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STAND STATUS AND YIELD ECONOMICS OF *ACACIA SENEGAL* (L) WILD AT ABDERAFI, NORTH WESTERN ETHIOPIA

Tatek Dejene[1], Omarsherif Mohamed[1], and Haile Adamu[2]
[1]*Ethiopian Institute of Agricultural Research, Forestry Research Center, P.o.Box 30708 Addis Ababa, Ethiopia*
[2]*Ethiopian Institute of Agricultural Research, Debre Zeiet agricultural Research Center, P.o.Box, 32 Debre Zeiet, Ethiopia*

ABSTRACT

Acacia senegal (L) Wild, is an important indigenous multipurpose tree species known for its gum arabic product. The species has diverse ecological and economic benefits. Despite its benefits, information on its stand status and yield potential is lacking particularly in the northern Ethiopia. Here we studied the stand status and yield economics of *A.senegal* at Abderafi, north western Ethiopia. A total of 52 sample plots of size 20 x 20 m were used for counting matured trees at 300m intervals by laying parallel transects with 500m regular interval. Smaller sample plots of size 5 x 5 m nested in the center of each plot were used for measuring saplings. Besides, the gum yield ha^{-1} $year^{-1}$ was estimated by multiplying the mean *A.senegal* stem density ha^{-1}. The result revealed that *A.senegal* is the dominant tree species constituted 70.70% of the vegetation with the mean density of 356 stems ha^{-1}. The population structure of *A.senegal* showed an inverted J-shape suggesting stable and healthy population. Also, the mean number of *A.senegal* trees from which gum arabic can be produced with DBH $\geq$ 4cm found 211stems ha^{-1} indicating adequate number of matured trees for gum production. Accordingly, 190 to 422Kg ha^{-1} $year^{-1}$ of gum arabic could be harvested that could worth $US ca 950 to 2110 ha^{-1} $year^{-1}$. More interesting, the regeneration status of A.senegal trees in the stand showed a huge potential to enhance the sustainable utilization of gum arabic from the natural stand in the study area.
Keywords: Abderafi, *Acacia senegal*, Dry land, Regeneration, and yield

INTRODUCTION

Dry land forests in Africa represent important resource base for livelihoods and economic development (Suderland and Ndoye, 2004; Shackleton et al., 2008; Paumgarten and Shackleton, 2009). If managed wisely they have the capacity to provide a perpetual stream of income and subsistence products, while supporting other economic activities through ecological services and functions (Lemenih and Teketay, 2004; Chikamai et al., 2009).
The Combretum–Terminalia and Acacia–Commiphora deciduous woodlands as dry forests form the largest vegetation cover in the Horn of Africa and the Sudano-Sahelian zone (Friis, 1992). These forests mainly are composed of various species of Acacia, Boswellia and Commiphora that are known to produce commercial plant gums and resins (Lemenih and Teketay, 2003). Moreover, the wood and non-wood products from these species play a significant role in the livelihood of many people in the dryland regions of Africa.
In Ethiopia, dry forest is the largest remaining forest type that currently covers 55 M ha (WBISPP, 2004). These forests are rich in Acacia, Boswellia and Commiphora species (Lemenih, 2005; Abiyu et al., 2010; Eshete, 2011), that provide the important export commodities such as gum arabic, frankincense and myrrh (FAO, 1995; Lemenih, 2005; Lemenih and Kassa, 2010; Abiyu et al., 2010; Eshete, 2011). These forests, however, are suffering from severe degradation due to anthropogenic pressures (Lemenih et al., 2007; Eshete et al., 2005; Abiyu et al., 2010). They are continuously shrinking by the expansion of agricultural lands and human settlement (Lemenih et al., 2007).
Acacia senegal (L) willd (family Leguminosae, Mimosoidea) is one of the promising multipurpose tree species in arid and semi-arid areas of Ethiopia, which have various socioeconomic and ecological benefits (Bekele et al., 1993). The natural stands of *A.senegal* found in the Acacia-Commephora woodlands in the western and southern lowlands of the country; West Tigray, Amhara, Benshangul

**Corresponding author:* e-mail: tdejenie@yahoo.com

Gumz, Shoa, Afar plane and Borena zone of Oromia (Bekele et al., 1993). It grows mainly in the low-lying woodlands and wooded grasslands, on steep rocky slopes, lava flows or in sandy river valleys at an altitude range between 600–1800 m a.s.l. (Bekele et al., 1993; Fitchel and Admassu, 1994). The survival of the species in such areas makes it a key stone species that can provide plant cover and plays an important role in desertification control. Apart from these, the species is highly valued for gum arabic production (Lemenih and Teketay, 2004) in which the gum is exudates from trunks, branches and twigs. However, in recent years, the forests that possessed *A.senegal* tree species, in the dryland part of Ethiopia are subject to increasing pressure (Lemenih et al., 2007).

Rapid population growth from natural birth as well as migration, clearance for cropland expansion, overgrazing and intensification of gum-resin extraction are some of the major factors driving deforestation and degradation of dry forests in Ethiopia (Eshete et al., 2005; Lemenih et al., 2007; Abiyu et al., 2010).

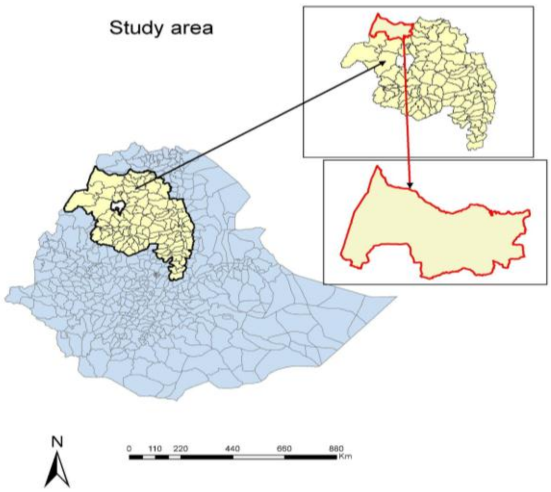
Unfortunately, in spite of its wide distribution and the increasing pressure, knowledge on the current status *A.senegal* is lacking. Moreover, the facts that the availability of increasing demand and attractive international market with increasing price for gum arabic, and the considerable socio economic benefits from the sector and availability of insufficient information about the distribution of the resource to be able to assess the potential for gum collection has generated considerable interest in the assessment of the potentials for the resource availability in North Gondar zone. The objectives of this paper were thus to (i) quantify the population structure and density of *A.senegal*; (ii) analyze the natural regeneration status of the species; and (iii) assess the possibility of commercial harvesting of gum arabic from the natural stand and see its economics.

MATERIALS AND METHODS

Study area

The study was conducted in Abderafi wereda of north Gondar zone, north-western Ethiopia located between latitude 13.7333° N and longitude 36.45°E (Fig. 1). It covers an area of 8148.12km^2 with an altitude ranging between 950m to 1100m a.s.l. The area receives a uni-modal rainfall, ca 885mm, from June to September. The annual mean minimum and maximum temperatures are 19.1 ^{0}C and 35.6 ^{0}C, respectively (Anonymous, 2005). Soils are predominantly black and have vertic properties (Anonymous, 2005). The district is inhabited by a total population of 32,618 (CSA 2007), most of which are sedentary agriculturists who practice a mixed crop-livestock production system (Anonymous, 2005). The vegetation zone of the study area is categorized under the Combretum–Terminalia or Broad-Leaved Deciduous Woodland (Eshete, 2002; Ogbazghi et al., 2006). About 70% of the district is covered with woodlands (Anonymous, 2005) but land cover/land use is changing rapidly.

Fig 1 Location of Abderafi district, the study area



Data collection and analysis

In order to obtain a contemplation of the status of the resource base, a reconnaissance survey was conducted across the woodland of the study area. Then a representative site selected to investigate the resource status of A.senegal. A total of 52 sample plots of size 20 x 20 m were laid at regular interval along parallel transects with smaller sample plots of size 5 x 5 m nested in the center of each plot for regeneration count. The transect line and the plots were laid with 500m and 300m intervals respectively. Diameters at breast height (DBH) of individual trees were taken for those individual trees with the heights of 1.5 m or more using diameter tape. For individuals with a height of less than 1.5 m, their basal diameters were measured using caliper (Eshete et al., 2005). In the regeneration plots the numbers of *A.senegal* seedlings encountered were counted. Then the status of *A.senegal* stands was examined based on the population structure, density of the species, and regeneration status.

The population structure of the species is depicted using frequency histogram of diameter classes and number of regeneration (Eshete et al. 2005). For the purpose all individuals of the species encountered in the quadrats were arbitrarily grouped by 4–cm diameter classes (0 – 4 cm, 4 – 8 cm, 8 – 12 cm, 12 – 16, 16 - 20…32 – 36 and >36). Frequency was obtained by counting the number of plots in which the species was recorded (Kent and Coker, 1994; Tadesse, 2003). Whereas density was calculated by the number of individuals of a species per unit of area (Eshete et al., 2005) using equation 1

$$\text{Density/ha} = \left(\sum_{i=1}^{n} d/n\right) * 25 \quad (1)$$

Where: d = is stem number/plot and n = number of plots

Gum yield (kg) per hectare and year was calculated by multiplying the mean A.senegal stem density per hectare calculated above with the mean yield (kg/tree/year) (equation 2). The latter was obtained from previous studies for the same species (Duke, 1983).

$$Gum\ yield/ha \cdot yr = \left(\sum_{i=1}^{n} d/n * 25\right) * y(kg/tree \cdot year) \quad (2)$$

Where: d = is stem density/plot, n= is number of plots and y =is gum yield per tree and year.

RESULT AND DISCUSSION

Species composition and tree density

A total of nine tree species (Table 1) were identified in association with *Acacia senegal* in the woodland of the study area. Compared to similar vegetation types in the nearby district in Ethiopia, the species composition of the study area is lower. For instance in Metema woodland it is found that 34 tree species in association with *Boswellia papyrifera* tree species (Eshete, 2002), the key frankincense producer tree species. However, it is more or less comparable with other vegetation types as was reported for the vegetation in the upper rift valley woodlands of Ethiopia (6 species, Aragaw et al., 1999 ; Getachew, 1999) and the wood-lands of Tigray (13 species Gebrehiwot, 2003).

There were more *A.senegal* tree species in the woodland of the study area followed by Acacia seyal (Table 1). *A.senegal* had the highest density of 356 individual stems ha^{-1} thus accounting for 70.70% of the stem composition of the study woodland in terms of tree density. This number is higher as compared to some similar vegetation types in Ethiopia. For example Lemenih et al., 2003 indicated that 59.6 ha^{-1} individual of *A.senegal* trees found in the Liben zone of Somali region. By and large the density of *A.senegal* tree species in the study woodland is an indication of the availability of more individuals of *A.senegal* trees for gum production though the optimum density that would ensure sustainable supply of gum is not known. The densities of associated trees species were presented in table 1.

Table 1 Density (Individuals ha^{-1}) and Percentage of tree species in the study woodland

Species name	Density ha^{-1}	Percent (%)
Acacia senegal	356.25	70.70
Acacia seyal	50.78	10.08
Diorostachys ginerea	29.69	5.89
Anogeissus leiocarrpa	8.59	1.71
Grewia bicolor	20.31	4.03
Grewia ferruginea	7.03	1.40
Balanytes aegyptica	14.84	2.95
Stereospermum kunthianum	0.78	0.16
Dalbergia melanoxylon	17.19	3.41

The average density of *A.senegal* trees with diameter ≥ 4cm (number of mature individuals) is 211 stems ha^{-1} thus accounting 58.61% of A.senegal stems of the study woodland (Table 2). This number is comparable with the harvestable size of *A.senegal* trees in the central rift valley vegetation of Ethiopia which is ranging from 12 – 209 ha^{-1} with the inclusion of individuals at diameter class of greater than or equal to 2cm (Yebenene, 2006). However in our estimation we did not include those individuals with the diameter ≥ 2cm. Yet the stand of *A.senegal* in the study woodland has sufficient number of trees for launching commercial harvesting of gum arabic in the study area. Thus, it is encouraging to start the gum arabic business in the study area.

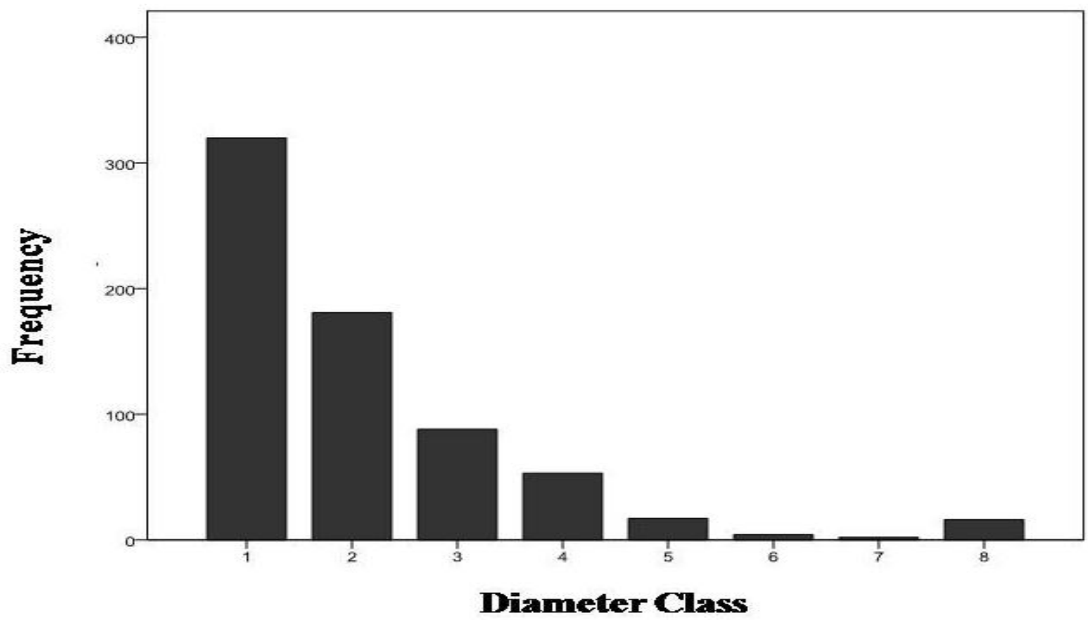
Table 2 Density (Individuals ha^{-1}) and Percentage of *Acacia senegale* tree species in different diameter classes

DBH Class	Density ha^{-1}	Percent (%)
2 - 5cm	166.41	46.6
6-10cm	120.32	33.7
11-15cm	51.56	14.4
16-20cm	14.06	3.9
>21	4.69	1.3

Population structure

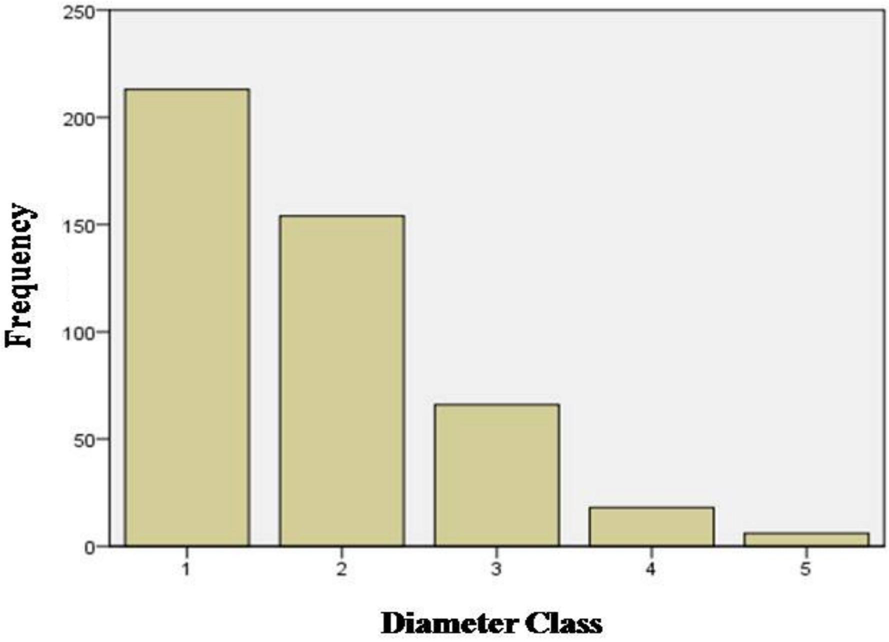
Information on population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence, used to forecast the future trend of the population of that particular species (Peters, 1996). The result of the present study indicated that the diameter class distribution of the whole vegetation of the study woodland exhibits a stable and growing population structure (Figure 1) where the majority of the species had the highest number of individuals at lower diameter with gradual decrease towards the higher diameter classes. This suggests good reproduction and recruitment potential of the vegetation (Senbeta and Teketay, 2001; Gebrehiwot, 2003). However, this pattern does not depict the general trends of the recruitment processes of a given species.

Fig 2 Population structure of the whole vegetation of the study woodland at Abderafi



Analysis of population structures of individual species could provide more realistic and specific information for conservation measures. Fortunately the population structure of A.senegal was similar with that of the structure of the whole vegetation (Fig 2). An inverted J shaped structure was exhibited by *A.senegal* representing higher number of individuals in the lower diameter class and gradual decrease in the frequency of higher diameter class exhibiting a stable and growing population structure which is suggesting good reproduction and recruitment potential of *A.senegal* in the study area (Senbeta and Teketay, 2001; Geberhiwot, 2003).

Fig 3 population structure of A.senegal in the study woodland of Abderafi



Regeneration status

According to Aragaw et al., 1999 and Geberehiwot, 2003, density of seedlings would indicate the status of the regeneration of a given population of trees. In this study, out of the 9 tree species only 4 were found to be in a good regeneration status (table 2). Of these species, *A.senegal* showed good regeneration contributing more than 54.48% to the total density of regeneration followed by *A.seyal* (19.84%), *Grewia bicolor* (8.17%) and *B.aegyptica* (5.84%). The good regeneration status of *A.senegal* in the study woodland might be the abundant seed production and soil seed bank formation of the species (Teketay 1996) or the thorny nature of the species which help the seedlings to escape the browsing effects of the cattle (Aragaw et al., 1999; Getachew, 1999). However, the result of regeneration in general indicated the sustainability and possibilities of future commercialization of gum arabic from the natural stand of *A.senegal* trees in the study areas.

Table 3 Frequency, density (ha^{-1}) and percentage representation of seedlings of tree species in the woodland

Species	Seedling density ha^{-1}	Percent (%)
Acacia senegal	140	54.48
Acacia seyal	51	19.84
Diorostachys ginerea	12	4.67
Grewia ferruginea	7	2.73
Balanytes aegyptica	15	5.84
Dalbergia melanoxylon	1	0.39
Anogeissus leiocarrpa	9	3.51
Grewia bicolor	21	8.17
Stereospermum kunthianum	1	0.39

Potential gum yields and its economics

As there is no information on gum yield of *A.senegal* from the natural stand of the study area, gum yield (kg) per hectare and year was estimated by multiplying the mean stem density of *A.senegal* per hectare with the mean yield (kg/tree/year) as the yield was obtained from previous studies (Duke, 1983). According to Duke (1983), annual yields from young *A.senegal* trees may range from 188 to 2856 g/tree (average 0.9kg), from older trees, 379 to 6754 g/tree (average 2kg).

The mean *A.senegal* stem density was 211 stems/ha (Table 2) with a mean gum production of 0.9 to 2kg/tree/yr, the mean gum arabic yield expected was ca. 190 to 422Kg/ha/year. This estimation included only those individuals of *A.senegal* trees with the diameter ≥ 4cm. Such good yield suggested that the possibilities of future commercialization and the sustainable production of gum arabic from the natural stand of *A.senegal* trees in the study areas. Accordingly, the price for gum arabic is $US 5000 per ton (FAO, 1995), about ca. $US 950-2110 ha^{-1} $year^{-1}$ could be obtained from *A.senegal* stand of the study woodland.

CONCLUSIONS

From the preset study it is understood that the vegetation in Abderafi Wereda shown to have high potential for gum arabic production from the natural stand of *A.senegal*. The result indicated that the population status of A.senegal is found to have higher density and good regeneration suggesting stable and healthy population. Moreover, the diameter distribution of individual trees of *A.senegal* indicated most of them are matured enough to be tapped signifying there is a possibility to start commercial harvesting of gum arabic if appropriate management activities are applied. Thus this study could be taken as baseline information for planning future economic development plan in the study area through considering the multiple uses of the species.

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