Woody species diversity, productivity and carbon stock potential of dry deciduous woodland in Alitash National Park, North West Ethiopia

Amsalu Abich¹*, Asmamaw Alemu¹, Tadesse Mucheye², Mequanent Tebikew¹ and Yohanns Gebremariam¹

¹ Department of General Forestry, College of Agriculture and Rural Transformation, University of Gondar, P.O. Box 196, Gondar, Ethiopia
² Department of Natural Resource Management, College of Agriculture and Rural Transformation, University of Gondar, P.O. Box 196, Gondar, Ethiopia

Abstract
Dry woodlands provide multifunctional benefits which grouped socioeconomic and ecological values. Despite these advantageous while recently threatened, the status of dry woodland attribute is not well understood, particularly Alitash National Park (ANP). Hence, woody species diversity, productivity and carbon stock potential of ANP were studied. Based on the collected data, a total of 24 woody species were identified. The computed Shannon-Wiener's diversity and evenness index were 2.11 and 0.66, respectively which indicated that moderate diversity and individual species were sparsely distributed horizontally. The study site was dominated by few individuals of woody species that exhibited the highest value of IVI. Population structure pattern of woody species showed F shape indicates the first class exhibited good regeneration. Whereas, species in the second classes interrupted the seedling establishment phase and transformation to sapling stage as a result of disturbance caused by anthropogenic, grazing and frequent firing. Stand basal area, volume and AGB were 8.57 m²ha⁻¹, 48.15 m³ha⁻¹ and 49.06 ton ha⁻¹, respectively. The estimated carbon stock of the stand was 27.7 ton ha⁻¹. In conclusion, the results of woody vegetation attributes showed ANP is affected negatively caused by different disturbance indicate the need of appropriate intervention and management system although ANP is protected.

Keywords: Dry woodland; Diversity; Population structure; Productivity; Carbon stock

Introduction
Ethiopia is the fifth largest flora diversity in tropical Africa (Eshetu, 2001). This is due to the country has diverse geographical configuration that has given rise to the development of wide diversities of flora and fauna rich with endemic elements. However, these biological rich resources are diminishing at an unprecedented rate resulted population growth driven agricultural land expansion, dependency of biomass energy and overgrazing (Lemenih and Teketay, 2006; Teketay, 1992; 2004-2005; Wassie, 2007). In addition, land-grabbing, biological invasive, and climate change have emerged as a new threats for forest destruction in the country. Current policy framework such as Growth and Transformation Plan in 2010 promoted large scale land leases to foreign and domestic investors in the agricultural sectors, particularly for the production of export crops and biofuels. In line with this, 1.2 million hectare of forest vegetation was converted to agricultural land between 2004 and 2008 (Stebek, 2011). These land use change contribute for shrinking of forest resources leads to affect ecosystem services negatively including biodiversity loss and climate change.

Ethiopian flora have been classified in to twelve major vegetation types (Friis et al., 2010). Among others, Combretum-Terminalia woodland vegetation type is characterized by small to moderate size with fairly large deciduous leaves and dominated by the family Combretaceae, Fabaceae and Burseraceae (Demissew and Nordal, 2010; Eshete et al., 2011; Wale et al., 2012). This vegetation provides socioeconomic and
ecological services at local and national level. Some of the benefits are livelihood diversification, create job opportunity, for livestock production, fight against desertification, biodiversity conservation, improve soil fertility and carbon sequestration (Lemenih and kassa, 2011). Furthermore, it is characterized by rich floristic composition (Wale et al., 2012). However, this ecosystem is under threatened due to natural and anthropogenic challenges. Empirical evidence indicated that change of climate variability (Eshete et al., 2011; Lemenih and kassa, 2011); socioeconomic activities such as wood extraction for construction and energy source, livestock production, land use change and frequent firing (Eshete et al., 2011; Lemenih and kassa, 2011; Wale et al., 2012); and government initiated resettlement (Lemenih and kassa, 2011) have been identified as major challenges for dry deciduous woodland ecosystem in North west Ethiopia. Eventually, these factors are influenced the dry deciduous woodland attributes, productivities and alters species composition negatively (Eshete, 2011).

National parks, a part of dry deciduous woodlands, safeguard habitats for vast range of indigenous flora and fauna. They maintain biodiversity and endangered endemic species or serves as in situ conservation to ensure the capacity of ecosystem service and goods. However, these protected area are faced by several challenges in meeting human and wildlife needs (Tessema et al., 2007). These challenges are human triggering including grazing, settlement, agricultural expansion, fishing, fire and improper collection of non-timber forest products (Menale and Jungmeier, 2011). These anthropogenic disturbances have brought substantial negative changes on the woodland attributes leading to deteriorate woodland ecosystem functions (Eshete et al., 2011). In Alitash National Park (ANP), few researches focused on investigations of challenges and opportunities (Menale and Jungmeier, 2011) and habitat association of rodents and insectivores (Hatamu and Bekele, 2008) have conducted. However, woody species attributes of this woodland ecosystem have not sufficiently understood. Generally, the attributes of dry forests and woodlands have received little attention in terms of research (Chidumayo and Gumbo, 2010).

Although anthropogenic disturbances are investigated by few researches the woody species attributes (Wale et al., 2012) and productivity of dry woodlands (Eshete et al., 2011; Sisay et al., 2017) in north west Ethiopia, the impact of these human induced factors and utilization on woody species diversity, productivity and carbon stock has not been well studied in ANP. This is because of harsh environmental conditions, inaccessibility, remoteness, inhospitability and instability, Ethio-Sudan border, in and round area. Moreover, these scholars information was inadequate for describing the productivity of vast dry land deciduous woodlands. Therefore, assessments of these woodland vegetation attributes are crucial for effective conservation planning, and the presence of rare or threatened indigenous woody plant species to be determined. Consequently, this information is used for preparing protected area management plan and designing conservation strategies. Thus, the objective of this study was to assess woody species diversity, productivity and carbon stock of ANP dry deciduous woodlands. Hypotheses of this study is protected area including national parks enhance woody species diversity, productivity and biomass production (Angassa and Obā, 2010; Mengistu et al., 2005; Wassie et al., 2009a; Yayneshet et al., 2009).

Materials and Methods

Description of the study site
The study was undertaken in Alitash National Park which is found in Quara, Amhara National Regional State, North West Ethiopia. It is located between 11°47’5.4” to 12°31’3.6”N latitude and 35015’48” to 35048’51” E. longitude in north western flat plain part of Ethiopia bordered with Sudan. ANP was established legally in 20th February 2006 published in regional legal issues publication news letter ‘Zekere Heg’ by regional council with Regulation act No 38/2005. The total area of the ANP is more than 2.666 x 105 hectares. The annual rainfall of the area goes up to 800 mm. Mean monthly temperature are ranged 13.6 to 19.2°C minimum and 34°C to 41.1°C maximum (Cherie Enawugaw et al, 2006). The mean altitude ranges from 500 masl around (Alga) in the northern flat plain to 900 around (Tsequa) hills in Southern part. The dominant soil types physically observed are vertisoles, fluvisols and alluvial deposits around River course dominated by sandy texture.

The vegetation cover of the park is characterized by five vegetation types. The dominant vegetation type is - mixed woodland vegetation where Combretum and Terminalia species are abundant. There are also other vegetation types which include Riverine vegetation, - Seasonal wetland vegetation and -open wooded grass.
land vegetation types, and hilly area woodland areas. Although few fragmented research exist, comprehensive scientific studies on the vegetation type, biodiversity composition and current status have not been undertaken in the ANP.

The community surrounding ANP is mainly dependant on Agriculture, crop and livestock production, and some related activities. The park is also served as routine which connected to Sudan for Illegal traders. Gumiz ethnic group is the only native residence round the park but recently most of the dwellers are settled by government. This national park is used as a grazing land for these local communities and ‘Felata' nomads.

**Sampling design for woody vegetation inventory**

Reconnaissance survey was carried out from May to June 2016 in the park. Three sites were selected based on species composition, distance, accessibility, safety, and resource with park manager and experts. Systematical random sampling approach and transect line method was applied for surveying woody species. The first transect was aligned randomly at one side of the forest using a compass; then the others was laid at 500 m intervals from each other. Along each transect, minimum size sample quadrats measuring 20 m x 20 m (for trees) was laid down (Kent and Coker, 1992) at 500 m interval. Sub-quadrats measuring 10 m x 10 m was set up in the center of each quadrat for recording of sapling. For regeneration assessment, sub-quadrats measuring 3 m x 3 m were laid down one in the center and four from each corner of the quadrat for counting of seedling. A total of 60 (20 from each site) quadrats were sampled. Individuals were classified in a series of Diameter at Breast Height (DBH) classes at specific intervals, ≥10 cm DBH, 3.5 to 10 cm DBH and DBH less than 3.5 cm are considered as tree, sapling and seedling respectively following (Dhaulkhandi et al., 2008; Tiwari et al., 2010). We measured stem diameter using forest calliper at breast height (1.3 m above the ground). In each of these quadrats, local species name, number and DBH of individuals of all woody species were determined and recorded. Plant specimen identification was conducted with knowledgeable local farmers and using Bekele (2007) field manual book.

**Data analysis**

**Woody plant species diversity**

Woody species diversity of ANP was analyzed using Shannon–Wiener Diversity Index (Magurran, 2004). The Shannon–Wiener diversity (H') and evenness (E') indices are calculated as a measure to incorporate both species richness and species evenness (Magurran, 1988). Species richness is the number of species in a sample of standard size (Whittaker, 1972). Species i comprises proportion \( pi \) of the total individuals in a community of \( S \) species,

\[
\text{Shannon – Wiener diversity index is } H = - \sum_{i=1}^{S} p_i \ln p_i \quad \text{Eq. (1)}
\]

\[
\text{Species evenness is } E = \frac{H}{H_{\text{max}}} \quad H_{\text{max}} = \ln S \quad \text{Eq. (2)}
\]

Where \( E = \) Pielou evenness (Pielou, 1966); \( H' = \) the observed value of Shannon-wiener diversity index; \( H'_{\text{max}} = \ln S \), and \( S = \) Total number of species

**Population structural diversity**

Woody species structure in ANP were analysed in terms of mean basal area (calculated from individuals with DBH ≥ 3.5cm), dominance and size class distribution. Dominance is described in terms of Importance Value Index (IVI) (Kent and Coker, 1992) which is the sum of relative basal area, relative density and relative frequency in the sample plots for each species (Curtis and McIntosh, 1950; Pascal and Pelissier, 1996). Woody species that has the highest value of IVI were selected for population structure analyses. Tree size class distributions were formed with 4.9 cm increment based on tree diameters for selected woody species. Population dispersion pattern were also analysed through abundance to frequency ratio following (Whitford, 1949). IVI can be computed as:

\[
\text{IVI}_i = R_{D_{i1}} + R_{D_{i2}} + R_{f_i} \quad \text{Eq.(3)}
\]
Woody species dominance is calculated by dominance of species $i$ in the sample (m$^2$) divided by total dominance of all individual species $j$ in the sample (m$^2$). It can be computed as:

$$R_{Di} = \left(\frac{D_{Di}}{D_{Dj}}\right) \times 100 \quad \text{Eq. (4)}$$

Density of woody species can be computed as the number of individuals of species $i$ in the sample ($D_i$) divided by total number of individuals of all species $j$ in the sample ($D_j$):

$$R_{Di} = \left(\frac{D_i}{D_j}\right) \times 100 \quad \text{Eq. (5)}$$

Frequency is defined as the probability or chance of finding a plant species in a given Sample area or quadrant. It is calculated with the formula; Relative frequency is the number of plots in which species $i$ occur ($f_i$) divided by total number of plots $j$ ($f_j$) and it can be computed as:

$$R_{fi} = \left(\frac{f_i}{f_j}\right) \times 100 \quad \text{Eq. (6)}$$

**Regeneration status**

Regeneration status of woody species in the Park was analyzed based on population size of seedlings, saplings and matured trees (Dhaulkhandi et al., 2008; Tiwari et al., 2010). Good regeneration if seedlings > saplings > adults; fair regeneration, if seedlings > saplings ≤ adults; poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults). If a species is present only in an adult form it is considered as not regenerating.

**Volume, height and biomass**

Individual stem volume, basal area and aboveground biomass were computed. Then these estimated individual variables were summed and converted to stand level. Aboveground biomass was estimated using Eq. 9 and 10 developed by Abich et al. (2018) for our study woodland vegetation (accepted for publication). An average 56.4% of carbon content (Abich et al., 2018) was used for estimating carbon stocks of the stand. Individual total trees heights were predicted using height – diameter relationships (Eq.7) (Abich et al., 2018). Individual tree variables were calculated as follows:

$$\ln (H) = 0.740 + 0.521\ln (DBH) \quad \text{Eq. (7)}$$

$$\ln(\text{AGB}) = -2.109 + 2.422\ln(DBH) \quad \text{Eq. (8)}$$

$$\ln(\text{AGB}) = -2.965 + 1.820\ln(DBH) + 1.157\ln(H) \quad \text{Eq. (9)}$$

Where $H$ is total height; DBH is diameter at breast height; AGB is aboveground biomass; and ln is natural logarithm.

**Result**

**Woody species composition, diversity and richness**

In ANP, a total of 24 woody species were recorded in the 60 quadrats. Twenty one woody species belonging to 17 genera under 13 families, 2 unidentified and 1 unknown species were identified in the park. The two dominant families were Combretaceae, comprising five species in 3 genera, and Fabaceae, comprising six species in 4 genera. The computed Shannon-Wiener's diversity and evenness index were 2.11 and 0.66, respectively.

**Population structural analyses**

**Density of trees/shrubs, sapling and seedling**

Total stem density of matured trees, saplings and seedling were 290.4, 220 and 8295 individual ha$^{-1}$, respectively. The highest woody species densities were observed for species *Combretum collinum* (97.5 ha$^{-1}$), *Combretum molle* (65 ha$^{-1}$), *Terminalia laxiflora* (27.5 ha$^{-1}$), *Anogeissus leiocarpa* (15 ha$^{-1}$), *Dalbergia melanoxylon* (14.6 ha$^{-1}$), and *Combretum harotomannianum* (13.8 ha$^{-1}$). The highest sapling densities were observed in decreasing order: 76.7, 65, 25, 18.3, 11.3 and 8.3 ha$^{-1}$ individuals for *C. Collinum, C. Molle, A*,
seyal, T. Laxiflora, C. harotomannianum, and Zonbelit (unidentified) species, respectively. The lowest trees/shrub densities were observed ranged from 0.42 to 10.8 individual’s ha\(^{-1}\) for species Stereospermum kunthianum, Dichrostachys cineerea, Acacia Polyacantha, Sterculia setigera, Fola (unidentified), Lanchocarpus laxiflora, Unknown, Pterocarpus lucens Balanites aegyptiaca, Zonbelit (unidentified), and A. seyal in descending order (Table 2).

The density of sapling and seedling were dominated by few species. Of the total woody species, 45.8% were not represented by their sapling. Out of the total seedlings, 84.3% of the seedlings were dominated by five species including C. Collinum (2114.7 ha\(^{-1}\)), T. Laxiflora (2022.7 ha\(^{-1}\)), C. Molle (1072 ha\(^{-1}\)), Dalbergia melanoxylon (958.7 ha\(^{-1}\)) and Dichrostachys cinerea (822.7 ha\(^{-1}\)). The lowest seedling densities were observed in Grewia bicolor, Lanchocarpus laxiflora, Stereospermum kunthianum which represented only 0.016% of each. Pterocarpus lucens and Fola (unidentified) species seedlings were not recorded in all studied quadrats.

**Basal area, IVI and DBH class distribution of trees and saplings**

The most frequent species in the study area was *Combretum collinum* species covering 16.6% of relative frequency in the total sampled quadrats followed by *Dalbergia melanoxylon* (12.7%), *C. molle* (9.7%), *T. Laxiflora* (9.4%) and *Lannea fruticosa* (9.1%). The estimated total basal area of matured trees and saplings were 7.910 and 0.656 m\(^2\) ha\(^{-1}\), respectively. *Combretum collinum, Combretum molle, Anogeissus leiocarpa* and *Terminalia laxiflora* were accounted 32.67, 16.30, 12.21 and 9.90 % of relative dominance among the recorded woody species, respectively (Table 1). DBH class distribution of individual species, grouped in to nine classes, was revealed F shape distribution pattern (Fig.1).

Importance value index was determined for each species which provides information about ecological significance of the species in a given ecosystem. Based on IVI, eight top woody species were selected for analysis of population structure such as *Combretum collinum* (75.3%), *Terminalia laxiflora* (42.7%), *Combretum molle* (39.6%), *Dalbergia melanoxylon* (28.1%), *Lannea fruticosa* (18.4%), *Anogeissus leiocarpa* (17.7%), *Combretum harotomannianum* (12.0%) and Zonbelit-unidentified (11.3%) which present in Table 1. *Combretum collinum, Terminalia laxiflora, and Combretum molle* were the most dominated woody species in the study site. Diameter class population structure distribution of selected woody species showed similar shapes except *Anogeissus leiocarpa*. "F" shape type of distribution is demonstrated on all population, when the first class exhibited highest individuals; the second and third class had absent/few individuals; the intermediate class (4, 5 and 6) had relatively higher individuals and with gradual decreased towards the larger classes. *Anogiossus leiocarpa* was formed "E" shape. "E" shape is formed when few numbers of individuals are found at the lower (2, 3 and 4 class) diameter class and higher at the intermediate diameter class (5, 6 and 7 class). In this type of shape, the number of individuals decreased at 8 and 9 diameter class and again individuals increased as diameter size increase (Fig.2).
Species distribution patterns
Abundance to frequency ratio values indicates the pattern of plant species distribution which receives the attention of ecologist and forester. Woody species distribution pattern in the study area were revealed contagious. The computed values of abundance to frequency ratio of all individuals were greater than one which is presented in Table 1.

Regeneration status of woody species
In the current study, 22 wood species were represented in the seedling class which DBH less than 3.5cm. In the total recorded woody species, seedlings can be comprised 94.2%. Matured trees/shrub and saplings were comprised 3.3% and 2.5%, respectively. Nine woody species depicted good regeneration status and eleven species showed fair regeneration. Two species showed poor regeneration. Whereas, Pterocarpus lucens and Fola (unidentified) did not shows regeneration (Table 2). Most woody species seedling emerged from the soil seed bank but C. collinum, T. laxiflora and Zombelit (unidentified) regenerated through soil seed and sprouting from the scared stump (field observation).

Stand productivity, aboveground biomass and carbon stocks
Individual stem basal area, volume and aboveground biomass were computed, summed and converted to stand variables. The result of computed stand variables is presented in Table 3. The total stand basal area, volume and aboveground biomass were 8.57 m²ha⁻¹, 48.15 m³ha⁻¹ and 49.06 ton ha⁻¹ respectively. The estimated carbon stock of the stand was 27.7 ton ha⁻¹.

Discussion
Species composition, richness and diversity
A total of 24 woody species were recorded. Of these, 21 woody species comprising 13 families, two unidentified and one unknown woody species were represented the site. This woodlands are characterized by Combretum - Terminalia woodland vegetation (Friis et al., 2010). The most species rich families were Combretaceae and Fabaceae in this study site. It was consistent with the finding of Savadogo et al. (2007) they found these two families were dominated the Sudanian Savanna woodlands. In Metema similar woodland vegetation formation, higher woody species composition ranged 36 -39 woody species (Eshete et al., 2011; Wale et al., 2012) were identified few distance apart from our study site. This difference in species composition among the two sites might be due to the difference in climatic variability-moisture (Eshete et al., 2011), soil characteristics and altitudinal gradients (Yeshitela and Bekele, 2002), altitudinal gradients (Lieberman et al., 1996) and soil attributes (Awas, 2007; John et al., 2007; Zhang and Chu, 2011). In addition, Grazing pressure (Hanke et al., 2014; Khatri et al., 2016) and frequent firing (Peterson and Reich, 2008; Teketay, 2005b) altered species composition. In our study site, anthropogenic activities including selective logging; increased grazing intensity; and frequent firing might be the responsible causes for changing woody species composition.

Species diversity, plant community attribute, measurement play crucial role in biodiversity conservation and ecological studies (Maguran, 2004). Shannon- Weiner diversity and evenness index were 2.11 and 0.66, respectively in the present study. Our results of woody species diversity and evenness value were similar compared with reports from studies in the Botswana dry woodland (Neelo et al., 2013), Alabama woodlands in southeast US (Khatri et al., 2016), Metema dry deciduous woodlands in North west Ethiopia (Eshete et al., 2011) but lower than Miombo woodlands in Tazania (Giliba et al., 2011), Sudanian Savanna woodlands in Burkina Faso (Savadogo et al., 2007), woodland savanna in Uganda (Nangendo et al., 2006) and woodlands in Ethiopia (Dibaba et al., 2014; Worku et al., 2012). The value of Shannon-Weiner diversity index is ranged 1.5 – 3.5 and rarely exceed 4.5 (Kent and Coker, 1992) which comprise both species richness and evenness (Manguran, 1988). Cavalcanti and Larrazábal (2004) also nominated this index value as high when it is exceed 3, medium when the value lay between 2-3 and low when the value is ranged 1-2. Whereas, if the value of H’ of a given community less than 1 it is considered as poor diversity. Based on this analysis, woody species diversity value in the present study falls at the medium diversity range indicates the presence of disturbance in this dry deciduous woodland. However, woody species evenness value (E = 0.66)
more or less comparable with that was reported in Ethiopia (Didita et al., 2010; Eshete, 2011), suggests the recorded individual species exhibited moderately evenly distributed in the area.

Environmental factors and anthropogenic disturbance have influenced the attributes of dry forest and woodlands. Several studies pointed out increasing fire frequency, common problem in dry woodlands, declined woody species diversity of dry woodlands (Bullock et al., 2009; Chidumayo and Gumbo, 2010; Peterson and Reich, 2008; Teketay, 2005b). This might be described by the presence of large fuel load, dry mass of litters, herbs and grasses on the ground which facilitate ignition. So, dry deciduous woodland vegetation are called fire prone ecosystem and the stem bark gradually changed to thick. In addition, despite intermediate grazing intensity can promote plant species diversity (Naveh, Z. & Whittaker, R.H. 1980), empirical evidence indicated that plant species diversity negatively affected by grazing intensity (Angassa and Oba, 2010; Mengistu et al., 2005; Pueyo et al., 2006; Wassie et al., 2010). It also might be altered the woodland conditions and interrupts the resource regulatory process (Yates et al., 2000) and changed to Savanna grassland (Bullock et al., 2009). Generally, plant species diversity in the terrestrial ecosystem is influenced by various factors including species interaction, disturbance processes and environmental factors (Connell, 1978; Huston, 1994; Whittaker, 1975). In our study, frequent human induced fire for preventing wild animal attacks, particularly by illegal traders, and heavy livestock grazing pressures by ‘felata’ ethnic groups and inhabitants are observed as a major disturbance. These indicating the ANP have not well designed fire break and has weak management system that received the attention of decision and policy makers.

Population structure
Population structure analyses of forest provide substantial evidence for quantifying seedling recruitment, population status and monitoring the indicators of stability, trends and rate of population change. The total stem density and basal area (DBH ≥ 3.5 cm) were estimated to be 510.4 ha⁻¹ and 8.57 m² ha⁻¹, respectively. Compared to similar woodland vegetation formation, woody species density is higher compared with that was reported in earlier study (Eshete, 2011; Wale et al., 2012) in Ethiopia, semi arid zone woodlands in Senegale (Ndiaye et al., 2014) and Sudanian Savanna woodlands in Burkina Faso (Savadogo et al., 2007). Whereas, our result is lower compared to earlier study undertaken Miombo woodland in Tanzania (Giliba et al., 2011). Despite ANP protected area, the result clearly shows there is sign of illegal selective wood removal in the park for construction and energy source. In addition, almost all quadrats were fired and we tried to find fire free places but couldn’t be found. Hence, the density of saplings, DBH ranged 3.5 -10 cm was influenced and underestimated which is not expected result (Fig. 3). This might be suggested that fire is damaged the lower diameter class (Peterson and Reich, 2001) that interrupted the progressive growth of sapling to mature trees (Fig 1).

Population structure and density analyses of major tree species can be provided better understanding of species regeneration status, past and present conditions and ecology of the forests or woodlands (Senbeta et al., 2007; Teketay, 2005a; Teketay, 2005b). In the present study, the overall basal area higher than the findings of Worku et al. (2012) but lower compared with the finding of Eshete (2011) suggests soil water stress and moisture availability (Eshete, 2011), climatic and edaphic conditions (Bullock et al., 2009) are influenced growth features of dry woodland. Basal area analyses of individual woody species revealed the area was dominated by few species (Table 1). *Combretum collinum, Combretum molle, Anogeissus leiocarpa* and *Terminalia laxiflora* were the most dominance woody species in descending order. This indicates the aforementioned species have more adaptive and resistance capability to harsh environmental conditions and human disturbance.

Several ecological studies demonstrated the contribution of individual species IVI value determination in relation to ecological significance of the species in a given vegetation formations (Girma et al., 2011; Kent and Coker, 1992; Neelo et al., 2013; Worku et al., 2012; Zegeye et al., 2006). In the present study, the dry deciduous woodlands dominated by few woody species that had greater than 11.3% of IVI value. This might be suggested that these woody species can be considered as the most ecologically important species contributed by their relative frequency, density and dominance. More than 50% of woody species had less than 5% IVI value suggests several woody species had lower abundance due to environmental factors,
disturbance and ecological requirement. Thus, these species should be prioritised for applying conservation efforts.

Analyses of population structure using diameter size class provides an understanding of structural diversity, regeneration status, disturbance response and changes of population structure of woody species (Bekele, 1993; Senbeta et al., 2007; Teketay, 2005a; Teketay, 2005b). The overall and individuals diameter class distribution of the sampled area was formed similar F shape distribution (Fig. 1 and 2). This type of population structure shows early good recruitment and establishment of seedlings following the rainy season. However, dry woodlands are characterized by long dry season, frequent firing, moisture stressed and poor soil nutrient availability (Bullock et al., 2009; Chidumayo and Gumbo, 2010) leads to interrupt the progress of succession from these seedling in the first class to sapling stage, in our case, the 2nd and 3rd class. Relatively higher individuals were presented in the intermediate class (4, 5, and 6) indicate the ability of species competitiveness and resistance to past disturbance in the area. Whereas, the number of individuals decreased towards the larger class due to human induced disturbance including selective tree harvesting (Pueyo et al., 2006; Teketay, 2005a; Wassie et al., 2010; Wassie et al., 2009a), inability to cop up frequent firing, disease, (particularly, T. laxiflora, C. molle and C. harotomannianum), wind throw, and may be ecological process. For instance, pole sized (DBH ranged 10-20 cm) and matured woody species including, C. collinum, C. molle, C. harotomannianum, P. lucens and D. melanaxylon have been used for various purposes in the study area. This is because of their good characteristic in terms of termite resistant, strengthens and durability, particularly Dalbergia melanaxylon species. Eventually, the combination of livestock-induced disturbances (Pueyo et al., 2006; Wassie et al., 2010); interspecific competition, herbivory, predation and mutualism (Tilman, 1986) and frequent firing are influenced vegetation structure.

Regeneration status
In this study, cumulative population structure, by grouping seedling, sapling and matured, of woody species exhibited reverse J shaped distribution (Fig. 3). This type of distribution is widely acknowledged and showed healthy regeneration, recruitment capacity and stable population structure (Alelign et al., 2007; Dibaba et al., 2014; Didita et al., 2010; Teketay, 2005a; Wassie et al., 2010; Zegeye et al., 2006) of a given forest or woodland. A total of 8805.1 individuals ha\(^{-1}\) were recorded in our study. Of these, seedlings were comprised 94.2% contributed by seven woody species such as T. laxiflora, C. collinum, C. molle, D. Melanaxylon, D. cinerea Zonbelit and C. Harotomannianum in descending order (Table 2). On the other hand, six woody species seedlings were absent / few ranged 0 - 4 individuals ha\(^{-1}\). Whereas, both saplings and matured were comprised 5.8% of individuals ha\(^{-1}\). Out of the recorded saplings, five species had relatively higher individuals but 70.8% of the recorded woody species sapling densities were represented by few (absent) individuals (Table 2). However, much higher seedling and sapling density were recorded in our study compared with the reports of Wale et al. (2012) in similar dry woodland vegetation. Seedling and saplings of Lonchocarpus laxiflorus, Pterocarpus lucens, Fola-unidentified, Stereospermum kunthianum, Anogeissus leiocarpa and Balanites aegyptiaca were poorly represented. It was consistent with the findings of Wale et al. (2012). Regeneration status of the dry woodland are characterised as 37.5, 45.8, 8.3 and 8.3% of woody species were showed good, fair, poor and no regeneration, respectively. However, the transition of woody species regeneration and seedling establishment to sapling stage or higher class is hampered/ takes a long time due to heavy grazing pressure, moisture availability, competition with other vegetation, frequent firing, and tree harvesting (Bullock et al., 2009; Gnüter et al., 2011; Teketay, 2005a; Teketay, 2005b).

Species distribution patterns
Spatial distribution patterns of plant species are associated with different factors including competition for limiting resources and light (Tilman, 1986); variation in soil attributes (Thomas and Packham, 2007); stages of succession and seed dispersal mechanism (Whitford, 1949); and dispersal modes, altitude and disturbance (Senbeta et al., 2005). In our study, Abundance to Frequency ratio (A/F) values of all the recorded woody species were > 1 (Table 1). According to Whitford (1949) the value of A/F ratio is ranged 0.025 – 0.05. If the computed value of A/F is < 0.025 indicates the species are distributed regularly; the value lies between 0.025 – 0.05 the species shows random distribution; and the value is > 0.05 it shows a contagious or clumped distribution. Contagious dispersion pattern is mostly common in natural vegetation (Venna et al., 1999) but it was also found in both secondary forest and plantation (Kumar et al., 2006). In our study,
woody species distribution patterns were exhibited contagious distribution suggesting the number of seedling density decreased with increasing the distance away from the mother trees. This implies the parent trees create micro-climate including moderate temperature fluctuation; moisture due to shading and nutrient accumulation through nutrient pumping and addition of organic matter under the canopy or dispersal limitation.

Productivity and aboveground carbon stock

Generally, the growth and productivity of dry woodland is less due to sever climatic variability, soil moisture availability, anthropogenic disturbance and low quality of soil attributes (Bullock et al., 2009; Chidumayo and Gumlo, 2010; Günter et al., 2011; Thomas and Packham, 2007). In the present study, the estimated basal area and volume were 8.57 m²ha⁻¹ and 48.15 m³ha⁻¹, respectively (Table 3). In similar dry woodland vegetation, the computed mean basal area was 12.19 m²ha⁻¹ and 9.55 m³ha⁻¹ for Metema and Avergele dry woodland, respectively; and the mean stand volume was 38.6 m³ha⁻¹, and 15.38 m³ha⁻¹ for Metema and Avergele dry woodland, respectively (Eshete et al., 2011). Sisay et al. (2017) also showed that mean volume of Mahiberesellassie dry woodland was 27.6 m³ha⁻¹. In another ways, lower basal area and higher volume were found in our study site compared with the aforementioned reports. This difference in stand productivity might be explained by variation in climate variability (Eshete et al., 2011), resource availability and environmental factors (Balvanera and Aguirre, 2006; Condit et al., 2013; Pausas and Austin, 2001) and human disturbance (Eshete et al., 2011; Pueyo et al., 2006; Wassie et al., 2010; Worku et al., 2012) across the site. These factors can be reduced tree growth, stem density and the number of large diameter tree in dry woodland vegetations suggesting lower productivity compared to dry Afromontane forests (Bullock et al., 2009; Günter et al., 2011).

Aboveground biomass of dry woodlands was 49.06 ton ha⁻¹ (Table 3). Carbon stock potential of this dry woodland was 27.7 ton ha⁻¹ higher than that was reported by Sisay et al. (2017) and (Vreugdenhil et al., 2012) in similar dry woodland vegetation, North west Ethiopia. This variation might be associated with the difference in site condition, disturbances and environmental factors (Chave et al., 2005; Henry et al., 2011; Premyslovská et al., 2007) and model selection (Abich et al., 2018; Salis et al., 2006; Sileshi, 2014). Generally, aboveground carbon stock potential of Alitash National Park dry deciduous woodland was 7.4 Mega tone which serve as climate change mitigation.

Conclusion and recommendation

The result indicated that Alitash dry deciduous woodland house 24 different woody species which provide various goods and services. Combretaceae and Fabaceae were the most dominant families in this study site. Woody species composition and diversity index value were medium which indicates the need of conservation from human disturbance although ANP is protected area. The frequency of woody species was relatively low with the exception of a few species indicating that environmental factors might be influenced horizontal distribution of individual wood species. This is also confirmed from the computed value of medium evenness value and higher abundance to frequency ratios (contagious distribution) in the study site. Population structure analyses result revealed that population structures negatively affected which hampered each stage of woody species succession. This indicate human disturbance including livestock grazing (browsing and trampling), recurrent firing and long dry season affect ecological succession of woody vegetation negatively which requires attentions and appropriate management intervention.

The result revealed that most of the woody species exhibited low value of density, basal area and IVI value and unstable population structure. Population structure of the whole population and selected woody species, particularly those grouped in population structure class 2 and 3, showed individuals species were few or absent in the lower diameter class. This indicates unable to transform from seedlings to saplings and saplings to intermediate diameter size class. The assessment of regeneration status based on seedling, sapling and matured tree count exhibited some woody species showed good to fair regeneration status but many woody species were poor or not regenerating. This indicates intensive livestock grazing, illegal tree harvesting, recurrent fire and long dry season affect dry woodland ecosystem attributes negatively. Despite human and natural disturbance affect the productivity of dry woodland ecosystem, ANP stored 7.4 Mt of carbon that mitigate climate change and prevent desertification. Generally, the result indicates the need of urgent conservation and appropriate management intervention in order to maintain and sustain
multifunctional benefits of this dry deciduous woodland. We suggested that plant community attributes at ecosystem level warrant further investigation rather than fragmented research on the natural dynamics of dry woodland vegetation, i.e. causes, mechanisms and factors which drive the rate of this ecosystem process.

Acknowledgement: The authors are grateful to the financial support for this study from University of Gondar. We are also thankful to the ANP staffs for supporting technical, logistic supports during the study.

Reference
[1] Abich, A., Mucheye, T., Tebikew, M., Gebremariam, Y. and Alemu, A. (2018). Species specific allometric equations for improving aboveground biomass estimate of dry deciduous woodland ecosystem in the North West lowlands of Ethiopia. Accepted in Journal of Forestry Research.

[2] Alelign, A., Teketay, D., Yemshaw, Y. and Edwards, S. (2007). Diversity and status of regeneration of woody plants on the peninsula of Zegie, northwestern Ethiopia. Tropical Ecology, 48(1), 37-49. ISSN 0564-3295.

[3] Angassa, A. and Oba, G. (2010). Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in southern Ethiopia. Journal of Arid Environments, 74, 111-120.

[4] Awas, T. (2007). Plant Diversity in Western Ethiopia: Ecology, Ethnobotany and Conservation. Biology: University of Oslo, Norway.

[5] Balvanera, P. and Aguirre, E. (2006). Tree Diversity, Environmental Heterogeneity, and Productivity in a Mexican Tropical dry forest. BIOTROPICA, 38(4), 479-491.

[6] Bekele, T. (1993). Vegetation ecology of remnant Afromontane forests on the central plateau of Shewa, Ethiopia. ACTA PHYTOGEOGRAPHICA SUECICA, 79, Uppsala. 61 pp. ISBN 91-72 10-079-6. (9 1-72 10-479- 1). 66.

[7] Bekele, T. (2007). Useful trees and shrubs for Ethiopia: Identification, propagation and management for 17 Agroclimatic zones. Nairobi: RELMA in ICRAF Project, 552p; ISBN 92 9059 212 5.

[8] Bullock, S. H., Mooney, H. A. and Medina, E. (2009). Seasonally dry tropical forest. (p. 457) Cambridge University Press, New York.

[9] Cavalcanti, E. A. H. a. and Larrazábal, M. E. L. d. (2004). Macrozooplâncton da Zona Econômica Exclusiva do Nordeste do Brasil (segunda expedição oceanográfica – REVIZEE/NE II) com ênfase em Copepoda (Crustacea). Revista Brasileira de Zoologia, 21, 467-475.

[10] Chave, J., et al. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145, 87-99.

[11] Chidumayo, E. N. and Gumbo, D. J. (2010). The dry forest and woodlands of Africa: Managing for products and services. In E. N. Chidumayo and D. J. Gumbo (Eds.) (p. 304): Earthscan LLC, 1616 P Street, NW, Washington, DC 20036, USA.

[12] Condit, R., Engelbrecht, B. M. J., Pino, D., Pérez, R. and Turner, B. L. (2013). Species distributions in response to individual soil nutrients and seasonal drought across a community of tropical trees. PNAS, 110(13), 5064-5068.

[13] Connell, J. H. (1978). Diversity in Tropical Rain Forests and Coral Reefs. Science, New Series, 199, 1302-1310.

[14] Curtis, J. T. a. and McIntosh, R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 31, pp. 434-455.

[15] Demissew, S. and Nordal, I. (2010). ALOES and LILIES of ETHIOPIA and ERITREA.

[16] Dhaulkhandi, M., Dobhal, A., Bhatt, S. and Kumar, M. (2008). Community structure and regeneration potential of natural forest site in Gangotri, India. Journal of Basic and Applied Sciences, 4(1), 49-52.

[17] Dibaba, A., Soromessa, T., Kelbessa, E. and Tilahun, A. (2014). Diversity, Structure and Regeneration Status of the Woodland and Riverine Vegetation of Sire Beggo in Gololcha District, Eastern Ethiopia. Monoma Ethiopian Journal of Science, 6(1).

[18] Didita, M., Nemomissa, S. and Woldemariam, T. (2010). Floristic and structural analysis of the woodland vegetation around Dollo Menna Southeast Ethiopia. Journal of Forestry Research, 21(4).
[19] Eshete, A. (2011). The fankincense tree of Ethiopia: ecology, productivity and population dynamics. Production Ecology and Resource Conservation (p. 161): Wageningen University, Netherlands.

[20] Eshete, A., Sterck, F. J. and Bongers, F. (2011). Diversity and productivity of Ethiopian dry woodlands explained by climate and soil stress gradients. Forest Ecology and Management, 261, 1499-1509.

[21] Eshetu, Y. (2001). Diversity of naturally regenerated native woody species in forest plantations in the Ethiopian highlands. New Forests, Vol. 22.

[22] Friis, I., Sebsebe, D. and Breugel, P. v. (2010). Atlas of the potential vegetation of Ethiopia. [Copenhagen]: Det Kongelige Danske Videnskabernes Selskab.

[23] Giliba, R. A., Boon, E. K., Kayombo, C. J., Musamba, E. B., Kashindye, A. M. and Shayo, P. F. (2011). Species Composition, Richness and Diversity in Miombo Woodland of Bereku Forest Reserve, Tanzania. J Biodiversity, 2(1), 1-7.

[24] Girma, A., Fischer, E. and Barthlott, W. (2011). Plant Communities, Species Diversity, Seedling Bank and Resprouting in Nandi Forests, Kenya. Universität Koblenz-Landau.

[25] Günter, S., Weber, M., Stimm, B. and Mosandl, R. (2011). Silviculture in the tropics. Heidelberg Dordrecht London New York: Springer.

[26] Hanke, W., et al. (2014). The impact of livestock grazing on plant diversity: an analysis across dryland ecosystems and scales in southern Africa. Ecological Applications, 24, 1188-1203.

[27] Hatamu, T. and Bekele, A. (2008). Habitat association of insectivores and rodents of Alatish National Park, northwestern Ethiopia. Tropical Ecology, 49(1), 1-11, ISSN 0564-3295.

[28] Henry, M., et al. (2011). Estimating Tree Biomass of Sub-Saharan African Forests: a Review of Available Allometric Equations. Silva Fennica, 45(3B).

[29] Huston, M. A. (1994). Introduction In Biological diversity: the coexistence of species on changing landscapes. Cambridge University Press, Cambridge.

[30] John, R., et al. (2007). Soil nutrients influence spatial distributions of tropical tree species. Proceedings of the National Academy of Sciences of the United States of America, 104, 864-869.

[31] Kent, M. and Coker, P. (1992). Vegetation description and analysis : a practical approach. Boca Raton; London: CRC Press ; Belhaven Press.

[32] Khatri, R., Karki, U., Bettis, J. and Karki, Y. (2016). Grazing with Goats Changed the Woodland Plant-Species Composition During Summer. Professional Agricultural Workers Journal, 4, 1-12, http://tuspubs.tuskegee.edu/pawj/vol14/iss11/10.

[33] Kumar, A., Marcot, B. G. and Saxena, A. (2006). Tree species diversity and distribution patterns in tropical forests of Garo Hills. Current Science, 91(10), 1370-1381.

[34] Lemenih, M. and kassa, H. (2011). Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia. CIFOR, Bogor, Indonesia; www.cifor.cgiar.org.

[35] Lemenih, M. and Teketay, D. (2006). Changes in soil seed bank composition and density following deforestation and subsequent cultivation of a tropical dry Afromontane forest in Ethiopia. Tropical Ecology, 47(1) ISSN 0564 - 3295.

[36] Lieberman, D., Lieberman, M., Peralta, R. and Hartshorn, G. S. (1996). Tropical forest structure and composition on a large - scale altitudinal gradient in Costa Rica. Journal of Ecology, 84(2), 137-152.

[37] Magurran, A. E. (1988). Ecological diversity and its measurement. Chapman and Hall, London.

[38] Magurran, A. E. (2004). Measuring Biological Diversity. Blackwell Publishing.

[39] Menale, H. and Jungmeier, M. (2011). Potentials and Challenges of Alatish and Dinder National Parks (Ethiopia, Sudan) for implementing Transboundary Park Cooperation. Economics, “Management of Protected Areas”: University of Klagenfurt, Austria.

[40] Mengistu, T., Teketay, D., Hulten, H. and Yemshaw, Y. (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. Journal of Arid Environments, 60, 259-281.

[41] Nangendo, G., Steege, H. T. and Bongers, F. (2006). Composition of woody species in a dynamic forest–woodland–savannah mosaic in Uganda. Biodiversity and Conservation, 15, 1467-1495.

[42] Ndiaye, O., Diallo, A., Wood, S. A. and Guisse, A. (2014). Structural Diversity of Woody Species in the Senegalese Semi-Arid Zone—Ferlo. American Journal of Plant Sciences, 5, 416-426.
Amsalu Abich, IJSRM Volume 06 Issue 10 October 2018 [www.ijsrm.in]
[65] Tiwari, G. P. K., Tadele, K., Aramde, F. and Tiwar, S. C. (2010). Community Structure and Regeneration Potential of Shorea robusta Forest in Subtropical Submontane Zone of Garhwal Himalaya, India. *Nature and Science*, 8(1), 70-74.

[66] Vreugdenhil, D., Payton, I. J., Vreugdenhil, A., Tilahun, T., Nune, S. and Weeks, E. (2012). Carbon baseline and mechanisms for payments for carbon environmental services from protected areas in Ethiopia. World Institute for Conservation and Environment, USA. (Unpublished).

[67] Wale, H. A., Bekele, T. and Dalle, G. (2012). Floristic diversity, regeneration status, and vegetation structure of woodlands in Metema. *Journal of Forestry Research*, 23(3), 391-398.

[68] Wassie, A. (2007). Ethiopian church forests: Opportunities and challenges for restoration Forest Ecology and Forest Management (p. 212): Wageningen University, Wageningen, The Netherlands.

[69] Wassie, A., Sterck, F. J. and Bongers, F. (2010). Species and structural diversity of church forests in a fragmented Ethiopian Highland landscape. *Journal of Vegetation Science*, 21, 938-948.

[70] Wassie, A., Sterck, F. J., Teketay, D. and Bongers, F. (2009a). Effects of livestock exclusion on tree regeneration in church forests of Ethiopia. *Forest Ecology and Management*, 257, 765-772.

[71] Whitford, P. B. (1949). Distribution of woodland plants in relation to succession and clonal growth. *Ecology*, 30(2), 199-208.

[72] Whittaker, R. (1975). Communities and ecosystems, 2nd edn. McMillan Publishing Company, New York.

[73] Whittaker, R. H. (1972). Evolution and measurement of species diversity. *Taxon*, 21(2/3), 213-351.

[74] Worku, A., Teketay, D., Lemenih, M. and Fetene, M. (2012). Diversity regeneration status and population structures of gum and resin producing woody species in Borana Southern Ethiopia. *Forest, Trees and Livelihoods*, 21(2).

[75] Yates, C. J., Norton, D. A. and Hobbs, R. J. (2000). Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia; implications for restoration. *Austral Ecology*, 25, 36-47.

[76] Yayneshet, T., Eik, L. O. and Moe, S. R. (2009). The effects of exclosures in restoring degraded semi-arid vegetation in communal grazing lands in northern Ethiopia. *Journal of Arid Environments*, 73, 542-549.

[77] Yeshitela, K. and Bekele, T. (2002). Plant community analysis and ecology of afro-montane and transitional rainforest vegetation of Southwestern Ethiopia. *SINET: Ethiop. J. Sci.*, 25(2), 155-175.

[78] Zegeye, H., Teketay, D. and Kelbessa, E. (2006). Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. *Flora*, 201, 483-498.

[79] Zhang, H. and Chu, L. M. (2011). Plant community structure, soil properties and microbial characteristics in revegetated quarries. *Ecological Engineering*, 37, 1104-1111.
Table 1. List of woody species recorded in ANP dry deciduous woodland: Densities (individuals ha⁻¹), RD = relative densities (%), F = frequencies (%), RF = relative frequencies (%), BA = basal area (m² ha⁻¹), RBA = relative basal areas (%), IVI = importance value indices and A/F = abundance to frequency ratios

| Scientific name                                | Family name     | Abu. | Density | F   | RF  | RD  | BA   | RBA | IVI | A/F |
|------------------------------------------------|-----------------|------|---------|-----|-----|-----|------|-----|-----|-----|
| Acacia polyacantha Willd. subsp.               | Fabaceae        | 26   | 33.25   | 5.00| 1.51| 0.38| 0.03 | 0.38| 2.26| 5.20|
| Acacia seyal Del. var. Fistula                 | Fabaceae        | 133  | 158.50  | 10.00| 3.02| 1.80| 0.23 | 2.74| 7.56| 13.30|
| Acacia sieberiana Dc.                          | Fabaceae        | 8    | 10.67   | 3.00| 0.91| 0.12| 0.00 | 0.00| 1.03| 2.67|
| Anogeissus leiocarpa (DC.) Guill. & Perr.      | Combretaceae    | 46   | 28.67   | 17.00| 5.14| 0.33| 1.05 | 12.21| 17.67| 2.71|
| Balanites aegyptiaca Del.                     | Balanitaceae    | 33   | 33.00   | 10.00| 3.02| 0.37| 0.25 | 2.96| 6.35| 3.30|
| Combretum collinum Fres.                      | Combretaceae    | 1862 | 2285.92 | 55.00| 16.62| 25.96| 2.80 | 32.67| 75.25| 33.85|
| Combretum harotomannianum Schweinf.            | Combretaceae    | 285  | 352.08  | 19.00| 5.74| 4.00| 0.20 | 2.28| 12.02| 15.00|
| Combretum molle R.Br. ex G.Don                 | Combretaceae    | 1000 | 1202.42 | 32.00| 9.67| 13.66| 1.40 | 16.30| 39.62| 31.25|
| Dalbergia melanoxylon Guill. & Perr.          | Leguminosae     | 754  | 973.25  | 42.00| 12.69 | 11.05 | 0.37 | 4.32 | 28.06| 17.95|
| Dichroacthys cinerea (L.) Wight & Arn         | Fabaceae        | 618  | 823.08  | 25.00| 7.55 | 9.35 | 0.00 | 0.04 | 16.94| 24.72|
| Diospyros mespiliformis Hochst. ex A.DC.      | Ebenaceae       | 16   | 21.33   | 3.00 | 0.91 | 0.24 | 0.00 | 0.00 | 1.15 | 5.33|
| Fola-unidentified                              | -               | 5    | 2.08    | 2.00 | 0.60 | 0.02 | 0.04 | 0.49 | 1.11 | 2.50|
| Gardenia ternifolia Schumach. & Thonn.        | Rubiaceae       | 10   | 13.33   | 4.00 | 1.21 | 0.15 | 0.00 | 0.00 | 1.36 | 2.50|
| Grewia bicolor Juss.                           | Tiliaceae       | 2    | 3.00    | 1.00 | 0.30 | 0.03 | 0.01 | 0.08 | 0.41 | 2.00|
| Lamna fruticosa (Hochst. ex A. Rich) Engl.    | Anacardiaceae   | 237  | 277.50  | 30.00| 9.06 | 3.15 | 0.53 | 6.17 | 18.38| 7.90|
| Lonchocarpus laxiflorus Guill. & Perr.         | Fabaceae        | 9    | 5.92    | 7.00 | 2.11 | 0.07 | 0.09 | 1.11 | 3.29 | 1.29|
| Pterocarpus lucens Guill & Perr.               | Fabaceae        | 10   | 4.17    | 4.00 | 1.21 | 0.05 | 0.37 | 4.31 | 5.57 | 2.50|
| Sterculia setigera Del.                       | Sterculiaceae   | 8    | 7.92    | 4.00 | 1.21 | 0.09 | 0.08 | 0.90 | 2.19 | 2.00|
| Stereospermum kunthianum (Cham, Sandrine. Petit) | Bignoniaceae    | 3    | 3.42    | 3.00 | 0.91 | 0.04 | 0.01 | 0.09 | 1.03 | 1.00|
| Strychnos innocua Del.                        | Loganiaceae     | 3    | 4.00    | 1.00 | 0.30 | 0.05 | 0.00 | 0.00 | 0.35 | 3.00|
| Terminalia laxiflora Engl. Ex Diels           | Combretaceae    | 1594 | 2068.50 | 31.00| 9.37 | 23.49| 0.85 | 9.89 | 42.75| 51.42|
| Unknown                                       | -               | 19   | 21.08   | 4.00 | 1.21 | 0.24 | 0.06 | 0.67 | 2.12 | 4.75|
| Ziziphus spina–christi (L.) Willd.             | Rhamnaceae      | 46   | 61.67   | 5.00 | 1.51 | 0.70 | 0.00 | 0.02 | 2.23 | 9.20|
| Zonbelit- unidentified                        | -               | 323  | 410.33  | 14.00| 4.23 | 4.66 | 0.21 | 2.40 | 11.29| 23.07|

Table 2. Regeneration status of woody species in ANP dry deciduous woodland with their densities (individual ha⁻¹)

| Scientific name                                | Seedling | Sapling | Matured | Rege. status |
|------------------------------------------------|----------|---------|---------|--------------|
| Acacia polyacantha Willd. subsp.               |          |         |         |              |
| Acacia seyal Del. var. Fistula                 |          |         |         |              |
| Acacia sieberiana Dc.                          |          |         |         |              |
| Anogeissus leiocarpa (DC.) Guill. & Perr.      |          |         |         |              |
| Balanites aegyptiaca Del.                     |          |         |         |              |
| Combretum collinum Fres.                      |          |         |         |              |
| Combretum harotomannianum Schweinf.            |          |         |         |              |
| Combretum molle R.Br. ex G.Don                 |          |         |         |              |
| Dalbergia melanoxylon Guill. & Perr.          |          |         |         |              |
| Dichroacthys cinerea (L.) Wight & Arn         |          |         |         |              |
| Diospyros mespiliformis Hochst. ex A.DC.      |          |         |         |              |
| Fola-unidentified                              |          |         |         |              |
| Gardenia ternifolia Schumach. & Thonn.        |          |         |         |              |
| Grewia bicolor Juss.                           |          |         |         |              |
| Lamna fruticosa (Hochst. ex A. Rich) Engl.    |          |         |         |              |
| Lonchocarpus laxiflorus Guill. & Perr.         |          |         |         |              |
| Pterocarpus lucens Guill & Perr.               |          |         |         |              |
| Sterculia setigera Del.                       |          |         |         |              |
| Stereospermum kunthianum (Cham, Sandrine. Petit) |          |         |         |              |
| Strychnos innocua Del.                        |          |         |         |              |
| Terminalia laxiflora Engl. Ex Diels           |          |         |         |              |
| Unknown                                       |          |         |         |              |
| Ziziphus spina–christi (L.) Willd.             |          |         |         |              |
| Zonbelit- unidentified                        |          |         |         |              |

Amsalu Abich, IJSRM Volume 06 Issue 10 October 2018 [www.ijsrm.in] FE-2018-93
### Table 3. Summary of the stand variables of dry deciduous woodland in ANP

| Variables                                      | Mean DBH | Mean Hpre. | Mean Basal area m²ha⁻¹ | Mean Volume m³ha⁻¹ | Mean AGB - Eq. (9) kgha⁻¹ | Mean AGB - Eq. (10) kgha⁻¹ | Mean C stocks kgha⁻¹ | SD     | N     |
|------------------------------------------------|----------|------------|------------------------|--------------------|----------------------------|--------------------------|----------------------|--------|-------|
| Acacia polyacantha Willd. subsp.               | 25.3     | 6.7        | 1.3                    | Good               |
| Acacia seyal Del. var. fistula                 | 122.7    | 25.0       | 10.8                   | Good               |
| Acacia sieberiana Dc.                          | 10.7     | 0.0        | 0.0                    | Good               |
| Anogeissus leiocarpa (DC.) Guill. & Perr.      | 12.0     | 1.7        | 15.0                   | Fair               |
| Balanites aegyptica Del.                       | 28.0     | 0.0        | 5.0                    | Good               |
| Combretum collinum Fres.                       | 2114.7   | 75.0       | 96.3                   | Fair               |
| Combretum harotomannianum Schweinf.            | 326.7    | 11.7       | 13.8                   | Fair               |
| Combretum molle R.Br. ex G.Don                 | 1072.0   | 65.0       | 65.4                   | Good               |
| Dalbergia melanoxylon Guill. & Perr.           | 958.7    | 0.0        | 14.6                   | Fair               |
| Dichrostachys cinerea (L.) Wight & Arn         | 822.7    | 0.0        | 0.4                    | Fair               |
| Diospyros mespiliformis Hochst. ex A.DC.       | 21.3     | 0.0        | 0.0                    | Good               |
| Fola-unidentified                               | 0.0      | 0.0        | 2.1                    | Not regenerated    |
| Gardenia ternifolia Schumach. & Thonn.         | 13.3     | 0.0        | 0.0                    | Good               |
| Grewia bicolor Juss.                           | 1.3      | 1.7        | 0.0                    | Poor               |
| Lannea fruticosa (Hochst. ex A. Rich) Engl     | 260.0    | 0.0        | 17.5                   | Fair               |
| Lonchocarpus laxiflorus Guill. & Perr          | 1.3      | 1.7        | 2.9                    | Poor               |
| Pterocarpus lucens Guill & Perr.               | 0.0      | 0.0        | 4.2                    | Not regenerated    |
| Sterculia setigera Del.                        | 6.7      | 0.0        | 1.3                    | Fair               |
| Stereospermum kunthianum (Cham, Sandrine. Petit) | 1.3    | 1.7        | 0.4                    | Fair               |
| Strychnos innocua Del.                         | 4.0      | 0.0        | 0.0                    | Good               |
| Terminalia laxiflora Engl. Ex Diels            | 2022.7   | 18.3       | 27.5                   | Fair               |
| Unknown                                        | 17.3     | 1.7        | 2.1                    | Fair               |
| Ziziphus spina–christi (L.) Willd.             | 60.0     | 1.7        | 0.0                    | Good               |
| Zonbelit- unidentified                         | 392.0    | 8.3        | 10.0                   | Fair               |

| Amsalu Abich, IJSRM Volume 06 Issue 10 October 2018 [www.ijsrm.in] | FE-2018-94 |
SD: standard deviation; N: number of sample trees and Hpre: predicted total height

**Figures**

Figure 1. Diameter class distribution of dry deciduous woodland in ANP, North West Ethiopia (1 < 3.5; 2 = 3.5-5.9 cm; 3 = 6-10.9 cm; 4 = 11-15.9 cm; 5 = 16-20.9 cm; 6 = 21-25.9 cm; 7 = 26-30.9 cm and 8 = 31-35.9 cm; 9 = 36-40.9 cm and 10 > 41 cm DBH classes)
Figure 2. Population structure of selected woody species in ANP dry deciduous woodlands, North West Ethiopia
Figure 3. Regeneration status of dry deciduous woodland in ANP, North West Ethiopia (1: diameter < 3.5 cm (seedling); 2: diameter between 3.5 and 10 cm (sapling) and 3: diameter ≥ 10 cm (matured trees))

Figure 4: Map showing the study site, Alitash National Park, North west Ethiopia