetical community in which all species are equally distributed was computed as:

(Evenness) $J = \frac{-\sum_{i=1}^{S} pi \ln pi}{\ln S}$

The composition and structure of the woodland in different land-use types were analyzed as a proportion in the percentage of the various species encountered concerning the total. Thus, the percentage of contributions of targeted species in various measurable entities compare to the associated species was analyzed as follows: The structure of the vegetation was described using frequency distributions of diameter at breast height. Tree or shrub, which is greater than 1.5cm diameter at breast height, and basal area values were computed on a hectare basis. Importance value indices (IVI) were computed to know the dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance. Finally, the regeneration status of *A. digitata L.*and other associated species in different land- use types were summarized based on the total count of regeneration (seedling and sapling) of species across all sample plots following (Adefires, 2006).

Results and Discussions

Density of *A. digitata L.* in different land-use types

Average densities of *A.digitata L.* in the three-study area of different land use types are described in table 1. The species generally had very low densities in all the study sites. The result showed that the highest *A. digitata L.* tree density was counted in the riverine forest land of Maytsebry (3trees /ha) and the second highest density was recorded in Quara homesteads. A study on the species in South Africa by Venter and Witkowski (2010) also revealed very low density and indicated that villages and fields had higher densities of trees (2.16±0.44 and 1.13±0.52 plants/ha) than plains and rocky outcrops (0.96±0.25 and 0.83±0.24 plants/ha).

Figure 3: Sampled *A.digitata L.* trees in four land use types (farm land, homestead, forest land & riverine forest. From left to right)

The distribution of *A.digitata L.*in the study area varied across the different landuse type and the data indicated that population is not evenly distributed. This could be related to the solitary nature of the species and lack of protection. In some areas, the population of *A.digitata L.* was found in clustered manner and where as in the other areas it was distributed more sparsely as indicated in figure 3. Based on the vegetation survey, population of the species in adjacent river vegetation and abandoned village and church areas were distributed in clustered pattern. Similarly, Lisao, (2015) showed that *A.digitata L.*population were mainly observed in settlements in Omusati region in Northern Namibia.

Table 1 Density of *A. digitata L.*in three land-use types and study areas

Study area	Land use type	Density (plants/ha)
Quara	Homestead	2.24
Quara	Agricultural land	1.57
Quara	Forest land	0.32
Kafta humera	Homestead	0.95
Kafta humera	Open shrub land	1.65
Maytsebry	Riverine forest	3

Population structure of *A. digitata L.* in different land-use types

Population structures of *A.digitata L.* in the three study areas are presented in figure 3&4. The largest *A. digitata L.* tree (360 cm wide girth) was recorded at a homestead in Quara woreda. About 373 cm and 340 cm largest trees were recorded in Kafta humera open shrub land and Maytsebry riverine forestland use type respectively. Relatively many trees with DBH <50 cm were encountered in different land uses: 15.8% in forest land-use types, the second 10.60% in agricultural land-use type and the lowest 3.57% in homestead land-use types of Quara woreda. In Maytsebryworeda higher proportion of trees with <50 cm DBH were recorded than in Kafta humera woreda (Figure 4). In Kafta humera relatively higher numbers of sub-adult trees were recorded in open shrub land (17.14%) than homestead land (10.53%). In all land-use types of Quara woreda, many *A.digitata L.*trees were recorded at 101-150 cm and 51-100 cm diameter size classes.

The survey showed that high number of *A.digitata L.*trees was recorded at 14.1-16 m height size class in Quara woreda as shown in the figure 4 A and about 26% of the trees belonged to this size class category. In Kafta humera and Maytsebry, woredas higher numbers of *A.digitata L.* trees were recorded at 12.1-14 height size class categories as indicated in the figure 5 B&C. The tallest trees (about 1%) were observed in the agricultural land-use type of Quara woreda that were recorded in the size class of 22.1-24 m. In Kafta humera, the tallest trees (2.86%) were recorded in open shrub land use type. In general, the majority of trees were laid in the middle height size class category of all study woredas.

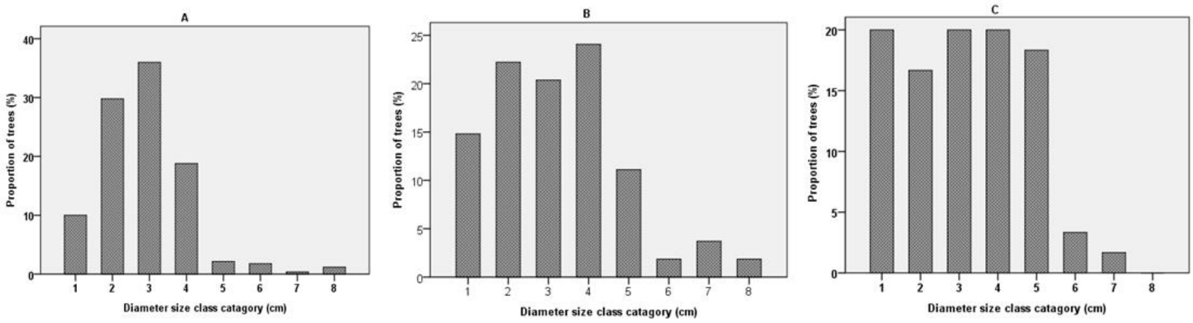


Figure 4: Proportion of *A.digitata L.*trees in the different diameter size classes.Proportion of trees in Quara woreda (A), Proportion of trees in Kafta humera woreda (B), Proportion of trees in Maytsebry woreda (C). Diameter size class (DSH) in cm; 1=1-50, 2=51-100, 3=101-150, 4=151-200, 5=201-250, 6=251-300, 7=301-350 and 8=351-400.

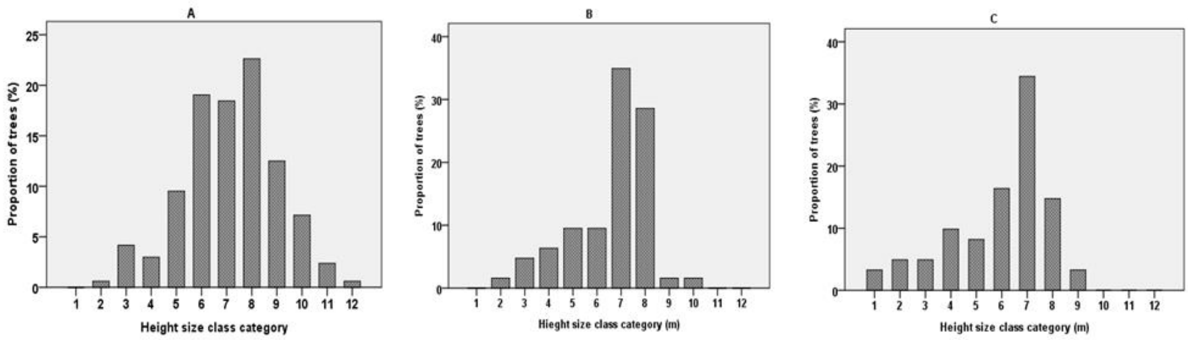


Figure 5: Proportion of *A.digitata L.* trees in the different height size classes.Proportion of trees in Quara woreda (A), Proportion of trees in Kafta humera woreda (B), Proportion of trees in Maystebryworeda (C).Height size class (m); 1= 0-2, 2=2.1-4, 3=4.1-6, 4=6.1-8, 5=8.1-10, 6=10.1-12, 7=12.1-14, 8=14.1-16, 9=16.1-18, 10=18.1-20, 11=20.1-22 and 12= 22.1-24.

Diversity, evenness and richness of woody species in forest and agricultural landuse type

Forest land-use types had higher diversity and evenness than agricultural land-use type in Quara woreda. Species richness in forest and agricultural land-use types were recorded 30 and 21 types of species were encountered respectively as indicated in figure 6. The diversity and evenness of woody species in forest land-use types were 2.37 and 0.70, and in agricultural land-use types 1.98 and 0.65 respectively. All individual species in forest landuse type are more equally distributed than agricultural landuse type species.

In western Tigray woredas (Kafta humera and Maytsebry) higher number of species richness were recorded in open shrub land-use types (11 species type) than riverine forest land (10 species type) and homestead land use type (7 species type) as indicated in the figure 6. The diversity and evenness of woody species in open shrub land-use type were 1.80 and 0.75, in homestead land 1.53 and 0.79, and in riverine forest land use type 0.97 and 0.42 respectively. The distribution of species in riverine forest land use type is more equally distributed than open shrub land and homestead land use types. According to the result of two woredas species characteristics, higher number of species richness and diversity were recorded in Quara woreda than Kafta humera and Maytsebry woredas. The variation of woody species characteristics between woredas and land use types may be due to difference of anthropogenic disturbance level like continuous cultivation (plough), free grazing, fire,pesticide and herbicide chemicals.

In agricultural land use type, local people had practiced extreme clear cultivation in Quara woreda andthis practice reduced the species distribution and composition in croplands. As a result, it is only some trees with high coppicing and resistance ability like *Ziziphus mucronata* and *Acacia polycantha* that were existed. Similar study in Metema woreda(Abeje *et al.*,2011), reveals that superior competitor species in low levels of disturbance monopolize resources and exclude other species whereas at high disturbance levels only the most resistant species survive. Additionally, the study suggested that the wet season length and soil variability were contributed to variation of species richness. Other study (Haileab *et al.*, 2011), argued that species diversity in each forest ecosystem might be varying, due to altitudinal difference, habitat diversity and low human disturbances.

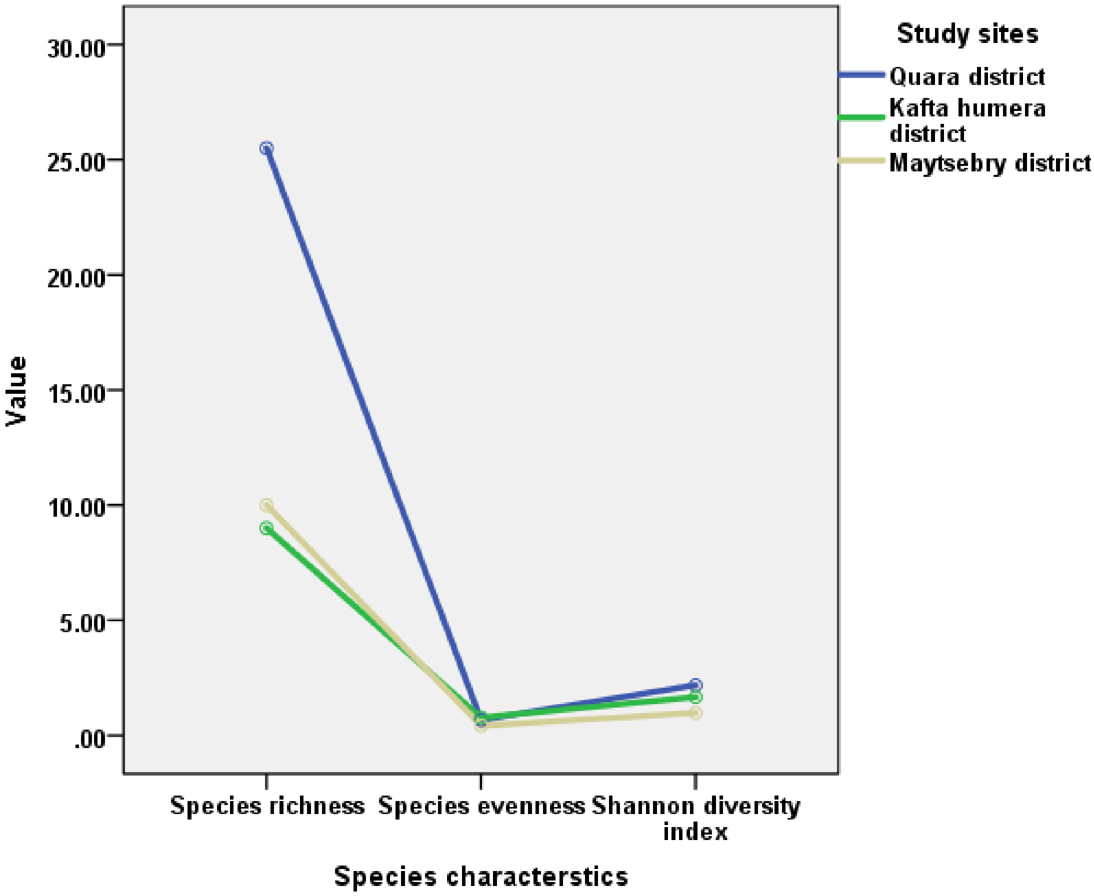


Figure 6: Species characteristics along study woredas

Density, frequency, dominance and importance value index of species in different land use types of three studyworedas, categories based on the degree of disturbances. The density of woody species in forest and agricultural land-use types of Quara woreda were recordedhigher number of stems per hectare rather than different land use types of Kafta Humera and Maytsebry woredas.

A few species of saplings and seedlings were found to pre-dominate the density of vegetation in the study areas. Five species, namely*Terminalia laxiflora*, *Combretum adenogonium, Acacia brevispica*, *Terminalia brownii*, and *Combretum molle* were contributed 74% of the total density at forestland use type of Quara woreda as indicated in annex 1. Similarly, in agricultural land-use type five species such as *Ziziphus mucronata*, *Acacia polyacantha, Cluttalanceolata*, *Piliostigma thonningii*and *Acacia brevispica* were contributed to 82% of the total density of woody plant species as indicated in table 2. In the homestead land use type of Kafta humera woreda, Acacia *senegal, Balanites aegyptica*, *A.digitata L.* and *Lannea fruticosa* contributed to 92.86% of the total density of woody plant species as indicated in annex 3. In open shrub land use type, *A. digitata L., Dalbergia melanoxylon, Acacia mellifera* and *Dicrostachyus cinerea* contributed to 82.80% of the total density as indicated in annex 4. Also in riverine forestland use of Maytsebry woreda, *A.digitata L., Tamarindus indica, Terminalia brownie* and *Acacia polycantha* species contributed 92.31% of the total densities of woody plant species as shown in annex 5.

The major species associated with *A.digitata L.* were *Anogeissus leiocarpus, Pterocarpus lucense, Combretum molle,* and *Terminalia laxiflora* in forest land-use type of Quara woreda in order of dominance. *A.digitata L.* is the second dominant tree species in forest land-use type. In the homestead land use type of Kafta humera woreda, *Lannea fruticosa, Steruculia setigera, Balanites aegyptica* and *Acacia senegal* species were associated with *A. digitata L.* species in order of dominance. In open shrub land use type, *A. digitata L.*species were associated with *Terminalia brownie, Anogeissus leiocarpus* and *Balanites aegyptica* species. *Tamarindus indica, Terminalia brownie* and *Acacia polycantha* species also associated in the riverine forest land use type of Maytsebry woreda.

In addition, *Terminalia laxiflora, Combretum molle, Anogeissus leiocarpus, Pterocarpus lucense,* and *Acacia brevispica* were the highest five ecological important species in order of importance in forest land-use type of Quara woreda. On the other hand, *Ziziphus mucronata* and *Acacia polycantha* were more ecologically important tree species in agricultural land-use type. In the homestead and open shrub land use types of Kafta humera, *A.digitata L., Acacia senegal, Balanites aegyptica, Dalbergia melanoxylon,* and *Acacia mellifera* were with the highest ecological importance value species in order of importance. In addition, *A.digitata L., Terminalia brownie* and *Ficus vasta* were the three highest ecological importance value tree species in riverine land use type of Maytsebry woreda in order of importance.

Regeneration status of a woody species

Regeneration status of all species found in forest and agricultural land-use types of Quara woreda are shown in the figure 6 and accordingly, *Terminalia laxiflora, Acacia brevispica, Terminalia brownie, Combretum adenogonium,* and *Combretum molle* had better regeneration status of species in forest land-use type (figure 6a). Whereas in agricultural land-use type, *Ziziphus mucronata, Acacia polycantha, Clutta lanceolata, Piliostigma thonningii* and *Acacia brevispica* species had better regeneration status as indicated in the figure 6b. However, in forest and agricultural land use types, there were no *A. digitata L.* recruitments**.**

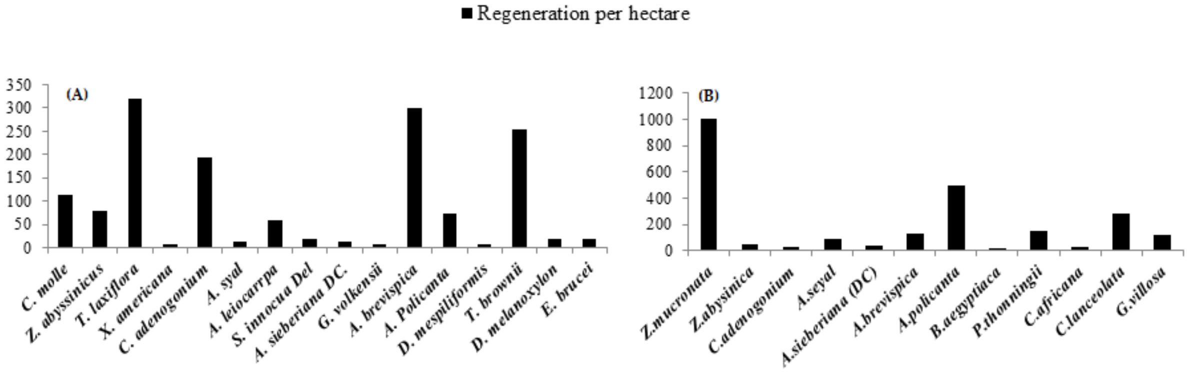


Figure 7: Regeneration status of woody species in Quara woreda of forest land-use type (a) and Agricultural land-use type (b)

Correlation coefficients between different variables

The Pearson correlation of diameter at breast height with height, crown diameter and diameter at stamp height was described in table 2.The correlation between diameter at breast height and crown diameter (r=0.876**) was strong and positively correlated. It was significant at 0.05 level (P=0.000) (Table 2). The correlation coefficient between dbh and height (r=0.382); height and crown diameter (r=0.331) were weak and were not significant, P=0.18 and P=0.25 respectively. Unlike other tree species, the stem form of *A. digitata L.* is irregular and therefore there is a need for further investigation on the correlation of diameter at breast height with diameter at stamp height. According to the current results, correlation of diameter at breast height with diameter at stamp height was strongly and positively correlated (r=0.926**). The relations of diameter at breast height and stamp height are also significant at 0.01 level (P=0.00). Further regression analysis was performed to determine the predicted value of the crown diameter by measuring only diameter at breast height. The result of predicting equation is presented as follows:

Crown diameter = 7,537+0.038 dbh

Table 2: Pearson correlation coefficients diameter at breast height with height, crown diameter and diameter at stamp height

Variables	Diameter at breast height (cm)	Height (m)	Crown diameter (m)	Diameter at stamp height
Diameter at breast height (cm)	1	0.382, (P=0.18)	0.876**,(P= 0.00)	0.926**, (P=0.00)
Height (m)	0.382, (P=0.18)	1	0.331, (P=0.25)	-
Crown diameter (m)	0.876**, (P=0.00)	0.331, (P=0.25)	1	-
Diameter at stamp height	0.926**,(P=0.00)	-	-	1

Phenology of *Adansonia digitata*

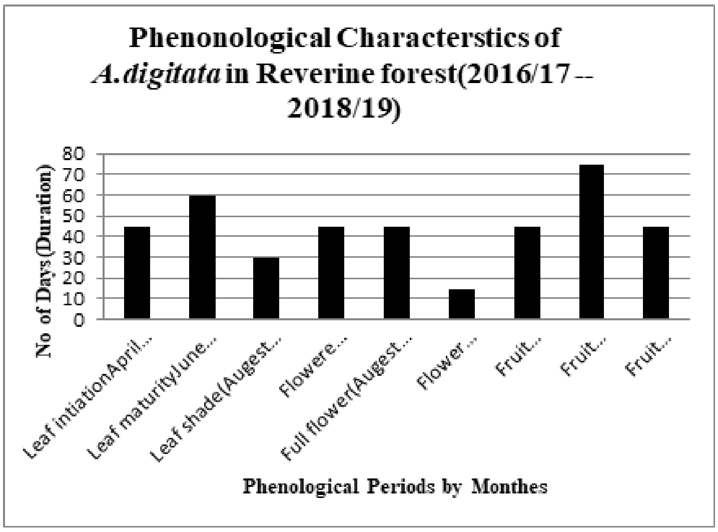
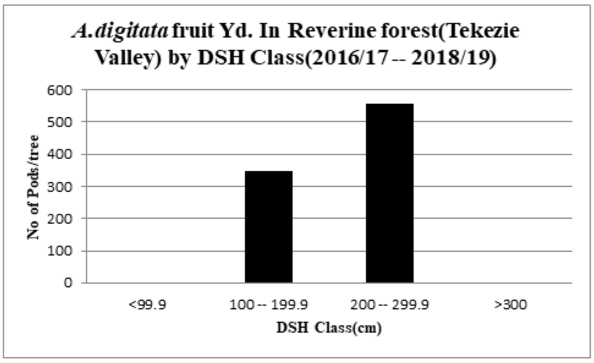


Figure 8: Phenological period of *A.digitata*

Fruit yield of *Adansonia digitata* in two Land cover types



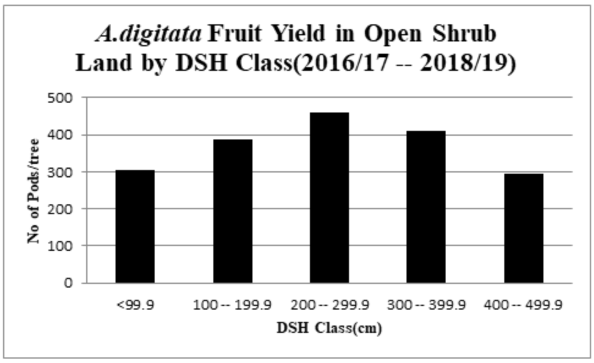


Figure 9: Fruit yield of *A.digitata*in two land cover types

The fruit yield study on *A.digitata* was conducted in riverine forest and open shrub land in western Tigray region. As shown in the above graphs, some variation in pod yield was observed and this might be due to the nature of soil and less presence of baboons in the open shrub land cover type. The sub-adult *A.digitata* trees that are found in diameter at stamp height (DSH) class of 200 cm – 299.9 cm gave better fruit pod yield than the other smaller and bigger DSH classes. The practices of the collection, utilization and selling of *A.digitata* fruits in local markets are poor in the woredas of North-western part of Ethiopia and local communities prefer to sell the Baobab fruits to the neighbouring country (Sudan) in cheap prices. Baobab fruit are harvested once in a year in the study areas.

Sampling and yield collection

A fruit yield potential study on *A.digitata* was conducted in open shrub land and riverine land cover types of western Tigray for two consecutive years (2017 – 2019). For the current fruit yield study, representative *Adansonia digitata* fruit trees from different DSH classes were selected in two land cover types i.e. riverine and open shrub land and was used to determine the fruit yield potential of the target tree.

A study was conducted on representative trees from different DSH class and systematic fruits count and collection was done on each tree. A total number of branches that can hold fruit pods were counted to determine the average number of pods per branch and tree. According to the result of the study, variability in fruit production was observed within different diameter classes and the number of pods per tree was found to be similar in two land cover types, especially within diameter class of 100 – 199.9 cm and 200 – 299.9 cm. This might be due to the youngness and similar age of tress. More number of pods per tree was observed on the trees that are found in the open shrub land within diameter class of 200 cm and 300 cm. This indicated that, trees growing on open shrub land with deep soil are more productive than that of riverine which is dominated by shallow soil and rock outcrop.

The result of the study showed some similarity with (Chapman et al., 1992; Botelle et al., 2002; Shackleton et al., 2002; Killmann et al., 2003). They suggested that stem diameters can reliably be used to distinguish between sub-adult and adult trees. Tree with lower diameter class produced smaller number of fruits than trees with bigger diameter class, thus, focusing on trees >100cm DSH would help in harvesting better biomass of pods and pulps per tree.

Fruit production figures from other parts of Africa are limited or not widely published. However, Ibiyemi et al. (1988) quoted an unsubstantiated figure of 250 fruit per mature plant. In contrast, Swanepoel (1993) reported that, over a four year period, baobabs in the Mana Pools area of the Zambezi River valley did not produce any mature fruit. Assogbadjo et al. (2005) reported that mean fruit production in Benin varied between 57.1 and 157.4 fruit per tree in different climatic zones. Fruit production in communal land in South Africa of 77.1±13.9 (SE) thus falls within the levels found in Benin. Site characteristics can influence fruit production (Peters, 1996) and Assogbadjo et al. (2005) found that variability in site conditions across three climatic zones in Benin significantly influenced baobab fruit productivity.

Conclusions and Recommendations

Relatively higher numbers of *A.digitata L.* tree species per hectare were recorded in riverine land use type of Maytsebry woreda. Statistically there are no significant differences of *A.digitata L.* density between land-use types. The majority of a species population was distributed in the middle diameter size class and height size classes. There was no *A. digitata L. sp*ecies regeneration in all land-use types and this situation will challenge the future population dynamics of *A.digitata L.*

A. digitata L. was highly associated with *Combretum-Terminalia*, *Ziziphus* and *Acacia* tree species in forest and agricultural land-use types. This species is dominant and has key ecological importance in the woodland vegetation; however, *A.digitata L.* has a very low importance value index.

Some local communities in the study areas have an experience of total harvesting of pods and fruits and using the young shoots and the kidney shaped seeds of Baobab trees as food and medicine. Due to this reason, Baobab trees have faced high risk of sustainability and extinction.

Recommendations

- In-situ and ex-situ conservation strategy should be considered for the sustainable development and utilization of this endangered and economically important tree species.
- There is no regeneration of *A.digitata L.* species and the population dynamics of the species is in a declining trend. Therefore, before the extinction of the species, domestication and protection will be crucial.
- The socio-economic importance and attitudes of different ethnic groups towardsBaobab trees should be studied in Benshangul Gumuz, Amhara and Tigray regions.
- The people living nearby neighboring country of Sudan buy Baobab fruits cheaply from Ethiopians and make juice from it and in turn sell the juice to Ethiopians.
- Total harvesting of Baobab tree fruits/pods should be controlled and minimized through awareness creation and training.

- Local people especially the youth should be encouraged and organized in making juice from pulps/fruits of Baobab trees.

Further research is required in the following areas:

- Adaptation and domestication trail on *A.digitata* in similar agro-ecological zones
- GIS based research on population dynamics, temporal, spatial factors that influence the distribution and fruit production of *A.digitata* trees
- The socio-economic importance of Baobab trees
- The nutritional and medicinal value study on Baobab fruits, leaf and flower parts

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Appendixes

Annex 1: List of species encountered in the study quadrates of forest land-use type. Density, frequency, relative frequency, relative abundance, dominance, relative dominance and Importance value index

No.	Species	D	F	RF (%)	RA (%)	D	RD (%)	IVI
1	*Combretum molle*	166.67	34	56.67	8.86	1.141	11.497	77.03
2	*Ziziphus abyssinica*	82.93	11	18.33	4.41	0.031	0.315	23.06
3	*Millettia ferruginea*	0.27	1	1.67	0.01	0.024	0.245	1.93
4	*Terminalia laxiflora*	416.00	47	78.33	22.12	0.811	8.172	108.62
5	*Pterocarpus lucense*	15.47	29	48.33	0.82	1.360	13.712	62.87
6	*Stricullia stegera*	2.67	7	11.67	0.14	0.269	2.712	14.52
7	*Piliostigma thonningii*	0.53	2	3.33	0.03	0.006	0.062	3.42
8	*Lannea fruticosa*	12.00	19	31.67	0.64	0.583	5.876	38.18
9	*Adansonia digitata L.*	0.27	1	13.33	0.01	1.453	14.651	4.00
10	*Ximenia americana*	7.73	1	1.67	0.41	0.008	0.078	2.16

11	*Combretum adenogonium*	225.33	18	30.00	11.98	0.263	2.653	44.63
12	*Combretum collinum*	5.60	9	15.00	0.30	0.150	1.516	16.81
13	*Acacia seyal*	15.20	7	11.67	0.81	0.029	0.296	12.77
14	*Combretum collinum Fr.*	0.53	1	1.67	0.03	0.008	0.083	1.78
15	*Anogeissus leiocarrpa*	100.27	28	46.67	5.33	2.470	24.903	76.90
16	*Tamarindus indica*	2.40	4	6.67	0.13	0.120	1.210	8.00
17	*Strychnos innocua Del*	20.53	2	3.33	1.09	0.015	0.148	4.57
18	*Balanites aegyptiaca*	56.00	5	8.33	2.98	0.168	1.694	13.00
19	*Acacia sieberiana(DC)*	14.13	4	6.67	0.75	0.039	0.395	7.81
20	*Ziziphus mucronata*	1.33	2	3.33	0.07	0.050	0.508	3.91
21	*Gardenia volkensii*	8.00	4	6.67	0.43	0.027	0.274	7.37
22	*Acacia brevispica*	306.40	21	35.00	16.29	0.015	0.148	51.44
23	*Acacia polycantha*	77.87	8	13.33	4.14	0.083	0.833	18.31

24	*Diospyros mespiliformis*	7.20	3	5.00	0.38	0.001	0.005	5.39
25	*Boswellia papyrifera*	1.87	3	5.00	0.10	0.083	0.833	5.93
26	*Terminalia brownie*	282.93	11	18.33	15.04	0.532	5.363	38.74
27	*Ficus thonningii*	0.27	1	1.67	0.01	0.002	0.022	1.70
28	*Stereospermumkuntbianum*	2.40	6	10.00	0.13	0.121	1.220	11.35
29	*Dalbergia melanoxylon*	28.00	6	10.00	1.49	0.057	0.573	12.06
30	*Erythrina brucei*	20.00	1	1.67	1.06	-	-	-

Annex 2: List of species encountered in the study quadrates of agricultural land-use type.Density, frequency, relative frequency, relative abundance, dominance, relative dominance and Importance value index

No.	**Species**	**D**	**F**	**RF (%)**	**RA (%)**	**D**	**RD (%)**	**IVI**
1	*Ziziphus abyssinica*	54.4	4	13.33	2.12	0.005	0.039	15.49
2	*Ficus sycomorusl*	4.8	5	16.67	0.19	2.187	17.948	34.80

3	*Pterocarpus lucense*	3.2	6	20.00	0.12	1.126	9.239	29.36
4	*Stricullia stegera*	1.6	2	6.67	0.06	0.613	5.033	11.76
5	*Piliostigma thonningii*	149.87	7	23.33	5.83	0.109	0.893	30.06
6	*Lannea fruticosa*	1.6	2	6.67	0.06	0.024	0.197	6.93
7	*Adansonia digitata L.*	38.93	7	23.33	0.06	6.841	56.134	18.24
8	*Acacia seyal*	96.53	7	23.33	3.76	0.133	1.090	28.18
9	*Anogeissus leiocarrpa*	3.73	4	13.33	0.15	0.151	1.243	14.72
10	*Balanites aegyptiaca*	0.53	1	3.33	0.02	0.020	0.166	3.52
11	*Acacia sieberiana (DC.)*	56	5	16.67	2.18	0.092	0.753	19.60
12	*Ziziphus mucronata*	1032	26	86.67	40.15	0.153	1.256	128.08
13	*Acacia brevispica*	135.47	3	10.00	5.27	0.002	0.018	15.29
14	*Acacia policanta*	511.47	14	46.67	19.90	0.336	2.757	69.32
15	*Cordia africana*	30.4	3	10.00	1.18	0.076	0.621	11.80

16	*Terminalia brownie*	3.2	5	16.67	0.12	0.214	1.755	18.55
17	*Stereospermumkuntbianum*	43.73	6	20.00	1.70	0.105	0.858	22.56
18	*Terminalia laxiflora*	13.33	1	3.33	0.52	-	-	-
19	*Clutta lanceolata*	280	7	23.33	10.89	-	-	-
20	*Combretum adenogonium*	26.67	1	3.33	1.04	-	-	-
21	*Grewia villosa*	120	3	10.00	4.67	-	-	-

Annex 3: List of species encountered in the study quadrates of homestead land-use type of Kafta humera.Relative frequency, relative abundance, relative dominance and Importance value index

Land use type	**Species name**	**Relative frequency**	**Relative abundance**	**Relative dominance**	**IVI**
1	*Acacia mellifera*	50	2.38	0.32	52.70
2	*Acacia senegal*	100	41.27	1.38	142.65
3	*Adansonia digitata*	100	15.08	81.57	196.64
4	*Balanytesaegyptiaca*	100	22.22	2.99	125.22

5	*Dalbergia melanoxylon*	100	3.17	0.34	103.51
6	*Laneafruictosa*	100	14.29	7.58	121.87
7	*Setruculiasetigra*	50	1.59	5.81	57.40

Annex 4: List of species encountered in the study quadrates of open shrub land-use type of Kafta humera.Relative frequency, relative abundance, relative dominance and Importance value index

No.	**Species name**	**Relative frequency**	**Relative abundance**	**Relative dominance**	**IVI**
1	*Acacia mellifera*	100	12.90	0.01	113.23
2	*Acacia senegal*	100	2.15	0.00	102.25
3	*Acacia seyal*	50	1.08	0.02	51.99
4	*Adansonia digitata*	100	35.48	1.56	228.66
5	*Anogaysusleocarpus*	100	6.45	0.03	108.31
6	*Balanitesaegyptica*	50	1.08	0.02	52.27
7	*Dalbergia melanoxylon*	100	23.66	0.01	123.99
8	*Dicrostachyuscinera*	100	10.75	0.00	110.77
9	*Girewa bicolor*	50	1.08	0.00	51.08
10	*Pteospurmumcontianum*	50	1.08	0.00	51.10
11	*Terminalia brownii*	50	4.30	0.03	56.34

Annex 5: List of species encountered in the study quadrates of riverine land-use type of Kafta humera.Relative frequency, relative abundance, relative dominance and Importance value index

No.	**Species name**	**Relative frequency**	**Relative abundance**	**Relative dominance**	**IVI**
1	*Acacia polycantha*	50	2.56	2.82	55.39
2	*Adansonia digitata*	100	76.92	71.19	248.11

3	*Anogaysusleocarpus*	50	1.28	0.17	51.46
4	*Dalbergia melanoxylon*	50	1.28	0.38	51.67
5	*Ficusvasta*	50	1.28	17.32	68.60
6	*Laneafruictosa*	0	1.28	1.64	2.92
7	*Pteospurmumcontianum*	50	1.28	1.81	53.09
8	*Tamarindus indica*	50	8.97	4.10	63.07
9	*Terminalia brownii*	100	3.85	0.37	104.22
10	*Ziziphusspinachristy*	50	1.28	0.20	51.48