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Full Length Research Paper

Assessment of vegetation characteristics and production of *Boswellia papyrifera* woodlands in north western lowlands of Ethiopia

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The dry land woodlands in Ethiopia possess diverse tree species that are known for their valuable non-timber forest products (NTFPs). The study was carried out in three districts namely Kafta Humera (Adi-Goshu), Metema (Lemlem-Terara) and Sherkole (Gemed). A total of 24 species were recorded across the three study sites. The average number of stems per hectare across the sites was 276 and the average basal area was estimated to be 9.33 m^2 ha^{-1}. Based on their population structures, the woodland species can be categorized as Group I contained species with a progressively declining numbers of trees with increasing diameter in Gemed site and Group II was comprised of both Adi-Goshu and Lemlem-Terara sites with a bell-shaped or irregular distribution. In addition, *Boswellia papyrifera* is known to occur in various parts of Ethiopia including Tigray, Amhara and Benshangul Gumuz regions. Therefore, the total production of gum olibanum and gum arabic in the three sites was recorded approximately 12,112.98 tons with the net income of 129.34 million Birr since 1999. Therefore, Ethiopia will be more benefited from the export of these products, provided efforts are made to develop and manage these resources in a sustainable way.

Key words: *Boswellia papyrifera,* Ethiopia, gum and resin, production, woodlands.

INTRODUCTION

Ethiopia is endowed with different vegetation cover in dry land areas. *Combretum-Terminalia* woodlands and Acacia-Commiphora woodlands are the two dominant vegetation types that cover large parts of the dry land areas in Ethiopia (Eshete et al., 2011). It is geographically distributed in drier parts of Africa from Nigeria in the west to Eritrea and Ethiopia in the East, being dominant in Ethiopia, Eritrea and Somalia (White, 1983; Ogbazghi, 2001). *Boswellia* in Sudan is also common savanna tree species as a pure stand or mixed with other species like *Sterculia setigera*, *Combretum* spp., *Terminalia* and *Commiphora* species on slopes and land hills (Salih et al., 2002; Adam, 2003). Forests provide a great variety of products and services to human kind. The major economic value of forests comes from wood of trees, used or traded as lumber, plywood, fuel wood or charcoal. Other economic importance includes food, medicines, fodder for livestock, natural gums, etc. The latter collectively called non-timber forest products (NTFPs) (Ros-Tonen et al., 1995). The dry land woodlands in Ethiopia possess diverse tree species that are known for their valuable NTFPs of local, national and international significance. One of the well-known species in this regard is *Boswellia papyrifera*. The species is a deciduous multipurpose tree with the potential for economic development and desertification control (Lemenih and Teketay, 2003, 2004). This species is found in the Combretum-Terminalia (broad-leaved) deciduous woodland and wooded grassland usually dominant on steep rocky slopes, lava flows or sandy

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valleys, within the altitudinal range of 950-1800 m above sea level altitude (Eshete et al., 2005).

In Ethiopia, *B. papyrifera* provides the widely known and traded frankincense that accounts more than 80% of the export revenues that the country is earning from gum and resin resources (Eshete et al., 2011; Eshete et al., 2012). Ethiopia is the leading producer and exporter of frankincense and with significant local and national economic benefits (Eshete et al., 2012). *B. papyrifera* provides several goods and services such as poles, timber, fodder, nectar and gum, which is useful for traditional medicine, religious ritual and income generation (Lemenih and Teketay, 2003). The major use of the species is the production of frankincense or “olibanum” by tapping the stem (Tucker, 1986), and in the Horn of Africa it has an important application in local communities for medicinal uses and during religious and coffee ceremonies (Coppen, 1995).

Therefore, woodlands are under heavy pressure: they are cleared for fire wood, expansion of cash crops and new settlements and apparently are shrinking overtime. Household income from various woodland products (gum and resin, fire wood, etc) are not compared through cost benefit analyses/opportunity costs. Additionally, dry land plantation development by introducing locally adaptive species to buffer the gum and resin bearing woodland species is not well studied and practiced. Hence, the objective of this study is to assess the vegetation characteristics and production and income of gum and resin products and the widely open opportunity to local farmers.

METHODOLOGY

Site description

The study sites for the present study were located in three selected districts/woredas (Kafta Humera, Metema and Sherkole) in the western lowlands of Ethiopia. The sites were gum and resin tapping concession sites owned by the Natural Gum Processing and Marketing Enterprise.

Kafta Humera district is located in the north-western Ethiopia and in the western part of Tigray Regional State within an altitude range of 560-1849 m a.s.l. The mean total rainfall ranges from 400-650 mm. The mean maximum temperature varied between 33ºC in April and 41.7ºC in May, while the mean minimum temperature is between 17.5ºC in August and 22.2ºC in July. The rainy season of the study area is from June to September. The remaining 8-9 months between October and May/June is dry and hot. The vegetation communities in the districts include Acacia-Commiphora, Combretum-Terminalia and dry evergreen woodlands (Eshete et al., 2011).

Metema district is located north western Ethiopia in the Amhara regional state. The total annual rainfall ranges from 700-900 mm with minimum annual temperature ranged between 22 and 28ºC and mean maximum annual temperature between 35 and 45ºC. The agroecological zone of the district is classified as semi-arid and the elevation is ranges between 550 and 1600 m above sea level. The site is one of the natural ecosystems of *B. papyrifera* where its population is found in a good stock and commercial tapping of incense is widely practiced (Eshete et al., 2012).

Sherkole district is located in Benshangul Gumuz regional state, western Ethiopia with in an altitude range between 500 and 1000 m a.s.l. The mean total rainfall varies from 900-1200 mm with mean annual temperature ranging in between 10.8-42ºC (Figure 1).

Tree sampling

Trees were inventoried from the circular plots with 15 m radius. For the aboveground biomass estimation, field transect of 200 m distance of circular sampling method was applied (Hairiah et al., 2001). All tree diameters in the larger plot were measured at breast height (DBH) (1.3 m aboveground level) and at stump height (DSH) (30 cm aboveground level) (Mac Dicken, 1997). In addition, the total tree heights (to the top of the crown) were measured using Hypsometer. In the plot, local names of trees were recorded and later scientific names were identified from “Useful Trees and Shrubs for Ethiopia” (Bekele, 2007).

Data analysis

Both primary (vegetation characterstics) and secondary (gum and resin production) data were analyzed using descriptive statistics. The result was illustrated in the form of table and graph using Microsoft Excel.

RESULTS AND DISCUSSION

Vegetation characteristics

A total of 24 species were recorded across the three study sites. A range of different plant characteristics such as DBH and height were also identified. The average number of stems per hectare across the sites was 276 and the average basal area was estimated to be 9.33 m^2 ha^{-1}. The highest number of plant species (15), number of stems (359 ha^{-1}) and BA (11.32 m^2 ha^{-1}) were identified and estimated for the Lemlem Terara site and the lowest for Adi Goshu (number of species, 13; number of stems, 224 ha^{-1} and BA, 7 m^2 ha^{-1}). As compared with other two sites, the average DBH (19.28 cm) and height (7.12 m) of the woody species were larger at Gemed site than Adi Goshu (18.81cm and 6.22 m) and Lemlem Terara site (18.77cm and 6.49 m). In Lemlem terara site, the

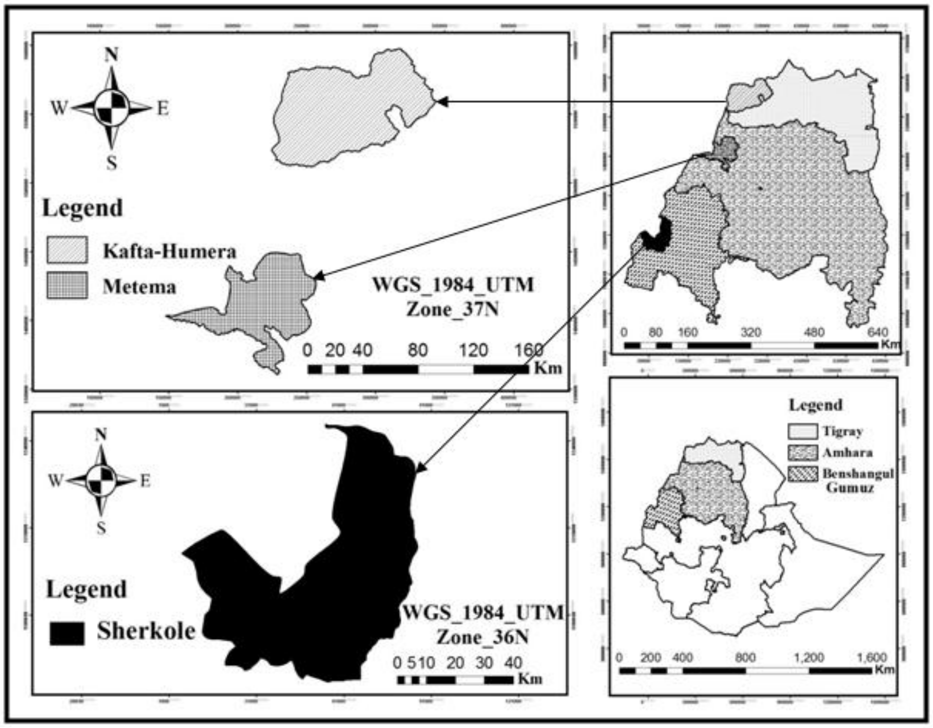

Figure 1. Map of the study sites (Kafta Humera, Metema and Sherkole Districts).

computed average above ground biomass, using the equation developed by Brown (1997), was the highest (54.94 t ha^{-1}) than in Gemed (51.73 t ha^{-1}) and in Adi Goshu site (33.43 t ha^{-1}).

$$AGB = 0.139\ DBH^{2.32}$$

Where, AGB = above ground biomass (kg/tree)
DBH = diameter at breast height (cm)

The population structure of the entire woodland showed higher stem densities in the middle diameter classes and progressively declining stem densities with increasing diameter classes at both sites of Adi-Goshu and Lemlem-Terara (Figure 2). Based on their population structures, the woodland species can be categorized into two diameter class distribution patterns. Group I contained species with a progressively declining numbers of trees with increasing diameter in Gemed site. Group II was comprised of both Adi-Goshu and Lemlem-Terara sites with a bell-shaped or irregular distribution.

The structure of wood land forest is consistent with other studies on dry forests. For example, the observed range of basal area (BA) is comparable with the ranges (3.84-10.36 m^2 ha^{-1}) reported by Singh and Singh (1991) and 6.58-23.21 m^2 ha^{-1} reported by Jha and Singh (1990) for several dry tropical communities in India. Similarly, the overall population structure of woodlands can help understand the status of the forest stand (Tesfaye et al., 2010; Worku et al., 2012). Reverse J-shaped distributions such as those shared by Group I species in the Gemed site indicate more or less a healthy or stable regeneration. In contrast, bell-shaped distributions (Group II species of Adi-Goshu and Lemlem-Terara sites) suggest hampered regeneration (Belayneh and Demissew, 2011). Similar population structures of *B. papyrifera* were reported from Eshete et al. (2005), Lemenih et al. (2007) and in Eritrea (Ogbazghi, 2001). Several studies in Sudan Jebel Marra, West Sudan by Khamis (2001) and Adam (2003) have also reported unstable populations of *B. papyrifera* in different sites. This is an indication that the species is under threat not only in the study area but also in several geographical locations in the region of its distribution due to continuous tapping for incense production, human induced fire, overgrazing and climatic anomalies.

Livestock and other wildlife are mostly browsers and damage the barks of woody perennials for example, *Boswellia* and *Commiphora* trees leading to outbreak. Exploitation of the vegetation in the silvopastoral areas also included cutting of woody plants, both illegally by people from urban areas and “legally” by villagers in search of extra incomes, together with exploitation of *Boswellia* and *Commiphora* trees as a wood reserve in times of scarcity. As a result, the natural resources of the silvopastoral areas were also increasingly overexploited. A possible explanation of the increasing pressure of livestock on silvopastoral areas may be the

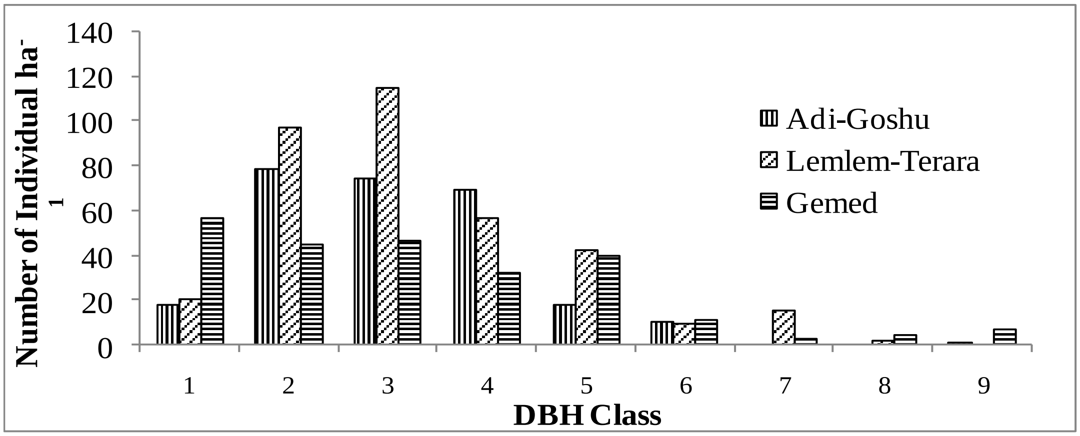

Figure 2. Diameter size class distribution of the entire woodlands. Diameter class in cm: class 1=5-10, 2=10-15, 3=15-20, 4=20-25, 5=25-30, 6=30-35, 7=35-40, 8=40-45 and 9>=45.

Table 1. Yield and Income of Gum Olibanum and Gum Arabic.

Year	Kafta-Humera		Gondar		Assosa	
	Yield (Tons)	Income (Million Birr)	Yield (Tons)	Income (Million Birr)	Yield (Tons)	Income (Million Birr)
1999	772.72	1.77	151.97	0.35	-	-
2000	856.18	3.73	267.32	1.16	-	-
2001	878.30	4.56	439.18	2.28	-	-
2002	529.29	2.85	575.62	3.10	-	-
2003	229.74	1.81	654.60	5.15	-	-
2004	149.73	0.96	835.53	5.35	-	-
2005	111.44	0.83	686.02	5.14	3.04	0.02
2006	28.35	0.25	360.61	2.29	1.68	0.01
2007	39.91	0.39	714.25	3.90	79.01	0.43
2008	147.46	1.37	613.60	4.31	110.22	0.86
2009	201.61	3.51	557.01	10.41	75.93	1.38
2010	205.64	5.70	764.28	21.89	290.87	7.13
2011	210.16	7.93	243.74	6.50	327.99	12.02

Source: Natural Gum Processing and Marketing Enterprise, 2012.

disappearance of the palatable, preferred species (both woody plants and herbs) and an increase in unpalatable, less preferred species. Moreover, herders were opening up woodland for agricultural development resulting in vegetation destruction (Hassan et al., 2011).

Despite indications of hampered regeneration, most of the species in Group II had a considerable number of individuals in the middle diameter classes that could be managed sustainably to improve their regeneration and produce gums and resins, in addition, the potential of carbon sequestration would enhance. Comparison of the ranges of tree diameters with respect to the above ground biomass accumulation revealed that tree species with lower range of diameter possess more density but accumulated less biomass. On the other hand, trees having bigger diameters were few in number but accumulated more biomass. Therefore, an inverse relationship was seen between tree density and DBH whereas a direct relationship was observed between the above ground biomass and DBH. In this regard, the findings from Terakunpisut et al. (2007) and Juwarkar et al. (2011), indicate similar results with the current study.

Yield of gum and resin

Long-term data (since 1999) on production of gum olibanum and gum arabic was obtained from Natural Gum Processing and Marketing Enterprise (NGPME) (Table 1). Accordingly, since 1999, in Kafta Humera the maximum yield in gum production was recorded in 2001, that is, 878.30 tons (4.57 million Birr) whereas the minimum yield obtained was 28.35 tons (0.25 million Birr), in 2006. On the other hand, the highest gum yield in Gondar (Metema, Merab Armachoho, Tsegede and Aelfa Takusa districts) was attained 835.53 tons (5.35 million Birr) in 2004 and the lowest was 151.97 tons (0.35 million Birr) in 1999. In Assosa site (Sherkole, Sirba Abay and Mao Komo districts) the collection was began in 2005. The maximum yield recorded was 327.99 tons (12.02 million Birr) in 2011 while the minimum was 1.68 ton (0.01 million Birr) in 2006. Therefore, the total production of gum olibanum and gum arabic in the three sites was recorded approximately 12,112.98 tons with the net income of 129.34 million Birr since 1999.

According Tilahun et al. (2007) showed that the *B. papyrifera* woodland yield 127 kg ha^{-1} $year^{-1}$ for the exclosure land and 84.5 kg ha^{-1} $year^{-1}$ for the free grazing land. In addition the annual frankincense yield at tree level yielded on the average of 471.5 g $tree^{-1}$ in Tigray region (Tilahun et al., 2012) and according Eshete et al. (2012) yield per tree per year largely varied and ranged from 41 to 1829 g. This resin yield increased with tapping intensity.

Value and functions of gum and resin

Ethiopia is one of the major producers and exporters of the natural gum and resins. Oleo-gum resins, such as frankincense, have been items of the great historical commerce in the Horn of Africa, in general, and in Ethiopia, in particular, (Fitiwi, 2000; Lemenih and Teketay, 2003). *B. papyrifera* is known to occur in various parts of Ethiopia including Tigray, Amhara and Benshangul Gumuz regions (Demissew, 1993). In addition to this there are different acacia species (*Acacia seyal, Acacia tortilis, Acacia abyssinica*, etc) which are the main source of the different gum and resin products. Tapping of frankincense provides not only considerable cash income and employment opportunity (Gebremedhin, 1997; Lemenih and Teketay, 2003), but also fetches valuable foreign currency.

B. papyrifera grows on dry and rocky sites where other tree species often fail (Gebrehiwot et al., 2005). In northern Ethiopia, where the majority of the soils (60-80%) are about 20 cm deep (Hurni, 1988), *B. papyrifera* trees are found on steep slopes with an average gradient of 30-40%. The species makes economic use of the marginal areas on which other species cannot grow. In these sites it provides plant cover and produces high biomass and hence protects the soil and provides shade. When Planted this species can economically and socially improve the overall value of a degraded area.

Incense collection offers off-farm employment for many farmers. In western Tigray alone, annually about 7000 seasonal laborers are employed; among which 31% are women. Men are mainly involved in tapping and collecting incense from the forest while women undertake sorting and grading of the product. A tapper can collect about 10-15 quintals of incense per annum and receives a net income of US $ 100 to 150 (Berhe, 1997). Women accrue an average income of US$ 16 per month (Gebremedhin, 1997).

Incense is being burnt in many churches in worldwide and used as oil extract for a number of applications, such as modern perfumery, traditional medicine, pharmaceuticals, fumigation powders, fabrication of varnishes, adhesives, painting, and chewing gum industries. It also gives a flavor in food industry, for example, bakery, milk products, different alcoholic and soft drinks (Tucker, 1986; Coppen, 1995; Deffar, 1998).

CONCLUSION AND RECOMMENDATION

On top of this the farmers around the woodland area would be beneficial for both non-timber products (gum and resin) and the income from the carbon trading; and this increases the farmer's adaptive capacity through diversified livelihoods. Incorporation of available knowledge on the production and management of gums and resins should be seriously considered for managing the woodland resources. Hence, appropriate policies should exist and be implemented to use these resources on a sustainable basis, both locally and nationally.

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