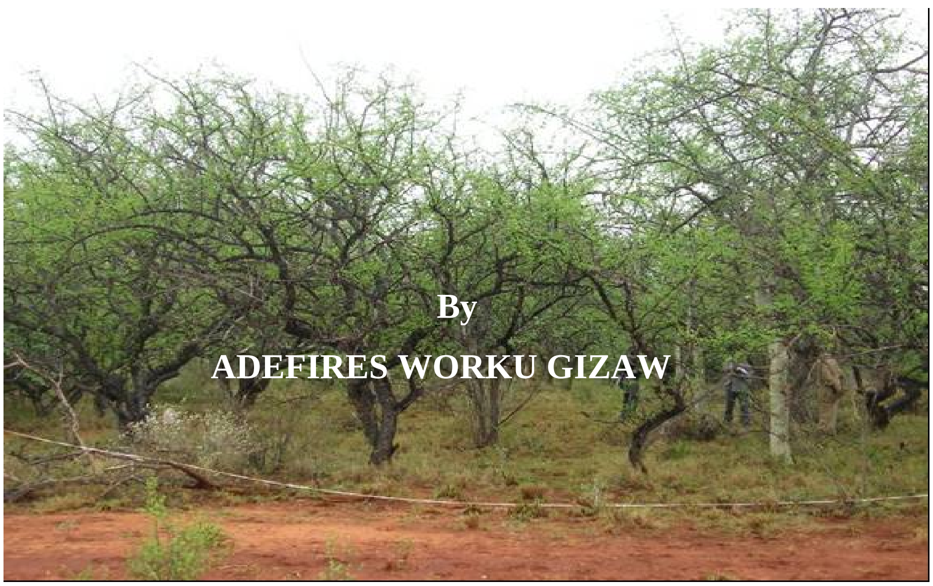
ADDIS ABABA UNIVERSITY, BIOLOGY DEPARTMENT

SCHOOL OF GRADUATE STUDIES

Population Status and Socio-economic Importance of Gum and Resin Bearing Species in Borana Lowlands, southern Ethiopia



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Abstract

A study on the population status (species composition, diversity, abundance, dominance, importance value, structure, regeneration) and socio-economic importance, mainly the roles in the livelihood of pastoral and agro-pastoral community, of gum and resin bearing woody species was carried out in Borana drylands, southern Ethiopia. The study was conducted at Arero and Yabello districts at several study sites, which were selected on the bases of the presence of good populations of the study species. A total of 75 sample quadrats, measuring 400 m^2 each and 300 m apart, were established in the woodland vegetation of the two districts using systematic sampling techniques. Quadrats were distributed in east west compass directions along established transect lines located at approximately 500 m from each other. In each quadrat, vegetation data such as identity, abundance, DBH, height, and counting of seedlings and saplings were made. To assess the socio-economic importance of the study species, 80 households were randomly selected from four villages (two from each district) surrounding the selected specific study sites. A semi-structured questionnaire was used to interview the household respondents. Group discussions were held with 12 selected key informants and with local administrators. Based on the analyses of the vegetation data, a total of 64 woody species distributed in 23 families and 31 genera were encountered in the sample quadrats. A total of 15 woody species (14 at Arero and 11 at Yabello), belonging to the genus Commiphora, Boswellia and Acacia, were identified important as oleo-gum resin producing species. Gum and resin bearing species were found to be the predominant species comprising 34% and 48 % of the species composition, 47.5% and 66.6% density ha^{-1} and 69.8% and 60.2% of the IV of the study sites at Arero and Yabello, respectively. The Shannon-Wiener diversity and Shannon evenness values depicted the diverse and even distribution of the population of the study species. The Structural analyses of the population of the study species indicated that most of them had a more or less good regeneration profile. This implies the existence of large potential for the production of oleo-gum resin products at the study areas. The socio-economic survey also disclosed that the Borana pastoral and agro-pastoral community has a deep attachment with gum and resin bearing species. The role of gum and resin bearing species in the livelihood of the local community was very immense. As the local residents mentioned, most of the study species are the primary sources of fodder, medicine, food, sanitation and wood. Gum and resin collection is found to be the most important means of income generation for thousands of households in the study areas. Above all, gum and resin extraction is almost non-destructive way of resource use. Hence, careful plan to integrate this sub-sector with other activities such as livestock is not only means of income diversification, but also a sustainable way of utilization of the natural woodland. By doing so, it is possible to contribute to combating the expansion of desertification (the prevailing problem in the area), environmental degradation, and lose of biodiversity, while making economic use of the resources.

Keywords: dryland, gum and resin, gum and resin bearing species, population status, socio-economic importance

1. Introduction

1.1 Background information and Justification

Ethiopia is one of those countries in the world that posses a unique characteristic fauna and flora with a high level of endemism (Tewoldebirhan G/Egziabher, 1989b). The topographic features that range from 110 meters below sea level to 4,620 meters above sea level has created quiet diverse ecological conditions in the country. This wide range of ecological variation coupled with the corresponding diverse socio-culture has made the country to be one of the very important diversity rich areas in the world. Large species of trees, shrubs, herbs, cultivated plants and their wild relatives are found in the different agro-ecological zones of the country (Tadesse Weldemariam, 2003; Alemayehu Wassie, *et al,* 2005).

Among the different agro-ecological zones existing in Ethiopia, arid and semi-arid areas together cover the largest proportion of landmass, whch is estimated to be about 620,000 km^2 (55%) (Mulugeta Lemenih, 2005). Such vast areas of the country is characterised mainly by scanty and erratic rain fall with no to marginal agricultural potentials. Borana zone, which is one of the administrative zones of the Oromia National Regional State, where this study was carried out, falls under such agro-ecology. According to Gemedo Dalle (2004), livestock production has been the dominant mode of life with little agro-pastoral system in the area. However, the recurring drought, and the consequent critical shortage of fodder and moisture are severely impacting the productivity of both livestock and agriculture, and hence the overall socio-economic development of the society. This implies that, as it was everywhere in most drylands of the country, livestock rearing and agriculture alone are no longer the main sources of livelihood in drylands of Borana (Vivero and Jose, 2002; Mitiku Tiksa, 2004). More importantly, the current trend of productivity decline in dryland ecosystems of the country is unlikely to improve as pressure on resources is increasing from time to time (Vivero and Jose, 2002; Gemedo Dalle *et al*., 2005).

Nevertheless, such drylands including the vast Borana lowlands are habitat for vegetation that has the potential to provide additional opportunity to improve the livelihood of the local community and nation at large (Kuchar, 1995; Mulugeta

Lemenih *et al.,* 2003; Abeje Eshete *et al*., 2005**)**. Within this vegetation we find ecologically adapted, economically valuable and socio-culturally preferred genera, among others, the genera of *Acacia, Commiphora*, *Boswellia*, and *Sterculia* (Kindeya G/Hiwot, 2003; Abeje Eshete *et al.,* 2005; Gemedo Dalle *et al.,* 2005). Several members of these genera, in addition to their use as fuelwood, construction, charcoal, forage, medicine, and various ecological services are known to produce economically valuable products, principally Oleo-gum resins: gum arabic, gum talha, frankincense/gum-olibanum, myrrh, oppopanex, and gum karaya (EFAP, 1994; Karamalla, 1997; Mulugeta Lemenih *et al.,* 2003).

Several recent studies indicated that the actual and potencial socio-economic, and ecological services obtained from gum and gum resin yielding species and the role they play in the livelihood of local society and nation at large is very significant (e.g. Wubalem Tadesse *et al.,* 2002; Mulugeta Lemenih *et al.,* 2003; Abeje Eshete *et al.,* 2005). Non-timber forest products (NTFPs) in general and oleo-gum resins in particular, were collected to serve as source of food mainly during slag periods, means of income generation, and employment among local poor communities. For instance, oleo-gum resin collection and sale is reported to provide an income equivalent of 80 USD/household/year in the Liban zone of Somali National Regional State of Ethiopia; an income which ranked second after livestock in the livelihood of the pastoral community living in the area (Mulugeta Lemenih *et al.,* 2003). Above all, frankincense and myrrh have been and still are used in enormous folk medicines (Mulugeta Lemenih *et al.,* 2003; Mulugeta Lemenih and Demel Teketay, 2003b). Besides their local use, oleo-gum resins are also phyto-toxically safe raw materials utilized in many of the advanced industries such as pharmacology, food industry, flavouring, beverage and liqueurs (Council of Europe, 1981; Farah, 1994; FAO, 1995a, b), cosmetics, perfumery, paints, adhesive and dye manufacturing. In countries such as Ethiopia, where rain fed agriculutre and livestock rearing is the mainstay of no less than 80% of the total population, and where the population growth is much higher than the agriculture and livestock productivity, the use of NTFPs in general and gum and resin, in particular become a neccessity than an option for income diversification and insure food security of the nation (FAO, 1995a; Mulugeta Lemenih *et al.,* 2003). These is even more pressing in drylands of Ethiopia where there is only few options to survive and desretification is expanding at an alrming rate.

Although there is no full national inventory on the resource bases, Ethiopia is supposed to have a large coverage of gum and resin bearing species, widely distributed through out its arid and semi-arid agro-ecological zones (Wubalem Tadesse *et al.,* 2002). According to Vollesen (1989) there are about six species of *Boswellia,* 52 species of *Commiphora* and many *Acacia* species in Ethiopia. Borana zone is among the areas rich in gum and resin yielding woody species in the country (Kuchar, 1995; Gemedo Dalle *et al.,* 2005).

Collection, use and trade of Oleo-gum resin is an age-old activity in Ethiopia and Ethiopia is one of the world's major producers and exporters of these products (Mulugeta Lemenih *et al.,* 2003; Abeje Eshete *et al.,* 2005). According to Mulugeta Lemenih (2005) in the period 1996 - 2003, Ethiopia exported 13,299 tons of natural gum and earned 141,064,151Birr (≈18, 000,000 USD). This does not include the informal trans-border trade with Somali, Kenya and Sudan. According to Coulter (1987), for instance, a large volume of myrrh produced and exported in Somali is actually originated from Ethiopia, mainly from Borana and Ethio-Somali zones. Hence, collection and trade of gum and resin in Ethiopian economy in general and the local communities, in particular can not be overlooked, as these sub-sector is still among the few export articles the country have to earn foreign currency.

However, despite the growing recognition of ecological and socio-economic importance of oleo-gum resins world wide, very little attention has been given to the woodland vegetation harbouring these versatile species as compared to the forests of the humid and sub-humid areas in Ethiopia (Kindeya G/Hiwot, 2003; Mulugeta Lemenih and Demel Teketay, 2004). This again has resulted in rapid decline in vegetation resource of drylands in the country (Mekuria Argaw *et al.,* 1999; Getachew Eshete, 1999). It was also very unfortunate that, until recently most of the studies conducted on gum and resin bearing species were confined to only the northern parts of the country (Tilahun G/Medhen, 1997) with scares/no work done in the southern parts, such as Borana (Wubalem Taddese *et al*., 2002, Mulugeta Lemenih and Demel Teketay, 2003a; Gemedo Dalle *et al*, 2005).

Hence, there is limited information on the biology, population status, soil seed bank, socio-economic importance, potential production, and development opportunities of gum and resin bearing species in the study areas. Moreover, there is also limited information on the perception of the local society on the future management and commercialization of these versatile commodities. Lack of quantitative data on the baseline information, on the other hand is a barrier to plan for the future promotion and sustainable use of these resources. It is also not possible to design and recommend any workable strategies with out having quantitative data on the resource under consideration. Therefore, the aim of the current study was to provide quantitative information on the population status and socio-economic importance of gum and resin bearing species in two districts of Borana zone of Oromia Regional State, Ethiopia, thereby contributing to the better management of the species in general and sustainable utilization of the products in particular.

1.2 Objectives of the study

1.2.1 General objective

To investigate the floristic composition and socio-economic importance of gum and resin bearing species in two districts of Borana zone, southern Ethiopia.

1.2.2 Specific objectives

1. To determine species composition and abundance of gum and gum resin bearing and the associated species in the study areas;
2. To assess the current regeneration status and possible factors that hamper the natural regeneration of gum and resin bearing species;
3. To determine the population structure and importance value of gum and resin bearing species;
4. To investigate the socio-economic importance of gum and resin production in Borana lowlands, its future prospects and the perception of the local communities to the future promotion and commercialization of gum and resins at the study areas.

1.2.3 Research question

The following research questions were emanated from the above objectives:

i. How is the composition and diversity of gum and gum resin yielding woody species in lowlands of Borana zone?
ii. How is the abundance, frequency, dominance, importance value of gum and gum resin bearing species in the study areas?
iii. How is the current regeneration status of the study species?
iv. What are the major factors that have impact on the vegetation in general and hamper the regeneration of gum and resin bearing species in particular of the study area?
v. What roles have gum and resins products have played in the livelihood of the local society, and what perception do the local people have on the future development and commercialization of oleo-gum resins?

2. Literature review

2.1 Extents and definitions of Drylands

Drylands, which are areas in which average annual evapo-transpiration exceeds rainfall, occur in all continents of the world. Generally, drylands have great variations in features. However, most drylands have the common features such as extremely variable and low precipitation or aridity (UNEP, 1992). Aridity, which is a negative water balance, remains the binding feature of all drylands. Aridity is expressed by aridity index, which is the ratio of average annual precipitation (P) to average potential evapo-transpiration (PET). Temperature is also often very high in dryland areas. Such high temperature has its direct impact in increasing the evapotranspiration, which prohibit plant growth in the area.

Dryland environment in general covers areas that fall under hyper-arid, arid, semi-arid and dry sub-humid ecosystems (Tamerie Hawando, 1997). These areas cover various ecosystems with unpredictable precipitation in time and space and with low total amount. The diurnal temperature is very variable in these environments. The seasonal rainfall regimes have high inter-annual and mean annual precipitation values, which vary from 800 mm in summer to 250 mm in winter. Drylands are found in more than half of the world's countries and cover about 47% of the world's land surface at global scale, and 72% of African land mass (Tamerie Hawando, 1997). Large areas of drylands are located in Africa, the Middle East, North and South America, Asia and the pasfic regions. Dryland ecosystems are home to more than 1 billion people world wide, which is 20 percent of the world's total population (Edmund, 1997). Drylands also support a significant proportion of the livestock (approximately half of the total), most of the endemic wildlife, and a considerable amount of other biological resources, which indicates they are endowed with diverse resource bases. However, today, everywhere in the world, these enormous areas of dryland ecosystems are facing serious problems of degradation, which calls for an immediate and concerted action.

2.2 Dry lands in Ethiopia

In Ethiopia, drylands cover approximately 71.5% (Mulugeta Lemenih and Demel Teketay, 2004) of the landmass in the country. They occur from below sea level (Afar depression in north east) to as high as 2700 m elevations. Arid and hyper-arid areas in Ethiopia range from 0 to 1000 m.a.s.l where nomadism is usually the dominant life style. Overgrazing, wind erosion, salinity and deforestation are the main causes of land degradation in these areas. Semi arid areas are found between the altitudes of 625 and 2550m (Tamerie Hawando, 1997). These areas are used by semi-sedentary agro-pastoralists and settled crop cultivators. Poor farming practices, overgrazing, water and wind erosion, salinity and deforestation are the major factors of degradation in these zone. Summarized mean rainfall, the corresponding evapo-trainspiration and area of land under each dryalnd climatic zone are presented in (Table 1). Besides the alarming desertification, drylands in Ethiopia show clear signs of vulnerability to global climatic changes. Mean annual precipitation has gradually declined in the last couple of decades. As a result, recurrent drought, fodder and crop failures, and the consequent famine are becoming common phenomena in the dryland of Ethiopia in general (EFAP, 1994; Mulugeta Lemenih and Demel Teketay, 2004) and Borana, in particular; Mitiku Tiksa, 2004).

Table 1. Data on rainfall, Evapo-transpiration, aridity index and land area of drylands in Ethiopia

Zone	Mean Rainfall (Mm/YR)	Mean Evapo-transpiration (MM/yr)	Aridity index	Land area Km^2 x 1000
Dry sub-humid	900	1510	0.50 – 0.65	300
Semi arid	656	1700	0.20 – 0.50	207-250
Arid	266	2213	0.05 – 0.20	300-310
Hyper arid	70	2831	< 0.05	53-55

Source: Mulugeta Lemenih and Demel Teketay (2004)

Thus, as these areas are home for millions of people and their livestock, unless significant measures are taken early enough to curb the prevailing environmental degradation and the consequent expansion of desertification in drylands; the consequence is likely to result into serious ecological and social breakdown in drylands of Ethiopia (Tamerie Hawando, 1997; Tefera Mengistu *et al.,* 2004).

2.3 Dryland Vegetations of Ethiopia

Drylands are extremely diverse in terms of their landforms, soil, flora, fauna, water balance and human activities (Edmund, 1997). Likewise, drylands of Ethiopia are endowed with a divers vegetation formation, collectively called the Somali-Masi vegetation formation (Zerihun Woldu, 1999; Friis, 1992). It was reported that, out of the 75 million ha dryland area in Ethiopia, 25 million ha was covered with woodlands and bushlands (EFAP, 1994). This implies that the largest vegetation resource of the country is found within drylands (Tefera Mengistu *et al*., 2005; Abeje Eshete *et al.,* 2005). However, this divers vegetation resource is under serious threat. This has been attributed to the fact that land has been used as a mine, rather than a renewable resource for centuries in the country (Tewoldebirhan G/Egziabher, 1989a). The main cause of degradation has been cutting of woody plants for various purposes.

The characterizing vegetation types in most of the dryland areas of Ethiopia include Broad-leaved deciduous and small-leaved deciduous woodlands, Lowland dry forest and Lowland semi-desert and desert vegetation (Zerihun Woldu, 1999; Gemedo Dalle, 2004). The first two constitute the vegetation formation of Borana lowlands, where the current study was carried out. As it is important to review and discuss the vegetation at which gum and gum resin species grow in combination with other species, the potential of *Acacia-Commiphora* woodland and NTFPs collection in relation to development, sustainable resources management, biodiversity conservation and environmental protection will be explored hereunder.

2.3.1 *Acacia-Commiphora* woodlands and its potential for development of drylands

Woodland and bushland vegetations in Ethiopian are largely restricted to the pastoral and agro-pastoral zones of the country (Mulugeta Lemenih *et al.,* 2003; Tefera Mengistu *et al*., 2004). These lands are an important source of fuelwood and construction material for the local communities; production of charcoal for urban markets and collection of NTFPs such as gum and gum-resins, essential oils, edible fruits and seeds, roots, tubers, leaves, barks, and honey. They are the principal sources of fodder and water for the livestock of the pastoral communities. Woodland vegetation are again the major means of medication for the local society, as only few people living in drylands of Ethiopia have access to advanced health centres. Moreover, some of the big rivers capable of irrigating large hectares of land and a significant amount of arable lands are found in drylands of the country, where these vegetation formations play the major role in maintaining the ecosystem functioning.

Extracting of NTFPs, which are supplied by such woodlands, is one of the day-to-day activities carried out among the people residing in the drylands of the country. Generally, as it is elsewhere in various part of the dryland environments in the world, NTFPs are extensively used to supplement diets and household income in Ethiopia, notably during the dry season, and to help meet medicinal needs. NTFP's are often acknowledged as an important natural means (as economic buffer) mainly in hard times. On the other hand, climate is changing globally and the associated consequences of such changes are immense everywhere in the world. A sustained increase in mean ambient temperatures beyond 1°C would cause significant changes in forest and rangeland cover, species distribution, species composition and biome leading dryland environments to be unproductive (Tamerie Hawando (1997; Kuchar, 1997). Arid to semi-arid sub-regions and the grassland areas of eastern and southern Africa, as well as areas currently under the threats from land degradation and desertification are particularly vulnerable, which is also the case in Ethiopia.

Meanwhile, the key role of the characteristic species comprising the *Acacia-Commiphora* woodland and other dryland vegetation formation in combating the ever-expanding desertification is very significant, as dryland adapted species are known to grow in harsh and marginalized environments (FAO, 1995b). This implies the diversified role woodlands play, mainly in drylands of the country, where there exists only few options for survival. The main genera that comprise the woodlands of Borana in particular are *Commiphora, Acacia, Boswellia, Balanites, Euphorbia, Combretum, Sterculia, Grewia* etc. Some of the member species of the genera *Commiphora, Boswellia, Acacia* and *Sterculia* are known to yield commercially valuable products, principally gum and gum resins.

2.3.2 The role of NTFPs extractions in sustainable managements of the vulnerable dryland vegetation

As the ecological balance in arid and semi-arid environments is delicate, sustainable land-use practices are required if people's basic needs for the future are to be fulfilled. On the other hand, the results of many studies in past decades revealed that, utilization of a given biological resources in such a way where its exploitation not compromised with its regeneration is unsustainable. Such phenomena were very common in developing tropical countries (Tewoldebirhan G/Egziabher, 1989b). Failing to strike the balance between consumption and conservation of a given resource will affect the goal of achieving the production of goods and services on sustainable bases. Dryland ecosystems are often vulnerable to such a problem of unsustainable resources management, as there is a high dependency of the local society on the nearby natural resources. The issue is even more aggravated in some places due to lack of clear land ownership in drylands of the country (Tefera Mengsitu *et al*., 2004).

Likewise, in Ethiopia the woody biomass in woodland vegetations is being rapidly depleted by the spread of sedentary farming, increased numbers of pastoralist population and their livestock, and the increasing urban demand for fuelwood and charcoal (Gemedo Dalle, 2004). The open access to resources of dryland ecosystems has resulted in the woody biomass harvest that exceeds the annual growth of most of the species. Hence, since resource degradation and its consequent effect on biodiversity and other ecosystem processes are primarily human-induced, then modification of human land use practice for better resource management must be part of the solution. In this case, NTFPs in general and oleo-gum resin in particular, were proved to be an important key to the management of forest resources in a sustainable way in such a vulnerable ecosystems (FAO, 1995b; Peters, 1996).

The contributions that gum and resin can make to rural livelihoods, and the fact that their use is less ecologically destructive than timber harvesting, have encouraged the belief that more intensive management of forests for such products could contribute to both development and conservation objectives. These days such a promising opportunity behind managing a given forest or woodland has led to initiatives to expand commercial use of NTFPs. More specifically, such an approach is increasingly proposed by many ecologist as a potential means of ensuring sustainable management of forest biodiversity, while generating income for rural inhabitants. For instance, in our case, where we left with only few scattered trees in most of the dry ecosystems, exploitation of NTFPs, rather than converting the ecosystem to other land use type or killing the live tree itself to produce charcoal is a sustainable way of resources management (FAO, 1995b). However, accomplishing these dual goals requires an understanding of how NTFP extraction and marketing functions in the regions.

2.3.3 Gums and resins as means of biodiversity conservation and environmental protection in drylands of Ethiopia

Major loss of biodiversity in drylands of Ethiopia is occurring through the destruction of habitat owing to extensive deforestation and conversion of forests to agricultural lands (Mekuria Argaw *et al.,* 1999). The current policy of re-settlement in the country to reverse food insecurity in most degraded areas of the highlands has been witnessed to have its significant impact on the dryland vegetation resources. Loss of biodiversity has also been taking place in a progressive fragmentation and subsequent isolation of forest communities subjected to other land use systems. As observed during the field survey, such impact was very common phenomenon in the rift valley in general, and Borana zone mainly in Yabello in particular. More importantly, drylands cannot accommodate activities that kill the standing plant as the probability of regeneration and establishment of some of the important species may be retarded due to the harsh environment. Therefore, managing at least some parts of the woodland resources in dryland for their NTFPs value in general and gum-resin production in particular could be one of the best approaches in the context of biodiversity maintenance (FAO, 1995a, b; Mulugeta Lemenih *et al.,* 2003; Abeje Eshete *et al.,* 2005).

NTFPs, in general are believed to be an important resource, mainly for immediate household consumption, and also as a means to maintain or to increase the value of standing forests discouraging deforestation. In other words, they contribute to household economy on the one hand and to biodiversity conservation on the other hand. For example, since the early 1990s, NTFPs have been assumed to effectively contribute to the conservation of tropical forests and the improvement of forest dwellers' economic situation. This simple and promising approach of double use of the resources can rapidly be put into practice in many forestry-related development projects in tropical countries, such as Ethiopia. Besides, the maintenance of a forest-like structure associated with NTFPs production is generally acknowledged as being positively contributing to some of the classical forest environmental functions like carbon storage, nutrient cycling, erosion control and hydrological regulation which in one way or another affect biodiversity (FAO, 1988).

2.4 Socio-economic benefits of gums and gum resins

The ever-increasing number of human population and the associated stress on the natural environment in the world, has led to the complete lose and/or decrease in productivities of various ecosystems. Such a phenomenon showed that, agriculture and livestock rearing (which are the dominant activities in Borana area) alone are no longer the main sources of income. Furthermore, the current situation of decline in productivity of land is unlikely to improve as pressure on land resources increase with the population growth. It is therefore, essential for rural households to look for other alternatives that could contribute to the livelihood of the society while maintaining the balance of ecosystems (Vivero and Jose, 2002; Arnold and Perez, 2001).

As a matter of fact, the livelihood of the majority of rural households and a large proportion of urban households in African drylands, including Ethiopia, depend on the forest and woodland products to meet some of their needs (FAO, 1988; Chikamai, 1996). The use of NTFPs, in general and gum and resin in particular is as old as human existence. In subsistence and rural economies the role and contributions of gum and resin collection is crucial because of their variety of application as food, herbal potions, hygiene, cosmetic and cultural values. Gums and resins provide raw material to support processing enterprises. They include internationally important commodities used in food and beverages products, flavourings, perfumes, medicines, paints, polishes and even more. Some 80 percent of the population of the developing world, who do not have access or capital to buy medicines, depends on traditional medication for their primary health (Kebu Balemie *et al,* 2004). They are also involved in the national and international markets, contributing to the country's export earnings.

In terms of commercial importance and livelihood support, gum and gum resin producing trees and shrubs in the drylands of Ethiopia occupy a central position. The importance of gum and resin production often lies more in its timing than in its magnitude in rescuing rural populations from famine and even poverty if well managed and integrated with other options of land use (Abeje Eshete *et al*., 2005). The increased demand for natural products in the global market offers a good opportunity to plan for development strategies that improve the livelihood of people by making use of natural resources such as gum and resins (Kindeya G/Hiwot, 2003). Beside big amount of money, collection of these commodities has created an employment opportunity. For instance, NGPME yearly employs between 20,000 and 30,000 people for gum and resin collection and processing which is higher when compared to the employment opportunity created by the forest industry (timber related industries), which is 9,583 per year (Mulugeta Lemenih and Demel Teketay, 2004). In general, the direct national economic contribution of the dryland vegetation resources in Ethiopia far outweighs that of the forest resources in the humid and sub-humid areas.

2.5 Gum and gum resin resources of Ethiopia: opportunities and constraints

Ethiopia has more than half of its land cover under dry agro-climatic condition. Such vast areas of arid and semi-arid lands are known to be dominated by the *Acacia-Commiphora* and *Combreteum-Terminalia* woodlands. These vegetation types are promising habitats for several economically, culturally and ecologically important plants species. Particularly, gum and gum resin bearing species predominate the species composition in most of these drylands of the country. For instance, about 17 species of *Acacia*, 5 *Boswellia* and 17 *Commiphora* species have been identified as gum and gum resins bearing species in some of the drylands of Ethiopia (Mulugeta Lemenih and Demel Teketay, 2004). In addition, different authors (e.g. Mekuria Argaw *et al,* 1999; Getachew Eshete, 1999; Gemedo Dalle, 2004) have confirmed the abundant and wide distribution of *Acacia senegal* in the Rift Valley system of Ethiopia.

Present estimate indicate that there is over 3.5 million ha of drylands in the country that host gum and gum resin bearing species of various types, with over 300’000 tons of potential annual gum and incense production (Mulugeta Lemenih and Demel Teketay, 2004). In general, Ethiopia is one of the richly endowed countries with respect to gum and gum resin producing species diversity and abundance, and remains one of the world's major producer and exporter country for oleo-gum resins. Gum and gum resin products, besides, several local applications such as religious rituals, folk medicines and income generation, have been generating considerable national income to the country.

However, there are several constraints that are barriers to the full utilization of these commodities. Some of these constraints include: market related problem, deforestation and conversion of woodlands that harbour the species into other forms of land use, lack of national scale co-ordination for the conservation and sustainable utilization of resources, inaccessibility for optimum utilization and the like (Mulugeta Lemenih and Demel Teketay, 2004). Lack of adequate knowledge on the biology, ecology, management, and harvesting, processing, storing, value adding and marketing of these resources is also a major constraint as far as gum and resin development is concerned. Production, processing and marketing of natural gum in Ethiopia is also hampered by the inaccessibility of gum producing regions since they are located far from ports or market centres. Lack of quality control means, and parallel across-border trades are also constraints. Mixing up of gums from different species, and same species but different colour, at collection time or at post-harvest handling stage results in variability and is thus a prime cause for poor quality and consequent poor price. These are some of the potential challenges for the future commercialization and domestication of gum and gum resins in Ethiopia and need for action.

Currently the introduced invasive/alien species and bush encroachments have also become a serious threat to some of the gum and gum incense bearing species. The on-going government lead re-settlement program, which is mostly confined to the lowlands where these species are abundantly occurring, is causing huge damage through land conversion from woodland to mono-cropping. Insect damage, termites, fungal and viral attack have also their share in deteriorating the regeneration and establishment of these species (Mulugeta Lemenih and Demel Teketay, 2004). Hence, mitigation measures through well designed and integrated approaches will be a timely issue to be dealt for sustainable gum and resin production in the country.

2.5.1 Local uses of gum and gum resin bearing species in Ethiopia

Most of the *Commiphora* and *Boswellia* species are used for live fencing, making agricultural implements and household furniture. Their different parts including the resin are used as medicine to treat different diseases. Moreover, lowlanders chew the gums to prevent or quench thirst. The leaves of the above genera including the *Acacia* species that yield gum acacia are sources of fodder. The flowers are source of nectars for honeybees (Tilahun G/Medhin, 1997; Abeje Eshete *et al.,* 2005). Traditionally resins are used in unprocessed ways such as burning incense at home, churches and mosques. Resins are also used as an adhesive to fasten the broken materials. Resins of some *Commiphora* species are used as ordinary soap for sanitation. The solution made of resin is used as insect repellent. The elders of Borana prepared writing ink from resins. Gum collected from *A. senegal* is also used as famine food.

2.5.2 Efforts so far to develop gum and gum resin resources in Ethiopia

The efforts so far in the country are not really comparable to the social, ecological and economic contributions of gum and resin bearing species. However, there are some works focused on the regeneration, seed biology, population status, soil seed bank, tapping techniques and socio-economic importance of these species (Tilahun G/Medhin, 1997; Kindeya G/Hiwot, 2003; Abeje Eshete *et al.,* 2005). Unfortunately, all except one work done at Somali zone by Mulugeta Lemenih *et al* (2003) and few others at Rift valley Mekuria Argaw *et al*., (1999) and Getachew Eshete (1999), the rest were concentrated at the northern part of the country. There is limited research focusing on these species at the southern part of the country, such as Borana. On the other hand, there is information on the diversity of these species in these areas (Gemedo Dalle, 2004).

2.6 Other relevant concepts

2.6.1 Species diversity

A biological community has an attribute that we call species diversity and many different ways have been suggested for measuring it. Recent interest in conservation has generated a strong focus on how to measure species diversity in both plants and animals using different diversity indices. Biodiversity has a broad meaning than species diversity as it includes genetic, species, ecosystem and cultural diversity. However, species diversity is still a large part of the focus of biodiversity at local and regional scale (Kent and Coker, 1992). According to Krebs (1998), as ecological ideas matured and quantitative measurement introduced, it became clear that the idea of diversity involved two distinct components: species richness and evenness.

Two statistical distributions have been fitted to species-abundance data: the logarithmic series and the lognormal distribution and they recognized two categories diversity indices i.e. Type I and II indices. Type I indices are most sensitive to change in the rare species in the community sample. The Shannon-Wiener index is example of type I index. Type II indices are most sensitive to changes in more abundant species. Simpson index is an example of type II index. The choice of which heterogeneity measure to use should be made on this basis; whether the interest is to emphasise the dominant or rare species of the community in question. However, in most community works both data type I & II are obtained. In the present study Shannon-Wiener index was adopted. This is because, Shannon-Wiener function stands the most popular measure of species diversity, which combines species richness and evenness, yet not, affected by sample size (Shannon and Wiener, 1949; Kent and Coker, 1992). Based on this relationship, two types of data can be collected: the number of species and the number of individuals in each plot. Information content is a measure of the amount of uncertainty so that the larger the value of H' the greater the uncertainty. The Shannon-Wiener measure H', increase with the number of species in the community. According to Kent and Coker (1992), the values of H' is between 1.5 and 3.5 and it does rarely exceed 5.0 in practice.

3.6.2 Evenness

Since heterogeneity/diversity contains two separate ideas-such as species richness and evenness, then ecologist tried to measure the evenness component separately. Whittaker (1975), on the other hand expressed this concept as equitability. Its base is on the fact that most communities of plant and animals contain a few dominant species and many species that are relatively uncommon. Evenness measure attempts to quantify this unique representation against a hypothetical community in which all species are equally common such that all species have equal abundances in the community, and hence, evenness is maximal (Kent and Coker, 1992).

2.6.3 Population structure

According to Peters (1996), population structure is the numerical distribution of individuals of differing size or age within a population of a given species at a given moment of time. It can also be defined as the distribution of individuals of each species within a population in arbitrarily defined diameter height classes. Population structure data have long been used by foresters and ecologists to investigate the regeneration profile of a species of a given population in the study quadrats (Tadesse Woldemariam, 2003). In broad sense, computing the population structure of a given population can tell us two sets of information. First, the distribution of plants among age, or size class categories which again tell us something about the history and the future of the population and second information provided by age/size distribution is the immediate means of identifying the poorly represented stages of life history of a given population.

There are two methods of obtaining the population structure of a population (Peters, 1996). One method is monitoring the frequency and abundance of seedling establishment over a period of several decades and to record the resultant increase or decrease in population size over time. The second method is by analyzing the size or age distribution of the individuals within its population on the basis of static vegetation data. The first method gives reliable information on the age distribution of individuals and is a good predictor of future population trends. The second method is less laborious and time consuming than the first method, which is also based on the analysis of size or age class distributions (SCDs) of trees and shrubs to achieve information about the regeneration status of a number of species. This is because the recruitment history of a particular tree species is reflected by the size or age distribution of the individuals within its population. It can show the regeneration status of a species and whether the recruitment occurs continuously or periodically (Peters, 1996; Tefera Mengistu *et al.,* 2005).

Ecologists often use diameter and height size-class distribution to indicate the health of a population because of a lack of well defined growth rings and the difficulty of accurately determining tree age in the tropics. Accordingly, population structure can be constructed by employing the total number of individuals that were grouped into different arbitrary diameter and height classes, and summarized using descriptive and simple statistical calculations for both diameter and height class distributions of each species and has been shown by simple frequency histogram (Kindaya G/Hiwot, 2003; Tefera Mengistu *et al.,* 2005). For this particular study, population structures were constructed following this approach.

It has been indicated, periodic monitoring of this important parameter is an easy, yet reliable, method to assess the ecological health of a tree populations (Lamprecht, 1889) and can be used to guarantee the long-term sustainability of NTFPs extraction. The analysis of population structure is a basic tool for orienting management activities, for identifying species susceptibility to local extinction, to reveal compositional changes of the vegetation, and for assessing the impact of resource exploitation. Based on the data from constructed population structure, it has been depicted that, tree species with population structure skewed to an inverted ‘J’ (Silvertown, 1982), or an ‘L-shaped’ distribution i.e. with many small individuals and few larger ones, are considered to have a favourable status for regeneration and, hence, stable populations. If the population structure constructed from both diameter and height class frequency distributions has very few individuals at lowest classes, then that particular species has serious problems in regeneration (ibid).

3. Materials and Methods

3.1 Description of the study area

3.1.1 Location

The study was under taken at two semi-arid districts of the pastoral and agro-pastoral rangelands in the Borana zone, southern Ethiopia. The two districts considered were Arero and Yabello. Borana zone in general is found in southern part of Oromia Regional State, which is also most southern part of Ethiopia, at approximatly 500 km (the capital of the zone) from Addis Ababa. Borana zone lies between 3^{0}36’-6^{0}38’N and 36^{0}43’-41^{0}40’E geographical grids. Borana zone covers an area of 69,373.3km^2, and is sub-divded in to12 districts and 14 urban centers. Altitudnally, it covers the range between 700 and 3200 m.a.s.l. The zone comprises 69.1% Kolla (arid to semi-arid), 28.5%Woinadega (dry sub-humid) and 2.4 % Dega (Humid and cool) agro-climatic zones (Coppok, 1994; Gemedo Dalle, 2004).

Arero district is found at an approximate distance of 680 km from Addis Ababa and covers an area of 10,890km^2. Arero is found in the south eastern part of the zone. Altitudnaly, it lies between 750 (Melak Guba or Dawa river) and 1700 m.a.s.l (Meta Gafersa). Yabello district is found at about 560 km and has an area of 5, 550 km^2. It is found in the south western part of Borana zone. Altitudinaly, Yabello district lies between 1350 and 1800 m.a.s.l. Obda highland and El-Waya are the major features in this districts.

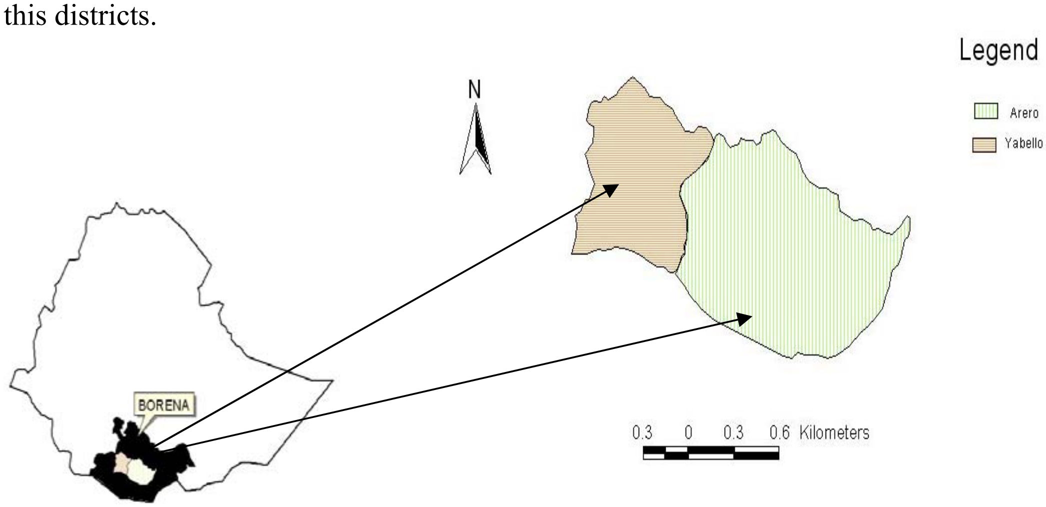


Figure 1. Map of the study areas

3.1.2 Geology and soil

The dominant soil types found at Arero district were Chromic and Eutric Luvisol, Calcaric and Eutric Fluvisol and Chromic, Eutric and Calcari, whereas Yebello district is predominated by Chromic and Eutric Luvisol soil types and they cover about 68% of the districts total area **(**Oromia Bureau of Planning and Economic Development, 2000**).** According to Gemedo Dalle (2004), bottomland of the Borana rangeland are predominated by vertisols.

3.1.3 Climate

Climte is one of the decisive factor affecting productivity mainly in arid and semi-arid ecosystems, such as Borana lowlands. Generally, the climate of Borana rangland is typical of the equatorial regions of East Africa, but localy modified by altitude. The seasonal distribution of rainfall is almost entirely controled by the annual north and south shifting of the Intertropical Convergence Zone that forms the northern boundary of the area of equatorial low pressure (AGROTEC, 1974). The rain fall regime in Borana drylands is bimodal with two rainfall seasons (Fig. 2). The main rainy season, known as the long rainy season is between March and May with the pick in April, and short rainy season is between September and November, with pick in October.

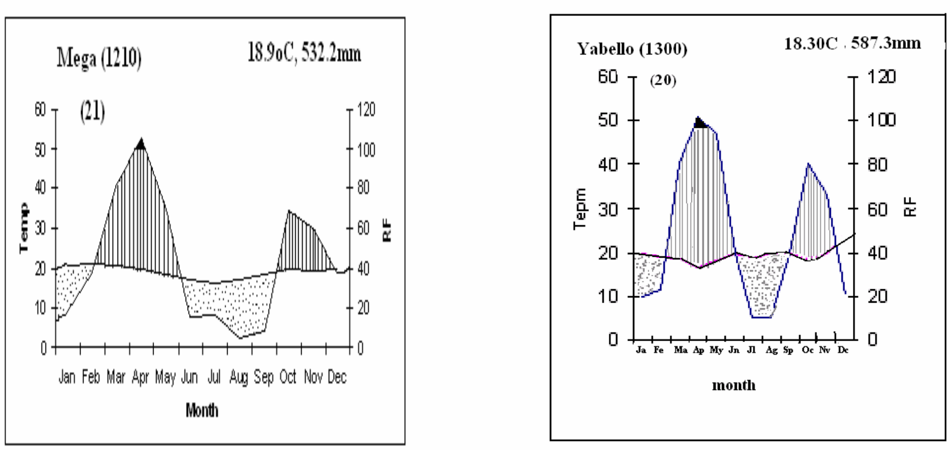


Figure 2. Climatic diagram of Mega and Yabello Stations respectively, Borana zone, Ethiopia

Generally, rainfall decreases towards the southeast with increase in temperature and decrease in altitude. The major featuring in rainfall characteristics of the rangelands of Borana or low rainfall areas of East Africa in general are tremendous variability that occurs between years and localities (AGROTEC, 1974). Such variability makes the rainfall arithmetical mean a very unsatisfactory way of expressing rainfall probabilities. Since there is no Meteorology station at Arero district, data from the nearest station (Mega station) was used for Arero. Hence, based on 20 (1984-2004) years meteorological data the mean monthly rainfall at the nearby station was 47.1mm. The mean annual rainfall of the district was 532.2mm. There is slight variation in mean temperature throughout the year. The mean monthly minimum and maximum temperature of Arero as taken from Mega station was 16.2^0C, 18.3^0C, respectively. The mean annual temperature was 18.9^0C. In Yabello stations the mean monthly rainfall was 48mm. The mean annual rainfall of the district was 587.2mm. There was also variation in temperature as it was in Arero. The mean monthly minimum and maximum temperatures of Yabello were 15.6 and 18.8^0C, respectively, with mean annual temperature 18.3^0C.

3.1.4 Vegetation

Borana lowland is mostly coverd with East African evergreen and semi-evergreen bushland and thickets along the high lying areas with relatively higher rainfall (AGROTEC, 1974). The southern, eastern and western parts, where this study was conducted, are covered with a woodland dominated by *Acacia-Commiphora* vegetation formation and related genera, mostly appeared in shruby habits (Plate 1). In broad sence, *Combretum-Terminalia* (broad leaved decidious) woodland and *Acacia-Commiphora* (small leaved decidious) woodland are the two vegetation types covering the Borana lowlands (Gemedo Dalle, 2004). The charatcteristic genera in the woodlands of Borana are that of *Combretum* and *Terminalia*, whereas the bushlands and thickets, which covered the majority of Borana lowlands are represented by species of the genera *Acacia* and *Commiphora*. Additionaly, species of the genera *Bosica*, *Maerua*, *Lanea*, *Balanites, Boswellia*, and *Aloe* are common (Coppock, 1994; Ayana Angasa, 1999; Gemedo Dalle, 2004). The rangelands of the Borana zone is thought to be rich in gum and resin bearing species. For instance, Gemedo Dalle *et al.*

(2005) had identified more than 10 indigenous woody species that yield gums and resins in a study conducted at three districts of the Borana lowlands.

Plate 1. Photo of the vegetation at the Wachille study site (Arero)

3.1.5 Population

Arero district has a population size of 32,300 of which 4,443 were urban, and 27, 905 rural. The district's crud population density was estimated at 3 person per km^2. The major town of the district is Arero. Yabelo has a population size of 61, 300 of which 49,768 rural (24,889 males) and 11,523 urban (5,763 male). The district's crud population density was estimated to be 11 person per km^2. The major town of the district is Yabello. The indegenous people of the study area are called Borana, the eldest branch of Oromo ethnic group in Ethiopia. They are mostly pastoralist (Oromia Bureau of Planning and Economic Development, 2000; Gemedo Dalle *et al.,* 2005).

3.1.6 Land tenure and land use type

In Ethiopia, the government is the sole owner of land. Farmers or landholders have only use right, which can be revoked at any time. Land use type in Borana can generally be categorised in to rangeland and farm lands. The basic source of income for Borana is livestock rearing and most of the land in the area is used as rangeland for their cattle. However, there are small scale agricultural practices whenever there is good rain. In most cases, NTFPs collection and use in general and gum and gum-resins, in particular is another dominant activity in the area, mainly during the drought season (Gemedo Dalle *et al.,* 2005; Perso.com. with district experits)**.**

3.2 Methods of data collection

This study had two major components. These are (i) investigating the population status of gum and gum resin bearing species, and (ii) assessing the socio-economic contributions of these species in the livelihood of the local society including the local societies' perception on the future promotion and commercilization of these commodities.The methods used for data collection, therefore, were designed to achieve these two different activties as follows:

3.2.1 Selection and description of study sites

As the aim of this particular research was to study gum and gum resin yielding species (here after refered to as study species), first a review of literature was made on the potential and distrbution of these species in the Borana drylands in general. Several study reports such as Ayana Angasa (1999), Girmai Fitwi (2000), Wubalem Tadesse *et al.* (2002), Mulugeta Lemenih and Demel Teketay (2003a), Mulugeta Lemenih *et al.* (2003), and Gemedo Dalle *et al.* (2005) were examined during the literature review phase. This was followed by a thorough discussion with different bodies among which were the Zonal and Distrcits Agricultural experts, Natural Gum Processing and Marketing Enterprise (hear after refered as NGPME, Yabello branch), and local elders who have knowledge on the study species. The discussion made was focused on the distribution of the study species and accessibility of the districts for the study. Finally, an intensive field recconaisance survey was made to complement the previous efforts to select the study districts. Accordingly, Arero and Yabello districts were selected on the basis of the above criteria.

Plate 2. Vegetation of the specific study sites at Arero (*Boswellia neglecta* stand)

Within the two selected districts sites with relatively good population of the study species were purposively identified. Hence, in Arero district, Wachille woodland, an area about 54 killometers in south eastern direction from Arero town was selected for the study. Wachille woodland was found to be one of the best habitat harboring most of gum and gum resin yielding species with good abundance in Borana zone (Gemedo Dalle *et al.,* 2005; perso. obs.). For instance, Plate 2 shows the abundant population of *Boswellia neglecta* stand selected for the purpose. Within Wachille, four sites namely: Buno, about 7 killometers, Wachu Taka' 35 killometers and Boji 50 killometers from Wachille village in southeastern direction were selected as specific study sites. The other specific study site was Welensu, which was 12-40 kilometers from Wachille village in south western direction on the way to Dire district. According to the discussion made with Zonal Agricultural Office and Yabello branch NGPME, those areas were representative areas with relatively dense vegetation cover and good representaton of the study species**.**

The same procedure was followed to select the specific study sites at Yabello distrct. Three different sites, two of which were dominated by mixed *Acacia-Commiphora* and *Commiphora-Boswellia* and one dominated with *Acacia seyal* were selected for the study. The first study site, Harweyu, is 13 killometers from Yabello town on the way to Dire town and then 7 killometers to the right of the main road. The other two sites, Adegeljet and Ofuu were located on the way to Konso, southwest of Yabello town at an approximatly 45 and 70 killometers respectively. These sites were the major gum and resin production centers at Yabello district (Peros. Com. with Head of NGPME, Yabelo branch).

3.2.2 Vegetation survey

At each selected study site transect lines were systematicaly laid in a north-south compass direction. Transect lines were laid at 500 meters distance appart. Generally, systematically laid transect lines were opted since they are of considerable importance in the description of vegetation changes along environmental gradients or in relation to some marked features of topography (Mueller-Dumbois and Ellenberg, 1974). Along each transect lne quadrats having a size of 20 x 20 meters (400m^2) were systematcally laid at the distance of 300 meters. Accordingly, a total of 75 quadrats (43 at Arero and 32 at Yabello) were used to collect data on the vegetation of the area.

To study the composition and diversity of the woodland in general and study species in particular, data on identity, density, frequency, diameter at breast height and height were recorded for tree, tree/shrub and shrub species rooted in all sample quadrats following the procedures in Tamrat Bekele (1994), Tadesse Woldemariam (2003), Kindeya G/Hiwot (2003) and Gemedo Dalle (2004). Tree diameter was measured using Diameter Tape, while tree hieght was measured using Clino meter. In this particular study, trees or tree/shrubs are defined as woody species with height $\geq$ meter, saplings woody species with hieght $\leq$1meter, whereas seedlings were smaller woody plants with hieght ≤ 50meter (Kindeya G/Hiwot, 2003). In this study, for trees and tree shrubs forked below 1.3 meters, individual stems were separatly measured and then average DBH was taken.

Regeneration pattern of study species were assessed by employing total count of seedling and saplings within the main quadrats. In this case, to make counting easier, each main plots were sub-divided into four squares ($100m^2$) each using ropes and pegs and counting was made within these sub-plots. Plant identification was mostly done at the field level and for those not identifiable at field level, voucher speciemens were collected and further identification was made at the National Herbarum of Ethiopia, Addis Ababa University. Nomenclature of species followed Flora of Ethiopia (Hedberg and Edwards,1995, 1989; Edwards *et al.,* 1997, 2000). Other relevant data like level of vegetation disturbance, soil type, and etc. were collected and recorded based on visual observations while altitudinal data were collected using GPS.

3.2.3 Socio-economic survey

To assess the socio-economic importance of gum and resin bearing species, a semi-structured questionnaire was used to interview household[*] respondents. Interview was made using local language (Afaan Oromoo). A total of four villages, two from each districts surrounding the selected vegetation were systematically identified and 20 housholds from each village were randomly selected. In addition, 12 key informats, 5 from Arero and 7 from Yebello were invited for group discussion. Large number of respondants were not used because of logistic constraints. Discussions with the regional officials, local merchants and NGPME, Yabello branch has also served as source of information.

The respondents were interviewed on different issues like experience in gum and resin collection, species from which they collect, seasons of collection, method of collection, monthly estimated amount of collection, number of collection days per month and number of families participated in collection, purpose of collection, problems associated with gum and resin production and management and the over all

[*] The term household in this paper is used to refer to a household representative individual not an entire family. Because, an individual is selected for interview from a household

perception of the local community on the future sustainable production and commercialaiztion of gum and resins in the area.

The selected households at each site were also asked to group themselves into different categories of wealth status and about 38% of the respondents were categorized as rich, 40% medium and 22% poor households on average. The major criteria they used were number of livestock a household possesses, family size, accumulated capital, and numbers of children sent to school. Generally the selected respondents had an average family size of 7, somewhat large as compared to the national family size, which is 5 (Oromia Bureau of Planning and Economic Development, 2000). The average level of education of the interviewed respondents was only about 17% (including these who at least can write and read) indicating that a considerable proportion of the members of the households did not received any formal education. From the total selected respondents, male accounted for 60 % and female 40 %.

3.3. Data processing and analyses

3.3.1. Vegetation data analyses

Based on the collected ecological data the population status of gum and gum-resin yielding species in particular and all the vegetation in general were examined by computing the abundance, frequency, dominance, importance value (IV), and by constructing population structure. Heterogeneity of the woodland and study species were also determined using Shannon-Weiner diversity and Evenness indices. Comparisons were also made between the vegetation of the two districts. Descriptive statistics were employed to summarise the socio- economic information. Details of the analyses methods used are presented below.

Generally, the composition of the woodland was analyzed as a proportion in percentage of the various species encountered in relation to the total. Thus, the percentage contribution of the study species in various measurable entities compared to the associated species were analzed as follows.

Abundance: Two sets of abundance value were calculated in this study. These were (i) average abundance per quadrats, calculated as the sum of the number of stems of a species from all quadrats divided by the total number of quadrats, (ii) Relative abundance, calculated as the percenetage of the abundance of each species divided by the total stem number of all species ha $^{-1}$ following Kindeya G/Hiwot (2003).

Density: which referece to the total number of stem of a species ha $^{-1}$ was calculated by suming up all the stems across all sample quadrats (abundance) and translated to hectare base for all the species encountered in the study quadrats.

Frequeny: Two sets of frequencey were computed following Kent and Coker (1992) and Kindeya G/Hiwot (2003). Absolute frequency, which is the number of quadrats in which the species recorded (Tadesse Woldemariam, 2003), and relative frequencey of a species, computed as the ratio of the absolute frequency of the species to the sum total of the frequency of all species.

Dominance: It refers to the degree of coverage of a species as an expression of the space it occupied in a given area. Usually, dominance is expressed interms of basal area of the species (Kent and Coker, 1992), and two set of dominace were calculated in this case: absolute dominance (the sum of basal areas of the individuals in m^2/ha), and relative dominace, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species. Dominance was calculated for individual stems with Dbh $\geq$2.5cm.

Basal area (BA) was caculated for all woody species with DBH $\geq$ 2.5cm as BA= $\pi d^2/4$, where BA = basal area in m^2; π =3.14; D =diameter at breast height

Population structure: Population structure of the whole vegetation was constructed to provied the overall regeneration profile of the vegetation and specific study species. To determine the population structure, individuals of each species encountered were grouped into an arbitrary diameter class of size 4cm and height 2m and structure of the species were depicted using frequency histogram of both diameter and height-class disributions following Peters (1996), Mekuria Argaw *et al*., (1999), Kindaya G/Hiwot (2003) and Abeje Eshete *et al.,* (2005). The resulted frequency histograms of the study species, in particular were then interprated as an indication of variations in population regeneration pattern/dynamics following Kumlachew Yshitila and Taye Bekel (2003) and Simon Shibru and Girma Balcha (2004). Further, the histograms were compared and categorised into three most common size-class distributions exhibited by tropical tree populations following Peters (1996). These are: Type I, II and III, whose meaning is discussed in discussion section. In this particular case, structures of the study species were examined using diameter class distribution only.

Regeneration trend analyses: The regeneration status of the study species in particular were summarized based on the total count of seedling and sapling of each species across all quadrats and presented in tables and frequency histograms following Demel Teketay (1996), Mekuria Argaw *et al.,* (1999).

Importance value (**IV**): it was calculated to find out the relative ecological importance of each study species in the woodland. IV was calculated as the sum of relative abundance (%), relative dominance (%), and relative frequency (%) of the species following Kent and Coker (1992), where:

Relative abundance = $\frac{\text{Total no. of individuals of species A}}{\text{Total no. of individuals of all species}} * 100$

Relative Dominance = $\frac{\text{Dominance of species A}}{\text{Dominance of all species}} * 100$

Relative frequency = $\frac{\text{Frequency of species A}}{\text{Frequency of all species}} * 100$

Species diversity: the Shannon-Wiener diversity of the whole vegetation and study species were analysed following Shannon and Wiener (1949). The Shannon-Wiener diversity formula was used to compute the heterogeneity of the sites in terms of species composition and abundance as follow:

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

Where, H'=Shannon-Wiener index

S= the number of species

Pi=the proportion of individuals or the abundance of the ith species expressed as a proportion of the total

$Ln = \log base_n$

In this case, Biodiversity Professional, Version 2 Soft Ware Program (Niel, 1997) was used to run the analyses.

Species richness: it is defined as the number of species per quadrat, area or community. In this particular case, the number of observed species across the whole sample quadrats were used as a representation of species richness.

Evenness: This is a new concept attempting to quantify the unique representation of a given species against a hypothetical community in which all species are equally common, such that when all species have equal abundance in the community, were calculated following Kent and Coker (1992). Biodiversity professional, Version 2 Soft ware program (Niel, 1997) was used to run the analyses.

$$\text{Equitability (evenness) } J = \frac{-\sum_{i=1}^{s} pi \ln pi}{\ln S}$$

Where; pi, lnS and ln were as mentioned above.

Coefficient of floristic similarity: the floristic similarity between the vegetations of the two districts, in terms of species composition of the whole species and the study species were compared using the Sorensen's similarity coefficient (Ks) as follows:

$$\text{Similarity (Ks)} = \frac{2c}{(a+b)} * 100$$

where:

a = number of species in district 1
b = number of species in district 2
c = number of species common to both districts

3.3.2 Analyses of socio-economic data

The content of the interviews of individual respondents and group discussions with the key informants were summerised and discussed using descripitve statistics such as percenetages and tables.

4. Results

4.1 Floristic composition of woody species

From the established sample quadrats at the two study districts, a total of 64 woody species (41 at Arero and 23 at Yabello) distributed in 23 families and 31genera were encountered (Table 2). Among the families, Burseraceae and Fabaceae were the two most diverse families each represented with 12 species and constituting 37.5% of the species composition of the study areas. Tilaceae was the second diverse family represented with 4 species and contributed to 6.25%, while 8 families were represented with only one species each. Among the recorded genera, the genus *Commiphora* was found to be the most diverse genus represented with 9 species and contributed to 14.1% of the species composition of the study areas. The second diverse genus was *Acacia*, which was represented with 5 species. Among the collected specimens 14 species were trees, 37 tree shrubs and 13 shrubs. Hence, of the 64-recorded species, trees and tree/shrubs were the dominant growth forms accounted for about 80% of the total species composition while shrubs contributed only 21% of the total composition.

Table 2. Summary of the number of plant families, genera and species found in the studied woodlands of Borana lowlands, Ethiopia

Entities	**Whole vegetation**		**Gum and resin bearing species**	
	Arero	**Yabello**	**Arero**	**Yabello**
Number of families	16	7	2	2
Number of genera	21	10	3	3
Number of species	41	23	14	11
Proportion of species composition of study species (%)			34	48

Referring to those species responsible to yield the socio-economically important products such as oleo-gum resins, they were much diverse in Borana lowlands. In this study, a total of 15 woody species (14 at Arero and 11 at Yabello) were recorded to hold commercial gums and incenses (Table 3). Among these oleo-gum resin bearing species, 9 species belong to the genus *Commiphora*, 3 to the genus *Boswellia* and 3 to the genus *Acacia.* Two of the *Commiphora* species namely*: Commiphora myrrha & Commiphora terebinthina* and two of the *Boswellia* species*: B. microphylla & Boswellia rivae,* which were among the lists of species in Arero district, were not found in any of the study quadrats at Yabello district. On the other hand, *Acacia seyal,* which was among the lists of species in Yabello, was not encountered in any of the study quadrats at Arero district. The rest of the study species were found to be common to both study districts (Tabel 3). Hence, Arero district is more or less richer in terms of species composition of the genus *Commiphora* and *Boswellia* than Yabello.

Table 3. List of gum and incense bearing trees and tree shrubs encountered at the selected study sites in Borana lowlands and their products types. ('x' show presence of the species, while '-'show absence of the species in the districts).

Scientific name	**Family**	**Arero**	**Yabello**	**Product**
Boswellia neglecta	Burseraceae	X	X	Incense
Boswellia micrphylla	Burseraceae	X	-	Incense
Boswellia rivae	Burseraceae	X	-	Incense
Commiphora africana	Burseraceae	X	X	Hagar
Commiphora baluensis	Burseraceae	X	X	Myrrh
Commiphora confusa	Burseraceae	X	X	Myrrh
Commiphora myrrha	Burseraceae	X	-	Myrrh
Commiphora habessinica	Burseraceae	X	X	Myrrh
Commiphora kua	Burseraceae	X	X	Myrrh
Commiphora terebinthina	Burseraceae	X	-	Myrrh
Commiphora boranesis	Burseraceae	X	X	Myrrh
Commiphora schimperi	Burseraceae	X	X	Myrrh
Acacia seyal	Fabaceae	-	X	Gum
Acacia senegal	Fabaceae	X	X	Gum
Acacia mellifera	Fabaceae	X	X	Gum

Note: In this study, category of the products was made following Karamalla (1997) and Mulugeta Lemenih *et al*., (2003).

A total of 27 woody species at Arero and 12 at Yabello were also found to grow in association with gum and gum resin bearing species. Based on the result of species composition analyses, gum and resin bearing species comprised 34 % and 48 % of the species composition of Arero and Yabello districts respectively. For the list of all species from the study areas, see (Appendix 1 & 2). *Grewia tembensis, Grewia villosa, Grewia bicolor, Blepharipermum pubescens, Harmsia sidoides, Vernonia cinerascens*, *Premna schimperi*, and *Ormocarpum trichocarpum* were among the common shrubs found to grow in association with the study species at Arero, while, *G. bicolor, G. villosa, H. sidoides and G. tenax* at Yabello district (Tables 4 & 5).

4.2 Density, frequency, dominance and importance value of woody species

The total density (expressed as the number of stems per hectare) of all woody species was found to be 2098 and 1307 stems ha^{-1} at Arero and Yabello respectively (Tables 4 and 5). A few species of trees, tree shrubs and shrubs were found to predominate the density of the vegetation of the study areas. For instance, five species: *G. tembensis, G. villosa, B. neglecta, A. senegal* and *C. africana* were contributed to 44% of the total density at the study sites at Arero. Similarly five species such as *G. bicolor, C. confusa, A. seyal, A. senegal and G. villosa* contributed to 53% of the total density ha^{-1} of the study sites at Yabello. On the other hand, gum and gum resin bearing species contributed to 47.5% and 66.6% of the density ha^{-1} at Arero and Yabello respectively. From these totals, gum and resin bearing *Boswellia*, *Commiphora* and *Acacia* species were contributed to 11.1%, 26.02% and 10% respectively at Arero, and 5%, 33% and 26% at Yabello (Figure 3).

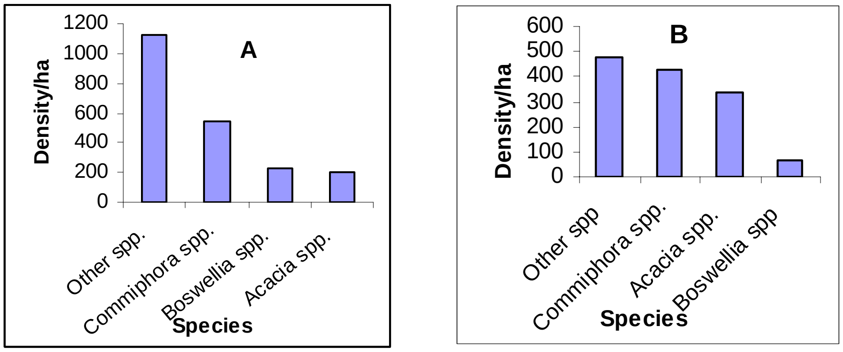


Figure 3. Proportion of the density (stem number ha^{-1}) of oleo-gum resin bearing and associated species at Arero (A) andYabello (B) districts respectively, Borana lowlands, Ethiopia

Considering the individual species, *B. neglecta*, *A. senegal* and *C. africana* were the three top abundant oleo-gum resins bearing species at Arero. These species had 162, 159 and 149 individual ha $^{-1}$ respectively, while, *C. baluensis, C. confusa, C. myrrha, B. micrphylla* and *C. habessinica* were the second abundant gum and resin species in the same district. Likewise, *C. confusa*, *A. seyal,* and *A. senegal* were the three top gum and resin species interms of their abundance at Yabello each represented by 151, 140, and 120 individuals ha $^{-1}$ respectively, while *A. mellifera, C. habessinica, and B. neglecta* were the second in this district. In comparative terms, *C. terebinthina*, *C. schimperi*, *C. boranesis* and *Boswellia rivae* were found to be least abundant resin yielding species at the study sites (Tabels 4 and 5).

Horizontal distribution of the species along the transect lines showed the existence of variation from site to site. For instance, *B. neglecta* and *C. africana* were found to be the most frequent species at Arero. These two species were recorded in 39 out of 43 sample quadrats. The second frequent gum species was *Acacia senegal*, which was recorded in 37 quadrats. In contrast, *Boswellia rivae* was encountered only in few quadrats at Arero. Like wise, *C. confusa* and *A. seyal* were the top two frequent gum and resin bearing species encountered in several quadrats at Yabello district. They were encountered in 25 and 19 out of the 32 sample quadrats, respectively. In this district, *A. senegal* and *C. boranesis* were the second frequent gum and resin species. All other gum and gum resin bearing species were found to be in more or less average horizontal frequencies. Among the associated species, *Terminalia brownii,* *Plectranthus ignarius, Maerua triphylla, Vernonia cinerascens, Indigofera volkensii, and Lanea triphylla* were found to be the least frequent species at Arero district. At Yabello district, *Harmsia sidoides, Dichrostachyus cinerea, Boscia mossambicensis, Grewia tenax, and Sterculia stencarpa* were among the least frequent species encountered in only two to three sample quadrats.

Considering the distribution of the study species across the study districts, most of them had encountered in both districts. For instance, *A. senegal, A. mellifera, B. neglecta, C. africana, C. confusa, C. habessinica and C. baluensis* were among those relatively frequent gum and resin bearing species found across sample quadrats established at both districts. Among the shrub species, *G. tembensis*, *G. villosa* and *G. bicolor* were most frequent at Arero, while *G. bicolor* and *G. villosa* at Yabello. Generally, frequency of the encountered species ranges from 1 to 39 at Arero and from 2 to 25 at Yabello. The result of the quantitative analyses of the density, dominance, frequency and importance value of woody species encountered at the study sites at Arero and Yabello is presented in (Table 4 & 5) respectively.

The result of the analyses of dominance (as calculated from the basal area data) revealed that, *B. neglecta, C. baluensis, C. confusa, A. bussei, and Delonix elata* were the five top dominant species at Arero (Table 4), while *C. confusa, A. seyal, C. habessinica, B. neglecta* and *A. tortilis* at Yabello district (Table 5). *Boswellia rivae* and *C. schimperi* were found to be the least dominant species among the study species at Arero, while *C. boranesis* and *C. schimperi* at Yabello (Tabels 4 & 5). The total basal area ha^{-1} of gum and resin bearing species at Arero was found to be 9 m^2 ha^{-1}. At Yabello district, the total basal area of gum and resin bearing species was 5.2m^2 ha^{-1}.

Table 4. List of species encountered in the study quadrats at Arero in abundance order. (RO= rank order of the average abundance per quadrats of the species. In this table D= density/ha, N=average abundance per plot; %N= relative abundance of the species; F=absolute frequency; %RF= relative frequency; DO=Dominance; RDO= relative dominance; %IV= percent IV)

RO	Scientific name	D	N	N %	F	RF %	DO	RDO %	IV %
1	*Grewia tembensis*	259	10	12.3	23.0	4.1	0.1	1.0	5.8
2	*Grewia villosa*	183	7	8.7	17.0	3.0	0.0	0.2	4.0
3	*Boswellia neglecta*	162	6	7.7	39.0	6.9	1.3	17.2	10.6
4	*Acacia senegal*	159	6	7.6	37.0	6.5	0.2	2.9	5.7
5	*Commiphora africana*	149	6	7.1	39.0	6.9	0.4	5.0	6.3
6	*Grewia bicolor*	94	4	4.5	11.0	1.9	0.0	0.1	2.2
7	*Blepharispermum pubescens*	78	3	3.7	9.0	1.6	0.0	0.5	1.9
8	*Harmsia sidoides*	78	3	3.7	11.0	1.9	0.0	0.2	2.0
9	*Commiphora baluensis*	75	3	3.6	32.0	5.7	1.0	12.9	7.4
10	*Ipomoea donaldsonii*	71	3	3.4	10.0	1.8	0.0	0.4	1.9
11	*Commiphora confusa*	63	3	3.0	28.0	5.0	0.6	7.8	5.3
12	*Commiphora myrrha*	59	2	2.8	21.0	3.7	0.2	2.1	2.9
13	*Boswellia micrphylla*	56	2	2.7	17.0	3.0	0.3	3.9	3.2
14	*Commiphora habessinica*	52	2	2.5	23.0	4.1	0.4	4.5	3.7
15	*Lanea rivae*	49	2	2.3	20.0	3.5	0.4	5.3	3.7
16	*Commiphora kua*	47	2	2.3	21.0	3.7	0.3	3.9	3.3
17	*Acacia bussei*	47	2	2.3	24.0	4.2	0.6	8.2	4.9
18	*Acacia mellifera*	44	2	2.1	20.0	3.5	0.1	1.5	2.4
19	*Commiphora terebinthina*	36	1	1.7	18.0	3.2	0.2	2.2	2.4
20	*Commiphora boranesis*	35	1	1.7	16.0	2.8	0.1	1.8	2.1
21	*Commiphora schimperi*	30	1	1.4	15.0	2.7	0.1	1.2	1.8
22	*Dodonea angustifloia*	30	1	1.4	4.0	0.7	0.0	0.1	0.7
23	*Vernonia cinerascens*	27	1	1.3	3.0	0.5	0.0	0.0	0.6
24	*Indigofera volkensii*	26	1	1.3	3.0	0.5	0.0	0.0	0.6
25	*Lanea triphylla*	20	1	0.9	3.0	0.5	0.0	0.2	0.5
26	*Premna schimperi*	20	1	0.9	6.0	1.1	0.0	0.0	0.7
27	*Kirkia burgeri stannard ssp Burgerii*	19	1	0.9	10.0	1.8	0.2	2.0	1.6
28	*Acacia tortilis*	19	1	0.9	10.0	1.8	0.2	2.9	1.9
29	*Sterculia stenocarpa*	19	1	0.9	13.0	2.3	0.2	2.6	1.9
30	*Delonix ellata*	19	1	0.9	16.0	2.8	0.4	5.7	3.1
31	*Acacia oerfota*	18	1	0.9	4.0	0.7	0.0	0.2	0.6
32	*Boswellia rivae*	12	0	0.6	10.0	1.8	0.0	0.5	0.9
33	*Erythria melanacantha*	10	0	0.5	7.0	1.2	0.1	1.6	1.1
34	*Plectranthus ignarius*	9	0	0.4	3.0	0.5	0.0	0.1	0.4
35	*Maerua triphylla*	5	0	0.2	3.0	0.5	0.0	0.4	0.4
36	*Delonix baccal*	4	0	0.2	4.0	0.7	0.1	0.7	0.5
37	*Sesamothamus rivae*	4	0	0.2	5.0	0.9	0.0	0.2	0.4
38	*Terminalia prunioides*	4	0	0.2	6.0	1.1	0.0	0.2	0.5
39	*Terminalia brownii*	3	0	0.2	1.0	0.2	0.0	0.1	0.1
40	*Ormocarpum trichocarpum*	3	0	0.1	2.0	0.4	0.0	0.0	0.2
41	*Hibiscus crassinervius*	1	0	0.1	2.0	0.4	0.0	0.0	0.1

Generally, the sum of the importance value (IV) of gum and gum resin bearing species were found to be 69.8% and 60.2% at Arero and Yabello respectively. Based on the result of the comparison of individual species in terms of their importance value (IV), *C. confusa*, *A. seyal*, and *A. senegal* were the three most important species at Yabello. Other important species include *C. habessinica, C. africana, B. neglecta*, *G. bicolor* and *A. mellifera* at the same district. At Arero, the top three gum and resin species with relatively high IV in ascending order were *B. neglecta, C. baluensis*, and *C. africana*. The next species with relatively high IV includes *A. senegal* and *C. confusa*. Among the gum and resin bearing species, *B. rivae*, *C. schimperi* and *C. boranesis* were species with least important value at Arero while, *C. boranesis* and *C. schimperi* at Yabello.

Table 5. List of species encountered in the study quadrats at Yabello in abundance order. (RO= rank order of the average abundance per quadrats of the species. In this table D= density/ha, N=average abundance; %N= relative abundance of the species; F=absolute frequency; RF= relative frequency; DO=Dominance; RDO= relative dominance; %IV= percent IV). The list of species that include scientific name, local name, families and growth habit of tree species is given in Appendex (2)

RO	Scientific name	D	N	N%	F	RF %	DO	RDO %	IV %
1	*Grewia bicolor*	176	7.03	21.09	11	4.82	0.01	0.10	6.13
2	*Commiphora confusa*	151	6.03	7.96	25	10.96	1.40	21.46	14.66
3	*Acacia seyal*	140	5.61	9.74	19	8.33	1.11	17.10	12.05
4	*Acacia senegal*	120	4.82	8.83	18	7.89	0.31	4.72	7.28
5	*Grewia villosa*	100	4.00	12.00	11	4.82	0.05	0.80	4.43
6	*Commiphora africana*	85	3.39	8.00	14	6.14	0.39	6.00	6.21
7	*Acacia mellifera*	74	2.97	6.13	16	7.02	0.17	2.67	5.12
8	*Commiphora habessinica*	66	2.64	6.21	14	6.14	0.51	7.76	6.31
9	*Boswellia neglecta*	65	2.61	6.62	13	5.70	0.49	7.51	6.06
10	*Commiphora kua*	47	1.88	5.64	11	4.82	0.32	4.91	4.44
11	*Commiphora baluensis*	44	1.76	5.80	10	4.39	0.31	4.76	4.17
12	*Acacia oerfota*	42	1.67	7.86	7	3.07	0.02	0.27	2.18
13	*Harmsia sidoides*	40	1.61	26.50	2	0.88	0.03	0.53	1.49
14	*Acacia bussei*	33	1.30	3.91	11	4.82	0.40	6.08	4.47
15	*Acacia tortilis*	32	1.27	3.23	13	5.70	0.45	6.88	5.01
16	*Commiphora schimperi*	24	0.97	4.57	7	3.07	0.13	1.92	2.28
17	*Lanea rivae*	20	0.82	3.38	8	3.51	0.19	2.98	2.68
18	*Dichrostachyus cinerea*	13	0.52	8.50	2	0.88	0.01	0.19	0.69
19	*Commiphora boranasis*	13	0.52	4.25	4	1.75	0.06	0.87	1.20
20	*Grewia tenax*	7	0.30	3.33	3	1.32	0.00	0.01	0.64
21	*Sterculia stenocarpa*	7	0.27	3.00	3	1.32	0.07	1.09	0.98
22	*Balanites aegyptica*	5	0.18	1.50	4	1.75	0.06	0.93	1.01
23	*Boscia mossambicensis*	3	0.12	2.00	2	0.88	0.03	0.45	0.52

4.3 Population structure

4.3.1 Population structure of the whole vegetation

The comparative patterns of the population structure of the vegetation of the two districts are presented in (Figure 4). The result depicts the existence of variations in diameter size classes of the vegetation at both districts. Abundance of stems, in general, was very high at lower diameter classes. Good abundance of individual stems was found up to the 4^{th} diameter class. The higher classes were represented with both few individuals and species, and hence, species richness decreased with increasing diameter class. For instance, at Arero district diameter class 8 & 9 were represented with few (4&1) individuals, while at Yabello, these classes were represented with only one individual each. Generally, the pattern of diameter size distribution of the vegetation was found to be inversely proportional to the increasing diameter class at both districts, but show more or less, uniform trend of declining of stem abundance. In other words, the vegetation structure at both districts was a reversed J-shape distribution.

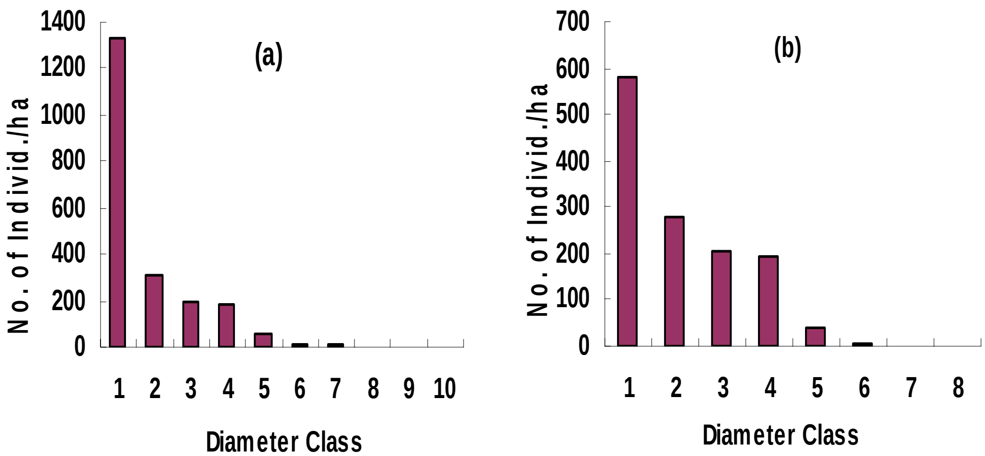


Figure 4. Diameter size class distribution of the entire vegetation at Arero (a) and Yabello (b) districts, Borana, Ethiopia. (Diameter class (DC) in cm: 1=0<4cm, 2=4<8, 3=8<12………… 10=34<38).

Mean while, the pattern of height size class distribution of the vegetation varied from species to species but more or less the same for the two districts (Figure 5). The height class distribution show the representation of few individuals at lower class, followed by abrupt increase in the second class (class 2) and then followed with a regular decline in abundance for both districts. The first classes were represented with most of the shrub species whose height was less than two meter. Most of the other species including gum and gum resin yielding species fall in class 2 &3 (Fig. 5). The next few classes (4&5), were represented with some of the *Acacia* species (*A. tortilis and A. bussei*) including some of the gum and gum-resin yielding species.

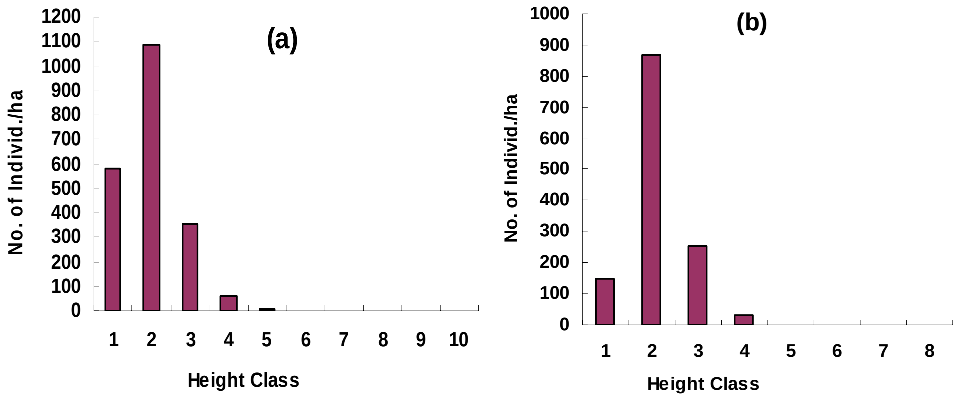
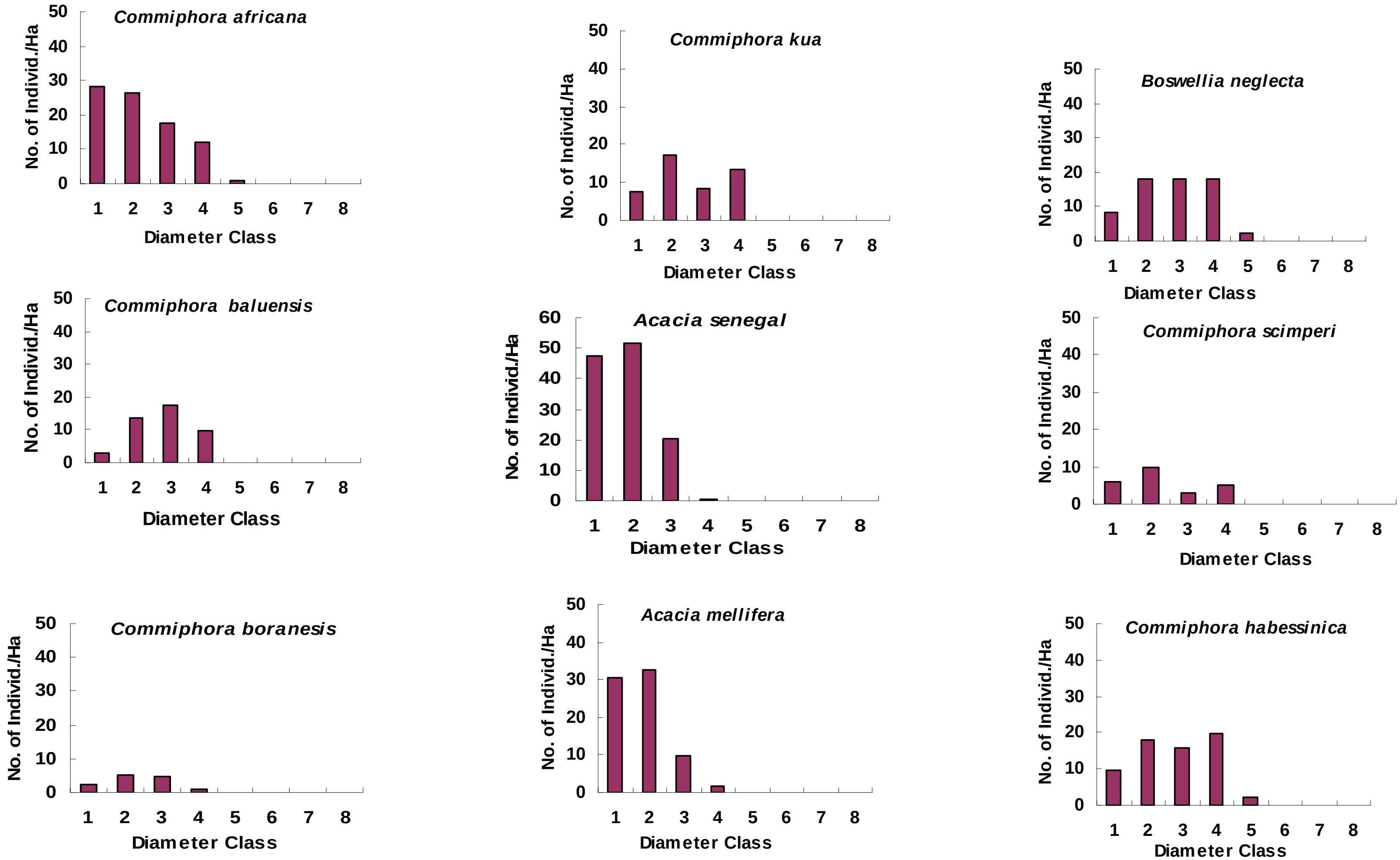


Figure 5. Height class distribution of the entire vegetation at Arero (a) and Yabello (b) districts, Borana, Ethiopia. (Height class (HC) in m: 1=0<2, 2=2<4…..10=16<20).

4.3.2 Stem diameter distribution of oleo-gum resin bearing species

The population structures of the study species were separately treated and presented in Fig. 6 and 7 for both study districts. Based on the analyses of population structures, the study species encountered at the study areas were grouped into three categories: type I, II, and III.

Accordingly, *C. africana, A. mellifera, A. senegal* were among the species showing type-I structural distribution. *C. kua*, *C. habessinica*, *C. schimperi, C. confuse,* and *A. seyal* were grouped as type-II at Yabello, while *C. baluensis* and *C. boranesis* were grouped as type-III at Yabello. At Arero district, *C. africana, C. myrrha, A. senegal, A. mellifera* and *C. schimperi* were grouped as species with type-I distribution pattern, while *C. kua, B. neglecta*, *B. microphylla, C. habessinica*, *C. boranesis*, *C. terebinthina, C. baluensis* and *C. confusa* were grouped as type-II species. In this district however, *B. rivea* was grouped in type-III distribution pattern.


Commiphora africana
Commiphora kua
Boswellia neglecta
Commiphora baluensis
Acacia senegal
Commiphora scimperi
Commiphora boranesis
Acacia mellifera
Commiphora habessinica
No. of Individ./Ha
Diameter Class

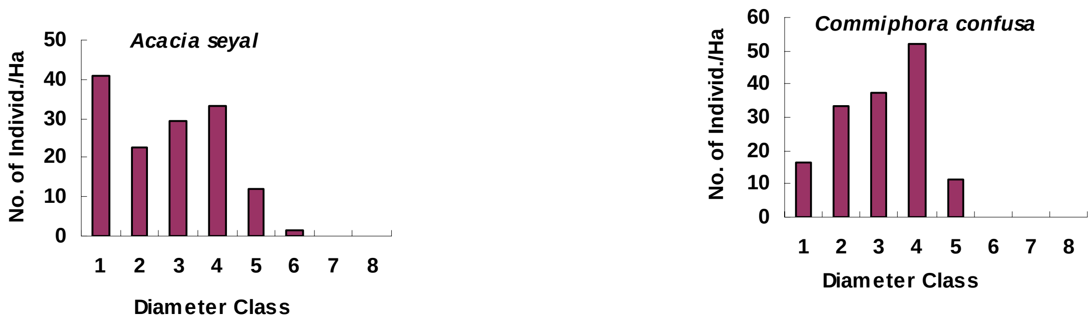
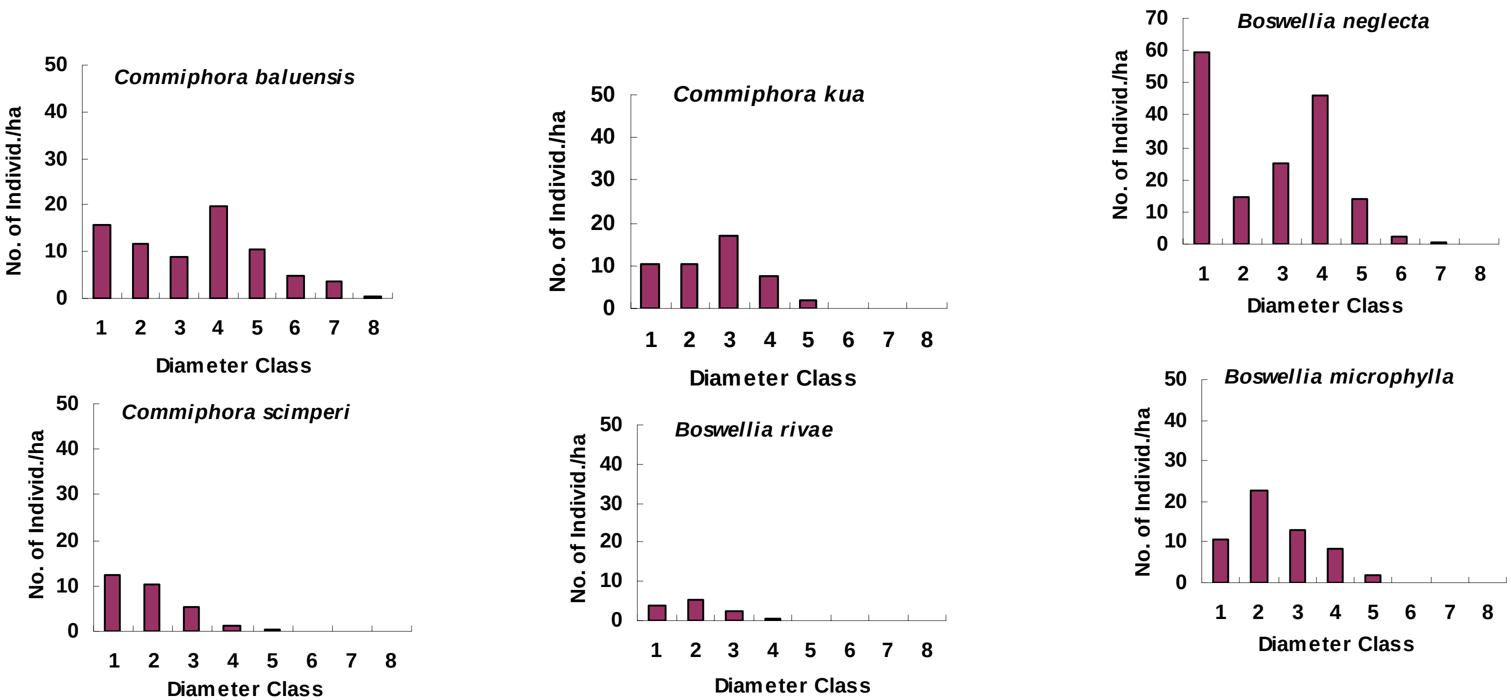


Figure 6. Diameter class distributions of gum and resin bearing species at Yabello, Borana. Diameter class (DC) in cm: 1=0<4cm, 2=4<8, 3=8<12, 4=12<16, 5=16<20, 6=20<24, 6=24<28, 7=28<32, 8=32<34, 9=34<38



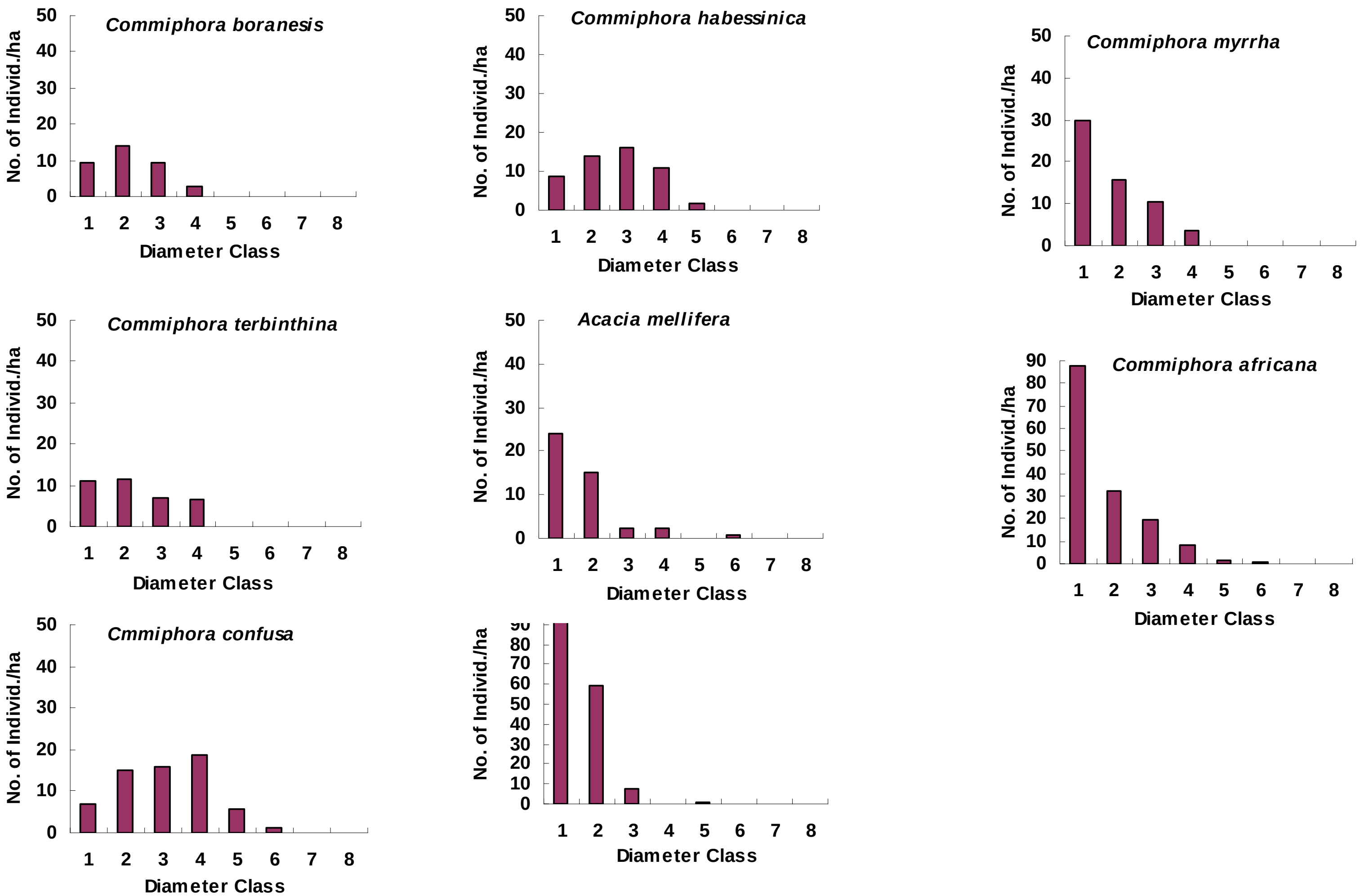


Figure 7. Diameter class distributions of gum and gum resin bearing species at Arero district, Borana. Diameter class (DC) in cm: 1=0<4cm, 2=4<8, 3=8<12, 4=12<16, 5=16<20, 6=20<24, 6=24<28, 7=28<32, 8=32<34, 9=34<38

4.4 Diversity, evenness and similarity of woody species

Summary of the computed Shannon-Wiener diversity H' and Shannon evenness for the entire vegetations and the study species is presented in (Table 6 and 7). Comparing the diversity of the vegetation of the two districts, the diversity of the vegetation at Arero was higher than Yabello (Table 6).

Table 6. Summary of diversity parameters for the whole species encountered in the study quadrats at Arero and Yabello districts, Borana zone

Characteristics	**Districts**	
	Arero	**Yabello**
Species richness	41	23
Density/ha	2098	1307
Evenness	0.87	0.78
Diversity H'	3.22	2.77

Considering the study species alone, the Shannon diversity H' was found to be 2.6 and 2.23 for Arero and Yabello respectively (Table 7). The Shannon evenness for the study species also depicted an even distribution of the species in the study sites. The Sorenson's similarity of all species encountered at the study sites of the two districts was found to be 56.25%, while the similarity between the study species of the two districts was 80 %.

Table 7. Summary of the diversity parameters for gum and gum resin yielding species at Arero and Yabello districts Borana, Ethiopia

Characteristics	Districts	
	Arero	Yabello
Species richness	14	11
Density/ha	980	830
Evenness	0.88	0.82
Diversity H'	2.6	2.23

4.5 Regeneration status of gum and resin bearing species

Regeneration status of the woodland as a whole was examined using the result of the diameter size class distribution of the vegetation as a whole (Figure 4). Hence, the frequency histograms of the vegetations of both districts were skewed to an inverted "J"-shape. The current regeneration status of a given plant species population can also be examined by counting the number of individual seedlings and saplings of that particular species. Accordingly, density/ha of seedlings and saplings of the study species was found to be 36 and 87 respectively at Yabello while it was 314 and 70 at Arero.

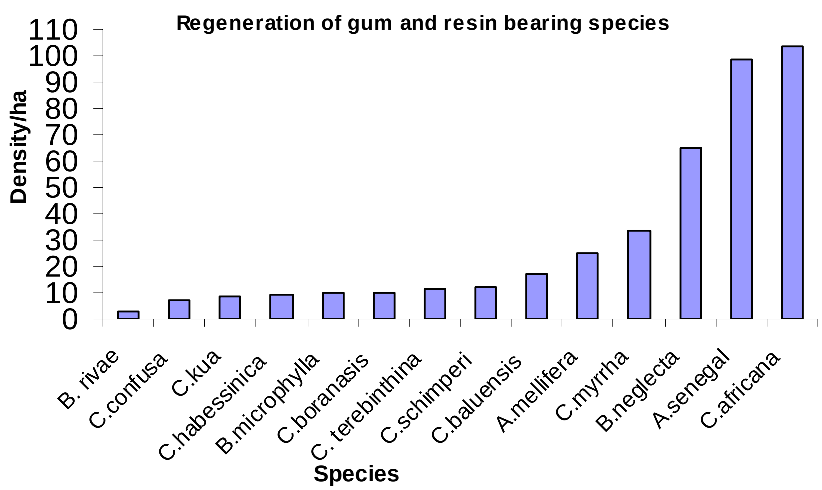


Figure 8. Regeneration status (seedling + sapling) of gum resin species at Arero district, Borana zone

Density ha $^{-1}$ of seedlings and saplings of the study species were given in (Figure 8 & 9) for Arero and Yabello districts respectively. Based on the comparison of the regeneration status of the study species among themselves, at Arero district, *C. africana, A. senegal and B. neglecta* were the top three species represented with better density of seedling/sapling, followed by *C. myrrha,* and *A. mellifera*. As compared to the other study species, *B. rivae* and *C. confusa* were found to be species with poor regeneration condition at Arero district (Figure 8). On the other hand, *A. seyal*, *A. mellifera, A. senegal* and *C. africana* were the most dominantly regenerated species at Yabello district. *C. confusa, C. baluensis, C. kua, C. schimperi* and *C. boranesis* were not found at seedling level in all the study quadrats in this district, even though they were represented at sapling stage. Like wise, *C. baluensis* and *C. boranasis* were found to be represented with only few individuals at early stage, showing hampered regeneration condition as compared to the other study species (Figure 9).

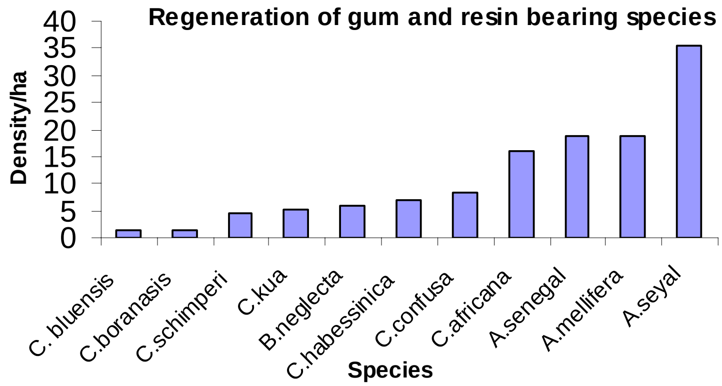


Figure 9. Regeneration status of (seedling + sapling) gum resin species at Yabello, Borana zone

4.6. Socio-economics of gum and resin bearing species in Borana

4.6.1 Major livelihood occupations of communities in the study sites

Generally, household resource base in the study areas has typical of subsistent pastoralist and agro-pastoralist nature. Almost 86.3% of the household respondents were dependent on livestock production, while 23.2% of the respondent households had combinations of farmland and livestock. The average size of the households owning farmland was 0.45-hectares, while the average livestock possession was 89 heads per household. Livestock rearing is identified as the major economic activity in both of the studied districts (Table 8). Comparng the two districts, the number of households with farmland are fewer at Arero than at Yabello. Collection of wood and NTFPs in general and gums and gum resins in particular also share a significant portion of the day-to-day subsistence activities of the communities (Table 8). Particularly, 7.5% households from Yabello and 5% from Arero were totally without both livestock and farmland, but depend purely on wood and non-wood forest products, mainly on collection and sale of gum and resins.

Table 8. Major livelihood activities and source of income in Borana lowlands, Ethiopia. (LS= livestock rearing, AG=agriculture, GR=gum and resins production and sale, OR=other activities. Numbers show the rank: 1 means main, 4 means least source of livelihood).

Householde livelihood strategy	**LS**	**AG**	**GR**	**OR**
Arero	1	3	2	4
Yabello	1	2	3	4

In Yabello farming become a common exercise compared to Arero, showing food crop production was the second major activity in that area. Whereas in Arero, where farming is less common, gum and incense collection and sale is the second predominant activity (Table 8). Very few people got employment opportunity, for instance in NGOs locally working on water and health center development, and few engaged in craft making and mini-trade in both districts.

4.6.2 Production of gum and gum resins by local people in Borana lowlands

4.6.2.1 Knowledge of the local people on the study species

The majority of the respondents in study area (98%) had good knowledge about the diversity, abundance, and regeneration status of gum and gum resin bearing species in their vicinity (Table 9). They were able to identify the species and type of gum they produce, best collection sites, factors affecting quality and quantity and good collection seasons. Moreover, most of the respondents, mainly the elders have good knowledge on the different uses of the study species (Table 11 and 12). Regarding the regeneration status of the study species, respondents recognized the declining state of the natural regeneration of some of the study species in the area. Nearly 100% of the respondents pointed out that recurrent drought, increased human population, expansion of permanent settlement and over domination of few species as a result of prohibition of human induced bush fire are the main factors affecting the natural regeneration of these species. About 51% of the respondents indicated that overgrazing impacted natural regeneration in two ways in the form of trampling and browsing of seedlings.

However, with respect to knowledge on the importance and value of gum and gum resins at national and international level, most of the respondents had little awareness.

Hence, they were not fully engaged in the production of these commodities, while good potential was there.

Table 9. Summary of the status of awareness/attitude of respondents to future gum and resin resources management and commercialization

Itemes	Yes%	No%
Do you know the abundant existence of gum and resin bearing species in your area ?	98	2
Do you collect gum and resin?	57.4	42.6
Do you collect for sale	90	10
Are you member of association/Waldaa?	35	65
Do you want to be member?	94.2	5.8

4.6.2.2 Types of gum and resin products collected and traded by the locals and their botanical sources

According to the survey result, about five types of gums and resins are currently collected either for local or commercial purposes in Borana lowlands. The most commonly known gum and resins in the areas are gum arabic and gum talha obtained from *A. senegal* and *A. seyal,* respectively, and frankincense, which is collected from *B. neglecta, B. mircophylla,* and *B. rivae*. Myrrh is collected from different species of the genus *Commiphora*. *C. myrrha, C. confusa, C. kua, C. habessinica, C. boranesis, C. schimperi* and *C. terebinthina* were among the species from which collection is being made at the moment. According to Ermias Dagne *et al.,* (1997), in strict sense the source of true myrrh was *C. myrrha*. Nonetheless, resins of other *Commiphora* species are collected and traded either as adulteration of the true myrrh or other forms of myrrh. Hagar is a product collected from *C. africana*.

Resins collected from *C. africana* and *C. baluensis* were mainly used for local purpose. The respondents also indicated that whenever there exist high demand and inviting price, collection of gum was made from different species of acacias like *A. drepanolobium* and *A. oerfota* (the major native encroaching bushes) and mixed with gum collected from *A. senegal* and *A. seyal* to increase trade volume. According to the key informants, collection was even made from *S. stenocarpa* and *L. rivae* and mixed with gum acacia. The local buyers, for instance, Gum and Resin Collectors

Association at Wachille and some of the key informants pointed out adulteration as one of the major factors affecting local price in the areas.

4.6.2.3 Production processes and collection materials used

Collection of gums and incenses in Borana area is performed on natural stands and naturally exuding (Plate 3). The producers are mainly herdsmen, women and children, and they do the collection side by side with herding and other activities. In this particular study, it was found that only 12.5% of the respondent households from Yabello and 5% from Arero district possessed trees in vicinity to their home or inside their homestead, and managing them as private resource. This indicates that gum and incense trees are not domesticated and owned individually but are confined mostly to wild and natural woodlands in Borana drylands.

Plate 3. Naturally oozed gum of *Acacia senegal* and incense from *Boswellia neglecta* tree, photo taken from Wachille woodland.

The Borana pastoral and agro-pastoral communities do not practice any tapping techniques even though tapping is a very important operation for effective harvesting. In most cases, collection was made when the tree trunk naturally ooze and collection made both from tree trunk and ground. As far as tapping is concerned, the respondents pointed out that, the naturally available resource was enough for the current demand. Children and women were the key actors in collection, transporting and marketing of gum and resin in the study areas (Plate 4). However, according to the group discussion results, some times mainly during the slag-periods, and when there was high demand for the products, collection was made without any discrimination of either age or sex. The discussion also revealed that, gum collection was a family work among those households with either few or no livestock and farmlands.

Plate 4. Children collecting gum and incense and the local materials they used for collection

The local collectors used materials like axe and knife to detach the gum from the tree trunk and branches. They used different bags and a material locally called biry during collection time and different bags and sakes for temporary storage purpose. Collection was made piece-by-piece, and then transported to market or sale to occasionally appearing buyers coming to the village. Gum grading is not as such a common practice in Borana. However, some times they grade using simple visual criteria such as colour, brightness and size. In some areas it had been observed that buyers fix the price based on the grade of the products. According to the household response, amount to be collected and consistency of collection was affected by social status, family size, market demands, price and the availability of resources near resident areas.

4.6.3 Collection schedules and factors affecting yield and quality

Though not strict, harvesting of gum and gum resin in Borana, is usually performed during the dry seasons. Good collection is often made between December and February and between June and August, which are the two dry periods in the area. These months are also periods when good quality gum and resin are collected. However, according to the key informants, poor families carryon the collection throughout the year, though quality and quantity is low especially during rainy seasons. Moisture was mentioned as major factor deteriorating gum quality. Prolonged rainfall, which shortens the dry season, is also known to affect both quality and quantity. The respondents revealed that, high temperature is conducive to good gum flow and to increases quality, even though an extended drought may reduce quantity. They further mentioned that altitude affect both quality and quantity. The respondents showed that as altitude increase the quality of gums and resins drop. The other major factor they mentioned as quality determinant was post harvest handling. For instance, drying under direct radiation cause change in color of gum arabic and it break the grains of incense in to smaller pieces. Storage time, storage materials and storage sites were also mentioned as factors to affect quality.

5.6.4 Contribution of gum and gum resin collection to households economy

Household income source assessment result showed that the contribution from gum and gum resin collection and sale is significant. The activity is an emmergency and regular means of cash income generation for households in both districts. Summary of the amount of cash income generated by a household from the sale of these products is presented in (Table 10). As shown in table 10, the estimated annual income generated per household is 2670 and 2400 birr at Arero and Yabello respectively. However, respondents and partcipants of group discussion mentioned that the annual income that can be generated from gum and insence could have far exceed the above figures as the potentials for production are very high in the areas. According to the survey result, currently only limited number of days per month and few members of the family were participated on gum collection (Table, 10). The respondents also pointed out that if market conditions, price and demand improve, they will increase both the number of participants and the number of collection days per month.

As it was in various parts of the country, farming practice in Borana was not able to produce food for all families and food shortage is a common event even in normal dry seasons at the area. Consequently, households are obliged to sale their cattle with low cost and buy grains with relatively high cost. Among the several advantages gum and resin had, their ability to be accessed by the household during the dry seasons where other options were either declined or not available at all. In line with these, the majority of the respondents (87.3%) believed that gum and resins may be the first most quick and even more sustainable means of getting income for the local society. More importantly, collection of gum and resin is almost the sole means of getting cash for school children and women, as they are not allowed to sale cattle or agricultural out puts without the permission of the head of the household.

Table 10 . Summary of the average annual collection volume and income generated by household from sale of gum arabic, frankincense and myrrh in Borana, Ethiopia. In this case, collection is made for six months/year and on average 3 members of the family participated in collection each for an average of 10 days per month.

Commodity	**Daily collection in Kg**		**Annual collection in kg**		**Local price in Birr**		**Estimated annula income in Birr**	
	Arero	**Yabello**	**Arero**	**Yabello**	**Arero**	**Yabello**	**Arero**	**Yabello**
Gum rabic	2.5	4	300	480	3	2	900	960
Frankincense	3	3	360	360	2	1.50	720	540
Myrrh	2.5	2.5	300	300	3.5	3	1050	900
Total							**2670**	**2400**

4.6.5 Other uses of gum and resin bearing species in Borana zone

As it had been discussed earlier, pastoralism is the dominant mode of life in Borana low lands, and livestock is their principal possession. Here comes the key role of the woodland vegetation as the major supporter of livestock in the study areas. According to the response of the local community, the family Burseraceae and Fabaceae were known for their provision of nutritious fodder for their livestock. If not all, most of the gum and gum resin bearing species were palatable to either livestock or other wild browsers.

A question was included to rank the woodland vegetation into different land use systems and thereby majority of the respondents (56.3%) ranked it as rangeland their first priority, while 41.7% want it to serve both as rangeland and gum and resin collection simultaneously. Very few respondents had wished some parts of the woodlands vegetation to be delimited and managed for better production of gum and resins and other NTFPs only.

Table 11. Gum and gum resin bearing species used for medicinal purpose, type of ailment and part used in Borana

No.	Species name	Part used	Purpose used for
1	*Commiphora baluensis*	Resin	Anti ticks and snakebite
2	*Commihpora kua*	Resin	Skin wound
3	*Commiphora habessinica*	Resin	Skin wound
4	*Commiphora africana*	Bark, resin and leaf	Snakebite, skin would, Tumour, tick control, stomachache
5	*Commiphpra myrrha*	Resin	Stomach-ache, to avoid erection of male genital organ
6	*Commiphora schimperi*	Resin	Treatment of wound/ulcer, Repealing calves from breast feeding
7	*Acacia mellifera*	Gum	Blood clotting
8	*Acacia seyal*	Gum	Treatment of dysentery
9	*Acacia senegal*	Gum	Treatment of gastro-intestinal and stomach pain

Those who preferred the vegetation to be managed as gum production stand were those who currently devoid of livestock, i.e. poor families. They justified their choice by indicating that livestock production is a risky business mainly during the drought season, and they became poor because all their livestock had been gone due to the past severe and recurrent droughts. They emphasized the need to diversify livelihood options in such away that reducing number of livestock so that significant portion of the woodland would be allocated for NTFPs in general and gum resin production in particular. They also recommended the need of intensive and well organized large-scale production of gum and resin so as to contribute to the solution of long lasting problems of the Borana pastoral communities.

Table 12. Summary of different use of gum and resin bearing species at local level in Borana and use of gum and resins at international level. In this case, (-) represents No, while (+) represents Yes.

Species name	**Purpose of use**					
	Famine food/ chewing gum	**Fodder**	**Sanitation**	**Fumigation**	**Cash**	**International application**
Commiphora baluensis	-/+	+	-	+	+	*Pharmaceutical/folk medicine/perfumery/incense*
Commihpora kua	+/+	+	+	+	+	*Pharmaceutical/folk medicine/perfumery/incense*
Commiphora habessinica	-/+	+	-	+	+	*Pharmaceutical/folk medicine/perfumery/incense*
Commiphora africana	-/-	+	-	-	+	*Pharmaceutical/folk medicine/perfumery/incense*
Commiphora myrrha	-/-	+	-	+	+	Pharmaceuticals
Commiphora terebinthina	-/-	+	-	+	+	*Pharmaceutical/folk medicine/perfumer/incense*
Commiphora confusa	-/+	+	-	+	+	Pharmaceutical
Commiphora boranasis	-/+	+	-	+	+	*Pharmaceutical/folk medicine/perfumery/incense*
Boswellia neglecta	-/+	+	-	+	+	*Pharmaceutical/folk medicine/perfumery/incense*
Boswellia microphylla	-/+	+	-	+	+	*Food/pharmaceutical/folk medicine/perfumer/incense*
Boswellia rivae	-/+	+	-	+	+	*Food/pharmaceutical/folk medicine/perfumer/incense*

Acacia senegal	+/-	+	-	-	+	*Food/beverage/pharmaceutical/textile/paper/adhesives*
Acacia seyal	-/-	+	-	-	+	*Non food industries*
Acacia mellifera	-/+	+	-	-	+	*Non food industries*

The local community has also stressed their long-standing tradition of using plant species as their main sources of medicine for both human and livestock diseases. The respondents pointed the uneven distribution of modern health centers in most parts of the study areas. Health center, if existed, they were confined at towns and not at rural villages being inaccessible for most of the pastoral community. Hence, they have developed a wealth knowledge of ethno-medicine and had historical dependence on traditional healing system. The traditional healers are able to treat different infections such as eye infection, bleeding, wounds, ulcer, stomachache, gastro-intestinal infections, skin infections, etc, at which gum and resin species are the most commonly used ingredients in preparation of the medicines. Though it needs further investigation, this is an implication that these species are active against in treating microbial infections. Summary of gum and resin bearing species reported by the local community as medicinal species, part used and ailment types are presented in (Table 11).

The hardened resinous plant exudates, extracted from various tree shrubs are also used locally for many other purposes. For instance, the Borana pastoralists usually use the aroma of frankincense and myrrh as fumigants on the religious and cultural occasions. Myrrh is commonly used for hygienic purposes by the local society. For instance, the resin of *C. kua* was put in boiled water and its suspension is used as an ordinary soap to wash cloth, body and other domestic vessels. They also use the suspension to dispel bad smells in house, and keep visiting flies, snake, ants, anthropods and mosquitoes away. The incense of *B. rivae, C. myrrha* and *C. kua* are locally used as candle.

Respondents also acknowledged the role of *A. senegal* gum as famine food mainly during food shortage periods. The local people also commonly chew gum of different *Commiphora* and *Boswellia* species as ordinary gums mainly to get relief from thirst. The Borana elders prepare writing ink and dyes from resin of *C. africana, C. habessinica and C. baluensis*. Furthermore, they prepare tea from the bark of *C. africana.* The local people use different parts of these species as construction, life fence, fuelwood, bee keeping and carving of different utensils. More importantly, gum and resin bearing species also served the community as shade trees, windbreaks and protecting the soil from the prevailing wind and water erosion and thereby maintaining the normal functioning of the ecosystems. Furthermore, they are source of bush meat through harbouring different wild animals. Arero and Yabello are also one of the Important Bird Areas (IBAs) in Ethiopia and these woodlands could be the potential source of eco-tourism as several bird watchers came to the areas and pay for the local people.

4.6.6 Perception/attitude of respondents on the gum and gum resin resources management and commercialization in the future

Broadly, the respondents were categorized into two groups based on their perception/attitudes on the future production of the commodities in the area. Majority of the respondents (94.2%) had an interest to make gum and resin collection one of their future major activities, while very few (5.8%) showed no interest, and these latter groups rather sought to rely on livestock and farming (Table 9). The first group, with interest of future involvement had an interest to integrate gum and incense production with livestock production. They also acknowledged the significant contribution of gum and gum resin bearing species to environmental protection, and to their economic and cultural needs. Some of these respondents even mentioned their interest to own the woodland and manage it partly for gum and resin production. Regarding domestication of the species, 52.4% from Arero and 74.2% from Yabello had an interest to domesticate some of the species, those with high economic return.

Majority of the household respondents, (92.3 %) from Arero and (96%) from Yabello were in favour of establishing collectors association. These groups wanted to fully participate in the business provided that they will be organized encompassing very interested individuals. This could be considered as one of the existing good opportunity to develop the gum and resin production at Borana lowlands in the future. In general, those households with very large livestock and other possessions are less interested than those with intermediate and poor households. As they were very loyal to traditional taboos, those rich groups consider gum collection as poor men business and they were ashamed of participating in such activities. Hence, they preferred if the woodland serve purely as rangeland. Different to the above situation, two respondents from Yabello were not interested in gum collection though they were categorized as very poor households. The reason they mentioned was traditional taboos. They had also less awareness on how these commodities can fetch income.

4.6.7 Views of experts and local merchants on trade and market potentials of natural gum and incense resource in Borana

Discussion was made with expertise from different offices and few local merchants who currently are engaged in trading of gum and incense. According to them, given attentions, this sub-sector will play a great role in countries like Ethiopia where capital shortage is the bottleneck to rural development. They also pointed out that, as there are many gum and resin bearing species found to grow in various drylands of the country and as there exist an increasing demand for these products at global level, it could be taken as a comparative advantage in solving the overwhelming famine and environmental degradation problems in the drylands of the country. According to them, this can be achieved through enhancing both the rate of production and export volume. They further discussed that, collection of gum and resin could have played significant role in helping the poor to have a daily access to money to achieve food security.

4.6.8 Potential constraints affecting the production and commercialization of gum and resins in Borana lowlands

Despite its big potential to contribute to development and conservation of drylands, there are several associated constraints that affect the full utilization of gum and resin resource in Borana lowlands. Broadly, the observed problems can be grouped as lack of: infrastructural facilities, low markets prices, lack of appropriate knowledge, traditional taboo, transboundary effects, and lack or scarcity of capital. Sites that hold good population of the resource species are found far off roads and residence centres such as major villeges. These sites are also characterized by lack of potable water, restorants, very high temprature that make working environment harsher, and high disease prevalence such as malaria. In general, the collected gum has to be transported several kilometers to get to market, and this is usually done by human labor. This in turn affects cost and volume of productions of gums and incense.

The existing low price as comparable to the tedious production activities is also another factor that constrain better production. Almost all of the respondents pointed out that collection is hardous and is not compatible to the local price offered in the market. A significant number of the respondents (61.4%) were mentioning that lack of approparriate technologies that increase efficiency of collection and preserve the quality of the produce even during post harvest are also lacking.

According to the group discussion, uncontrolled trade with neighboring counties such as Somalia and Kenya is also discouraging the registered buyers and affect the sustainability of market. The local buyers and gum associaition called Gum and Resin Collectors Association of Wachille mentioned that large volume of gum and incense was transported to the border, mainly to Moyale. Compared to other sectors, the gum and resin had also got less attention both by researchers and policy makers. According to the key informants there were only very few competent buyres with no private invester working on the development of the resources in the study areas. This has made material exchange very slow. From the interviewed respondents 23.7 % mentioned traditional tabboos as factors discouraging participation on collection. This is becuase many people associated the gum and resin business with social status and mainly they attached it with poor housholdes.

According to the key informants there has been a continuous increase in human population over the past few years in the area. The vegetation known to harbor gum and gum resin bearing species are, therefore, under increasing pressure of both natural and anthropogenic impacts.The major human induced threats, as summarized from both household interview and group discussions, were over grazing, bush encroachment, conversion of woodland to farmland, change in lifestyle of the pastoral community and the associated problems, and abandon of the traditional way of resource management. They further mentioned that the recurrent drought in the area and its consequent famine had exacerbated the challenges to sustainably manage and use the resources in Borana drylands. Each of these factors that are threatening the drylands of Borana are discussed below.

4.6.8.1 Browsing and trampling by livestock

As it had been well understood, the lowland of Borana is one of the major zone with high population of livestock in the country (Alemayehu Mengistu, 2004). More importantly, as the number of livestock per household is an indication of social status in Borana, every household is interested in keeping large number of livestock. The traditional system of free grazing with such large number of livestock is a problem to sustainable gum production in the area (Plate 5). As it was observed during the field survey and also reported in Gemado Dalle (2004), the previous traditional management of livestock, mainly pastoralism was not as such practised now and it was common to see many permanent settlements in the woodlands. Because of such a newly introduced mode of life, a large number of livestock are accumulated at a given areas, around water wells, in particular. Consequently, the ecological disturbances and damages caused, particularly the negative impacts of either browsing or trampling on natural regeneration of these vegetation of the area is very immense.

According to the discussion with the key informants, besides on the fast growth of the population of the native people, there was also a continuous influx of the neighboring pastoralist mainly from Somali and Kenya with a large number of cattle. They further mentioned that, since these new comers came to the area for short period of time, they didn't feel any accountability about the futures of the resources. Hence, they overstocked a given area and left it whenever it completely changed to bare soil. Such an abandoned place was seen around Wachille woodland during the field data collection time.

Plate 5. While livestock were freely grazing in the woodlands of Borana lowlands

4.6.9.2 Native bush encroachments

Several native acacia species among which *A. depannolobium, A. oerfota*, *A. mellifera* and many others were observed to be an emerging rampant species replacing some of the valuable species in general and gum and resin species, in particular both at Arero and Yabello. The respondents also pointed out that, due to its rapid expansion, *A. drepannolobium* was the most serious problem in the area (Plate 6). It had been observed during the filed survey that, this species had formed a pure stand replacing all other species used to grow at the area. According to the local communities view, such a serious bush encroachment happened in Borana because of the official ban of rangeland burning since 1970s. In order to sustain the productivity of the woodland as a whole and gum and resin in particular, appropriate resource management measures must be taken. These probably demand for the re-utilization of controlled fire as a management tool, and selective clearing of invasive species. Above all, strengthening of the traditional resource management system is very crucial.

Plate 6. *Acacia drepannolobium*, a native tree/shrub invading rangelands in Borana lowlands

5.6.8.3 Conversion to farmlands

As livestock rearing alone failed to sustain the livelihood, in the past few years the pastoral community of the Borana began to change to agro-pastoralist. It was common to see small farmlands encroaching the woodlands in various parts of the study areas. This was even more common at Yabello district. Based on the discussion made with key informants, there was continuous shift of the local communities from pastoral to agro-pastoral life style. This probably leads to the shift of the woodland from range to a complete farmland. Hence, as conversion of the woodland is not only affecting gum and resin bearing species, care must be taken in this case.

5.6.8.4 Damage due to Termites

Termite was also found to be another emerging issue in most of the study areas and it needs attention before it become out of control (Plate 7). During the survey time, several termite mounds were observed here and there in the woodlands. The respondents also pointed that, termites mainly interfere with regeneration and even kill mature trees of the preferred species. Hence, this also needs management measure before it become out of control.

Plate 7. Termites as an emerging issue encroaching the woodland in Borana lowlands.

4.6.8.5 Other factors

There were also many other problems observed. For instance, intensive exploitation of the woodlands for construction and fuelwood purpose due to the increased human population. Charcoal making was also becoming very common activity in the area. Others like disease prevalence and the like were some of the major challenges to the future of oleo-gum resin producing vegetation as well as the biological resources associated with them.

5. Discussion

5.1 Floristic composition

Basically, floristic composition of a given vegetation can be described in terms of its richness in species, abundance, dominance, frequency and IV (Lamprecht, 1989). In this study, a total of 64 woody species (Table 4 and 5) were recorded showing that the woodland was floristically rich as compared to studies made in other dryland areas of the country. For instance, Mekuria Argaw *et al.* (1999) and Getachew Eshete (1999) made a study in the woodlands of the Upper Rift Valley and found only six woody species along the established quadrats. Likewise, studies conducted in the woodlands of the northern part of the country had also reported only 13 species (Kindeya G/Hiwot, 2003) as compared to what was found in this particular case. This probably leads to the conclusion that, the selected study vegetations had diverse species composition compared to some other sites with more or less similar agro-ecology and vegetation formation in Ethiopia.

Such maintenance of relatively higher species richness, although dominantly attributed to the physical and edaphic characteristics of the area, may also be attributed to the intensive historical and traditional resources management of the Borana pastoral communities. This was also suggested by Ayana Angasa (1999) and Alemayehu Mengsitu (2004) who reported Borana rangeland as one of the finest rangelands in eastern Africa having a high level of rangeland species diversity compared to other rangelands in the Region. The high diversity of Borana rangeland was further substantiated by Gemedo Dalle *et al.,* (2005) who had reported the existence of over 327 species in just three dry districts of Borana zone.

As far as gum and resin bearing species are concerned, Borana zone was found to be rich with species in the genera *Commiphora*, *Acacia*, and *Boswellia*. In this particular study alone, a total of 15 woody species, of which 10 species were common to both study districts, were found to grow and yield gum and resin (Table 3) that could be traded at local, national or international markets. Likewise, Borana is by far richer in terms of gum and resin bearing species compared to other woodlands of similar climatic conditions. For instance, Abeje Eshete *et al*.(2005), and Kindeya G/Hiwot

(2003) had reported only *B. papyrifera* as a known incense bearing species in woodlands of the northern part of the country. Similarly, Getachew Eshete (1999) had reported only two *Acacia* species namely *A. senegal* and *A. seyal* as gum bearing species at the Upper Rift Valley zone of the country. On the other hand, Mulugeta Lemenih *et al.* (2003) reported 7 species as source of gum and incense at Liben, Somali zone, implying the existence of better diversity in southern and southeastern parts of the country. The results of the current study suggest that anthropogenic factors (associated with land use type) are the major factors that favor or disfavor species diversity and richness at a given area.

According to the result of the species composition analyses, gum and resin bearing species were the predominant species composing the vegetation of both study districts. The study species comprised a significant proportion of the species composition of the study areas (Table 4 & 5). In Yabello for instance, they comprised more or less half of the species composition of the area. The quantitative analyses of composition do not include (i) those gum species not encountered in the sample quadrats such as *A. drepanolobium* and some other *Commiphora* species even though their abundance was reported by the local society, (ii) species which were encountered in the sample quadrats with good abundance, but from which only occasional collection of gum was made and supplied to market as adulteration of the known gum acacias. Species of this kind are *S. stencarpa, A. oerfota* and *L. rivea*. Had it been those species were included in the quantitative data analyses, the value of the floristic composition of the study species comprised will even more than the obtained value. The rich occurrence of gum and resin bearing species in Borana lowlands is an implication to the existence of untapped resource that could be used as means of diversifying the livelihood of the pastoral and agro-pastoral communities that are engaged in more or less a monotype of livelihood such as livestock rearing, which in other words is a risky business mainly during the periods of recurrent droughts (Farah, 1997; Vivero and Jose, 2002; Mitiku Tiksa, 2004). The result of this study is in agreement with what had been reported by Mulugeta Lemenih *et al.* (2003).

The result in species composition of the two districts on the other hand showed difference in species richness despite their apparent similarity in environmental variables such as climate and altitude. There may be different reasons for this. During the field survey, it was observed that, there was lifestyle difference between the communities of the two districts. At Arero, for instance, the residents are more of pastoral community who keep moving following resource availability. The inhabitants of Yabello on the other hand have an agro-pastoral lifestyle as witnessed by the existence of several permanent villages (*Ollaa*) and small farmlands encroaching the woodlands surrounding these villages. Such a permanent settlement accompanied with a continuous grazing and farmland expansion probably had its adverse effect on the natural regeneration of some of the selected trees. Density of resident households per square km at Yabello was also higher as compared to Arero (Oromia Bureau of Planning and Economic Development, 2000) and this also probably had its impact on species composition of the nearby vegetation. On the other side, most of the study sites at Arero were not as such accessible, and woodlands were found far from towns that demanded high fuelwood and construction materials. The other potential factor may also be the cooking habit and house construction style of the pastorals communities as compared to the agro-pastoral community. Hence, these all factors might have contributed to the over-exploitation of some of the selected species at Yabello thereby contributing to lower species composition.

As the forgoing discussion shows, southern Ethiopia in general and Borana lowlands, in particular may be the most diverse and rich part of the country in terms of the composition of gum and gum resin yielding species (Wubalem Tadesse *et al,* 2002; Gemedo Dalle *et al,* 2005). Moreover, as these species are drought tolerant growing even in marginalized environments, it may offer an opportunity to integrate them in the future main-stream strategic development of drylands as means for combating desertification, which is an emerging issue in various drylands of Ethiopia. In this case, the nature of gum collection, which is an environmentally friendly, can help to integrate environmental rehabilitation with the fulfillment of the livelihood of the local pastoral communities. In line with this, in recent years there is renewed interest in gums and gum resins of natural stand as people start to care for their health and invest more on organic products (Muluget Lemenih and Demel Teketay, 2004). This is also another opportunity to be employed for the production of gums and resin at commercial standard, and thus contribute to poverty reduction and biodiversity conservation.

5.2 Density, frequency, dominance and importance value

The total density ha^{-1} of the vegetation at Arero was relatively higher than at Yabello, and this may be due to the difference in species composition and difference in land use system between the two districts (Tables 4 and 5). Information on density ha^{-1} is in one way or the other related to the size of gum and resin going to be produced at a given area. The more the density of species, the better the opportunity to collect more, as it is only a small amount a single tree can yield per year (Mulugeta Lemenih *et al.*, 2003; Abeje Eshete, *et al,* 2005). The study revealed the existence of variation in density among the oleo-gum resin yielding species, which points the need for care during plan for collection. At Arero district for instance, the density/ha of *B. neglecta, A. senegal* and *C. africana* was very high, thus creating good opportunity to plan for bulk production from these species. In this district, it was also possible to plan for trade volume collection of different products from *C. baluensis, C. confusa, C. myrrha, B. micrphylla* and *C. habessinica* (Tables 4). At Yabello, *A. seyal, A. senegal* and *A. mellifera* were the most abundant species growing over a large area, supplying the possibility of continuous production of gum acacia obtained from these species. In this district, following their abundance, it is also possible to plan for bulk collection of myrrh type from *C. confusa C. habessinica*, incense from *B. neglecta* and hagar from *C. africana* (Tables 5).

When compared to studies made in other woodlands harboring oleo-gum resin yielding species in the county, we find that density ha^{-1} of gum and resin species in Borana rangelands is more or less comparable. For instance, the density ha^{-1} of *B. papyrifera* was found to be between 87 and 175 stem ha^{-1} in North Gonder (Abeje Eshet *et al.,* 2005). Kindeya G/Hiwot (2003) reported the density ha^{-1} of the same species in different land use systems to be between 100 and 254. In this case, what makes Borana woodland peculiar is the existence of high diversity of gum and resin bearing species coupled with their good abundance. Such a high density of woody species was an indication to the existence of good regeneration condition of the plant species at the area. In the current study some of the economically important species were found to be less abundant. For instance, *B. rivae*, *C. terebinthina* and *C. schimperi* were the list abundant species at Arero while *C. boranesis* was the least abundant at Yabello. The low density of these species might be the result of selective cutting, or hampered natural regeneration requiring attention. On the other hand, *B. rivae*, *C. terebinthina and C. myrrha* were not at all found at study sites at Yabello, while *A. seyal* was not found in any of the quadrats at Arero. The absence of these species is probably because they were not at all grows at these areas, or they might be overexploited and locally threatened.

Shrubs were found to be the most abundant and characteristic species in both study areas. Some of the members of the genus *Grewia* dominated the study sites with a relatively high number of individuals. They were the most abundant species, which were predominant in the lower canopy. As far as their horizontal distribution is concerned, *G. tembensis* was not found at Yabello, while *G. tenax* was not found at Arero. *Delonix elata*, an important multipurpose tree yielding edible fruits, was also found in more or less good population at study sites, implying the potential to integrate this species in the future poverty alleviation strategy. The population of other woody species such as *A. tortilis, L. rivea, S. stenocarpa, and A. bussei* were also in more or less go od condition. *A. tortilis* was the characteristic species which dominated the upper canopy of the woodland at both districts, followed by *C. baluensis* and *A. bussei.* However, the key informants pointed out that there is high pressure on *A. tortilis,* mainly at Yabello, as this species is preferred for charcoal making.

Frequency, as indicated earlier reveals the uniformity of the distribution of the species in the study area, which again tell about the habitat preference of the species (Silvertown and Doust, 1993 cited in Abeje Eshete *et al.,* 2005), giving an approximate indication of the homogeneity of the stand under consideration (Kent and Coker, 1992). Frequency analyses in the present study revealed that most of the study species were in more or less good distribution across the study quadrats. For instance, at Yabello *C. confusa and A. seyal* were the most frequent gum resin yielding species (Table 5). *A. senegal* and *C. africana* were also in good distribution status. At Arero *B. neglecta* and *C. africana* were the most frequent species, showing wide range of distribution in the woodland (Table 4). Also, *A. senegal* and *C. baluensis* had good representation across the quadrats again indicating the existing potential of gum production in various sites in the areas. On the other hand, *B. rivae, C. schimperi,* and *C. boranesis* were the least frequent study species observed in the area. This might indicate that these species might either habitat restricted or their population may be affected by human impact. One evidence that may be cited is the observation that *B. microphylla* was found in more or less rocky and degraded sites. This is in agreement with Abeje Eshete *et al.,* (2005) who reported the sloppy and rocky sites preference of *B. papyrifera*.

The important value (IV) was calculated for the vegetation in general and study species, in particular. Information on IV, permits a comparison of species in a given forest type and depict the sociological structure of a population in its totality in the community. It often reflects the extent of the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992; Kindeya G/Hiwot, 2003; Simon Shibru and Girma Balcha, 2004). It is also important to compare the ecological significance of a given species. Therefore, it is a good index for summarizing vegetation characteristics and ranking species for management and conservation practices.

According to Lamprecht (1989), stands that yield more or less the same IV for the characteristic species indicate the existence of the same or at least similar stand composition, structure, and site characteristics and with comparable dynamics among species. Opposing this idea and as it is presented in (Table 4 and 5), almost all species showed variation in terms of their IV, showing the different ecological importance of each species at the study areas. At Arero district for instance, only few species hold the largest value of IV (Tables 4 and 5). *B. neglecta, C. baluensis, C. africana* and *A. senegal* were among the species with relatively high IV at Arero, which shows that these species were among the best adapted, dominant and with more or less good population status in the area. At Yabello, *C. confusa* had the largest IV, followed by *A. seyal* and *A. senegal* (Tables 4 and 5). According to Issango (2004) woody species with high resistance to anthropogenic disturbance and those with efficient regeneration capacity have relatively high chance of remaining the dominant and important species at an area.

In this study, some of the *Commiphora* and *Acacia* species, and *B. neglecta* became important, probably because they are resilient to disturbance. As it had been observed, these species were highly dense across the study areas, which might also contribute for bulk production of seeds to increase their stocking. The key informants also reported that, these species have high coppicing ability which might help them to stay dominant species at the area. The high IV for *Acacia* species was probably because, these species were able to produce high seeds and maintain persistent soil seed bank (Mekuria Argaw *et al,* 1999). Also their seedlings are not as such palatable to cattle because of the thorny nature of the species at early stages. On the other hand, some of the study species like, *B. rivae*, *C. schimperi*, *C. terebinthina* and *C. boranesis* at Arero and *C. boranesis* and *C. schimperi* at Yabello were found to be species with least observed IV. As mentioned earlier, information on IV of a given species can tell us the population status of that particular species (Lamprecht, 1989) and be used to prioritize species for conservation.

Accordingly, those species with least IV should need conservation measure to save them as they are important first in terms of ecological service they provide and second from the point of production of the valuable products such gum and resins. In conclusion, as gum and gum resin bearing species comprised 69.80% and 60.23% (Tables 4 and 5) of the IV at Arero and Yabello, districts, one can see that how much these groups were important species in maintaining functioning ecosystems at the area. Further, this could also be seen as an indication of the potential of collecting a large amount of gum and resin in study areas.

Dominance refers to the degree of coverage of a species as an expression of the space it occupies and is often expressed based on the result of stem basal area (Lamprecht, 1989; Kent and Coker, 1992). Dominance of the study species as well other associated species is given in Tables 4 and 5 for Arero and Yabello, respectively. Accordingly, *B. neglecta* and *C. baluensis* at Arero and *C. confusa* and *A. seyal* at Yabello were the first most dominant species in terms of their basal area. The high dominance of gum and resin bearing species indicates the possibilities of bulk production of gums and resins.

As basal area provides the measure of the relative importance of the species than simple stem count, species with largest contribution in dominance value could be considered as the most important species in the study vegetation (Kent and Coker, 1992; Simon Shibru and Girma Balcha, 2004). Other wise, in most cases shrubs could be the dominant species if only we consider density as a measure to indicate the over all dominance of the species. For instance, in Arero the most abundant species was *G. tembensis* followed by *G. villosa*, while in Yabello, *G. bicolor* took the led (Tables 4 and 5). The result further showed that some of the associated species, even though they were less abundant in terms of individual count, they were found to be at least the second dominant species in the area. *A. bussei, D. elata* and *A. tortilis* were some of the species scarcely located per hectare, yet with relatively average dominance and this is because of the big diameter size they had.

5.3 Diversity, evenness and similarity

The description of plant community involves the analyses of species diversity, evenness and similarity (Whittaker, 1975). Diversity and equitability of species in a given plant community is used to interpret the relative variations between and within the community and help to explain the underlying reasons for such a difference. Hence, diversity and evenness were calculated for the whole vegetation under consideration and study species in particular using Shannon-Weiner diversity index. The Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Kent and Coker, 1992).

In this particular study, the result showed the existence of high diversity in the case of the whole woody species encountered in the study sites (Table 6). However, as it was in the case of species richness, Yabello had relatively less value of Shannon index (H'=2.77) as compared to Arero (H'= 3.22) and this probably due to the aforementioned reasons. Nonetheless, the vegetations of both districts were more or less in the normal diversity ranges as mentioned in Kent and Coker (1992). According to the same authors, low Shannon evenness is an indication of the existence of unbalanced distribution of the individuals of species encountered at a given study areas. In this study however, the Shannon evenness for the whole vegetation of the study areas was found to be very high (Table 6), implying more or less the even representation of individuals of all species encountered in the study quadrats. Such representation in a natural stand may probably indicate less disturbance and healthy regeneration of the vegetations under consideration.

The Sorenson's similarity value showed that the vegetation of the two districts as a whole had less similarity. This may probably be due to differences in species richness, which might again result from the observed land use differences between the two districts. However, in terms of the study species, they had higher similarity value. This is because among the 15 encountered gum and resin bearing species, 10 of them are found to be common at both districts.

5.4 Regeneration status of gum and resin bearing species

According to Mekuria Argaw *et al* (1999) and Kindeya G/Hiwot (2003), composition and density of seedlings and saplings would indicate the status of the regeneration of a given population of tree. The result of regeneration analyses of the study species indicated, some of the study species were in poor regeneration condition during the survey time, while others were relatively in good condition (Fig. 8 and 9). At Yabello, for instance, *A. seyal, A. mellifera,* and *A. senegal* were represented at both seedlings and sapling stages in more or less higher densities (Fig. 9). *C. africana* was also in good regeneration status as compared to the others species at Yabello. The good regeneration of some of the study species such as *Acacia* might be associated with their nature of less-palatability to cattle, which are the dominant grazing livestock in the area.

Regeneration might also correlate with abundant seed production and soil seed bank formation of species (Demel Teketay, 1997). In this case, as most of the *Acacia* species are able to form soil seed bank, this might also contribute to the good regeneration after rain. Mekuria Argaw *et al* (1999) and Getachew Eshete (1999) reported the thorny nature of these species which help the seedling to escape browsing by cattle. Other gum and resin bearing species were scarcely represented in the study quadrats including some species with no individuals at seedlings level. For instance, *C. baluensis, C. habessinica, C. schimperi, C. kua* and *C. boranesis* were not represented at seedling stages at Yabello districts. Such poor regeneration condition of most of the study species at Yabello may due to the agro-pastoralist nature of the mode of life at the area which leads to a continuous trampling and free grazing which may again hinder regeneration of some of those species.

The result of the regeneration analyses further showed, even if there was variation in density, and horizontal distributions, all the study species at both districts were represented at sapling stage. As suggested previously, the abundance of *Acacia* species at seedlings and sapling stage may be an indicator to the impact of grazing on the palatable species. It was revealed by the key informants that most of the *Commiphora* and *Boswellia* species were palatable for livestock. According to them, early stages of these species are very much liked by small calves, goats and sheep and this might also lead to the poor regeneration condition of these species. During the field stay, it was observed that there were large numbers of small ruminants (goats and sheep) freely grazing in the study woodlands at Yabello as compared to Arero, which is because of the newly created market opportunity for goats and sheep at Yabello.

Unlike at Yabello, regeneration was relatively good at Arero district (Figure 8). During the field data collection, no study species were represented with zero value of seedling and sapling; even though *B. rivae* was represented with a single individual at seedling stage showing the species was under critical regeneration condition. This particular species was also represented with only two individuals at sapling stage. The abundance analyses of the species had also showed least value across the study quadrats. Such scarce distribution of the species might contribute to poor representation, as regeneration is directly correlated with presence of viable seeds on or in the soil. In line with this, the frequency analyses of this particular species was found to be very low (<1%) implying the distribution of the species was patchy thus requiring measures to facilitate its regeneration. *C. africana A. senegal* and *B. neglecta* were the three top abundant species at seedling level at Arero district. The predominance of *C. africana* at different vertical and horizontal distribution is in line-with the categorization of these species as bush encroacher in the rangeland of Borana (Gemado Dalle, 2004).

5.5 Population structure

Population structure, defined as the distribution of individuals of each species in arbitrarily diameter-height size classes was determined to provide the over all regeneration profile of the study vegetation and study species following Peters (1996), Tefera Mengistu *et al* (2004) and Kindeya G/Hiwot (2003). 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 population structure of the present study was interpreted using the three types or pattern of stem size distribution (Type I, II and III) following (Peters, 1996) as framework. Type-I, shows the case in which diameter/height size class distribution of the species displays a greater number of smaller trees than big trees and almost constant reduction in number from one size class to the next (Peters, 1996; Simon Shibru and Girma Balcha, 2004; Kumlachew Yeshitla and Taye Bekele). Such patterns of skewed reveres J-shape distribution in a forest are considered to have a favorable status of regeneration and recruitment and hence, stable and healthy population (Kindeya G/Hiwot, 2003). Type-II is characteristic of species that show discontinuous, irregular and/or periodic recruitment. In this type, the infrequency exhibited, for instance, in diameter/height size class causes no-table discontinuities in the structure of the population as the established seedlings and saplings grow in to larger size classes. Type- III reflects a species with whose regeneration is severely limited for some reasons (Peters, 1996).

In general the vegetation of the study sites fall in type-I, suggesting there was good regeneration status as a whole. The population structure of the vegetation of both districts exhibited the highest abundance at the lower diameter classes with a gradual decrease to the bigger class. This implied good opportunity to sustainabley manage and use the vegetation resources (Peters, 1996). In other words, the presence of small sized individuals in abundance in a given forest will be seen as the reserve for replacing cut, large sized and old individuals (Kumlachew Yeshitla and Girma Balcha, 2003). Nevertheless, such a distribution type might also be due to the existence of large number of small shrubs, which dominate the lower canopy of the woodland.

In this study, the result of population structure implies, most of the economically important species known to yield the socio-culturally valuable product, principally oleo-gum-resin, such as *C. africana, A. senegal, A. mellifera, C. myrrha,* and *C. schimperi* were categorized as type-I, mainly the first three were showing the same trend in both districts, regardless of the environmental and land use variations. The other important species such as *C. kua, C. habessinica, C. schimperi, and A. seyal,* from Yabello and *B. neglecta B. microphylla, C. boranasis*, *C. terebinthina, C. baluensis* and *C. confusa* from Arero were roughly fall under type-II indicating these species had a periodic recruitment. In this group, though the recruitment was periodical, there were reasonable number of seedlings and relatively large number of middle class individuals that could be managed for gum and gum resin production (Figure 6 & 7).

Contrary to reports by other workers like Mekuria Argaw *et al,* (1999) and Getachew Eshete (1999), the middle classes (class 3 & 4) were found to be in good abundance for most of the study species (Figure 6 & 7). This perhaps indicates that selective cutting of trees for charcoal and other use may be less at Borana. Some of the other study species such as *B. neglecta, C. baluensis, C. kua, C. confusa and A. seyal* had even better distribution of individuals in class 5. Even though there is no information on annual yield per tree from Ethiopia, such good representation of trees from medium to larger size classes might translate to higher yields, as yield is known to increase with tree diameter. Duke and James (1983) reported that young trees of *A. senegal* yields approximately about 900gm/season while mature tree of the same species yield 2000gm.

In this study only few species such as *C. baluensis* and *C. boranasis* from Yabello and *B. rivea* from Arero were grouped in type-III distribution pattern, showing these species were at risk of natural regeneration. Likewise, Abeje Eshete *et al.* (2005), who worked in the northern part of the country, reported the bell-shaped stem distribution of *B. papyrifera* with no individuals at lower classes, suggesting the species was under severe regeneration problem. In Borana drylands most species had good regeneration status.

Finally, the overall regeneration profile of the study species suggests the possibilities of future commercialization of these versatile resources in general and the sustainable production of gum and resin at the study areas. On the other hand, the forgoing discussion revealed there are progressing problems of drought and the advancing nature of the harshness of the environmet, which made livestock and agricultural sectors unpredictable. Hence, integration of gum and resin with these activities could be considered as an alternative source of livelihood in Borana drylands as managing the woodland as non-timber source, in general and oleo-gum resins, in particular is a dual purpose helping to meet both the objectives of livelihhods and combating desrtification (Peters, 1996; FAO, 1996; Vivero and Jose, 2002; Mulugeta Lemenih and Demel Teketay, 2004).

5.6 Socio economics of gum and resins in Borana

The livelihood of the Borana community as shown in this study is dependent to larger extent on animal husbandray. Such a livelihood of the Borana lowlanders were also reported by Gemedo Dalle *et al* (2005). Although livestock is the predominant occupation, in some places collection and sale of forest derived products are also playing significant roles in the overall soco-economic conditions of the inhabitants. Especially the non-timber forest product in the form of gums and resins collected from the woodland vegetation are sources of income for the community in the study area. This finding was also concurrent to the study by Mulugeta Lemenih *et al* (2003) who reported livestock, gum and resin collection and farming as the three major activities on which livelihood depended at Liben zone of the Somali Regional State a neghbouring zone to Borana. The Borana community is found to own rich ethno-botanical knowledge of the study species.

Like communities in other gum and resin producing sites in Ethiopia the community in Borana is also involving in the production and sale of gum and resins resources. However, the production processes in the Borana differ from those in the northern part of Ethiopia (Wubalem Tadesse *et al*., 2002 Abeje Eshete *et al*., 2005) in two perspectives. The first difference is in that while in the north artificial tapping is used for gum collection there is no such an activity in the Borana. The second difference is the absence of organized collection i.e. cooperative form of collection which is most popular in some northern regions especially in Tigiray. However, the practice of collecting natural exudates in the Borana is similar to gum collection process common to southern and southeastern lowlands (e.g. Mulugeta Lemenih *et al*. 2003).

Despite the huge gum and incense production potential of the woodland the Borana community however preferred as a first choice to utilize the woodland as rangelands. Such an attitude was also reported by Mulugeta Lemenih *et al,* (2003) for the Liban. This is also a reflection of the multiple role of the woodland in the livelihood of the community. Like it is in most gum producing areas of Ethiopia, Metema in North Gonder Abeje Eshet *et al.* (2005) and Liban in southeast Mulugeta Lemenih *et al* (2003), the Borana community utilize the study species and their products for multiple purposes. Thus, besides use as rangeland and income generation the community in Borana use gum and resin bearing species and their products for traditional medicinal, hygienic purposes, and the like.

Generally, as the overwhelming climate change and expanding of desertification had their advers effect on the livestock and agricultural sectors, the role of gum and gum resin production in household livelihood cannot be overlooked in drylands of the country in general and Borana, in particular. Given approapariate attention and problems solved, gum and incense sub-sector could be one of the viable business in sustaining the livelihood of thousands of householdes through minimizing risk of frequent crop and livestock failures. More importantly, the environmentaly friendly nature of this sector and its great role in conserving the threatned biodiversity of dryland ecosystems could increase its importance.

Besides gum and incense productions as discussed by Mulugeta Lemenih and Demel Teketay (2004) are among the top list of export commodities and by this virtue they generate a significant amount of foreign currency for the country and thereby contributed and will continue to contribute to the national economy. In this case, Borana lowlands could be one of these places with relatively rich in gum and resin bearing species and also with relatively good population status of these species. More importantly, the existing mode of life at the area (keeping the woodland as rangeland) can help to make the production system sustainable compared to those areas with intensive agriculture. Hence, it is possible to integrate gum and resin sector with the existing livelihood activities.

Nonetheless, collection and post harvest management of gum and resin in Borana is almost traditional. This has its adverse effect on the quality and quantity of gum produced and thus on the role that they could play both at local and national level. Moreover, the mixing up of gum and resins of different species for the sake of increasing trade volume which leads to adulteration, and hence poor quality, is one of the big problems affecting the market condition for gums and incenses produced in the Borana. Although gums and gum resin bearing species own high actual and potential socio-economic and ecological roles, different human induced factors especially overgrazing and expansion of settlement are threatening their future in Borana drylands. Of course the effects from these problems are in agreement with the reports of Gemedo Dalle (2004), and Coppock (1994).

6. Conclusion and Recommendations

6.1 Conclusions

Livestock production, the dominant occupation at Borana lowlands, is impacted by the recurrent drought and the consequent fodder shortage thereby leading to food insecurity and famine. Hence, looking for other alternative strategies that diversify the pastoral and agro-pastoral livelihoods is very important. This is also imperative because dryland ecosystems are delicate, and once damaged their reclamation is almost impossible or at least very costly. This also needs care in selecting type of development work to be implemented in these areas. To this end, this study revealed the fact that exploitation of the drylands for the production of gum and incense, and integrating this sector with other land use options will form one of the sustainable livelihoods to the community while leading to environmentally friendly resource management. This is particularly so because gum and incense extraction (which would cause almost no damage to the vegetation resource) is a kind of land use that integrates livestock production, biodiversity maintenance, and minimization of desertification expansion, while providing immense economic significance.

This study showed that gum and incense producing species are the dominant components of the vegetation of the study areas. Many of the study sites were rich in composition of such species, most of which were with good regeneration profile implying the possibilities for sustainable production of gum and resin in Borana drylands. Finally, this study revealed that, under the existing population status (richness, diversity, abundance, regeneration condition), interest of the communities to participate on the business and the global shift to the use of organic products, carefully planned and managed exploitation of gum and incense in the Borana lowlands does not only generate local and foreign income, but also is a sustainable system of production. Thus, there is a need to promote and commercialize the use of such a viable resource through involvement of the local community so that local level accountability of resources management will be enhanced, and thereby food security improved.

6.2 Recommendations

Based on the results of the vegetation survey, assessment of socio-economic importance and observations made during the field study, for attempts to develop, manage and sustainable use the natural gum and incense resources of the Borana, the following recommendations are given:

1. As it had been observed, the potential of the currently existing resources was by far exceeds the supply being obtained today. The current collection was mainly concentrated only on few species, marginalizing many others with potential economic value. In this case, the first and foremost important activity to be done was to create awareness on how these resources have global importance and demand, and show them how much they can produce and contribute to the changing of their livelihoods. Training must encompass different aspects such as species identification, method of collection, quality maintenance, post harvest handlings, transportation, storage and etc. This also need for the introduction of new technologies that help to improve quality and quantity.

2. Development of a policy strategy on gum and resin collection and marketing that will benefit the local collectors. It had been observed that collection from naturally oozing trees is so tedious compared to the return obtained from the sale of the products. Moreover, the respondents pointed out that it was only the buyers who decided on the local market and this had made the market unfair and discouraged collection. Hence, there must be market policy that compromise between workload and revenue. Assessment of more market routs and networking collectors to these opportunities is very important. The policy must also look for solutions in discouraging the illegal trans-boundary trade of gum and gum resins.

4. Most of the woodlands harbouring gum and resin bearing species were found to be far from the towns, villages and infrastructures as a whole. Water, food and medication centres are not available at the production centres. As weather is very hot and dry, collectors need large amount of water sources to drink. Hence, it is good to develop access to food and water at least at the main collection centres. Transportation was one of the potential obstacles in the area and there must be at least

seasonal roads and vehicles to transport the products to main centres so that the collectors get access to good markets.

5. Formulation and implementation of integrated community based natural gum and incense resources development, conservation and utilization need to be considered at national and regional levels. These must also encompass strengthening the existing collectors association and establishing more of them.

6. Lack or scarcity of capital was repeatedly mentioned by the key informant as one of the major constraints for the association or private buyers. This needs an intervention through arranging small loans so that they can get money and expand their business.

7. A competetive market can be created through invitation of more private investors. This needs establishing infrastructure facilities and security.

8. These days the issue of resource certification is a global issue. A product from certified vegetation has known to get better market and hence getting certificate for the vast woodlands of the Borana lowlands will be one of the options to wine faire market.

9. Gum and resins are expected to enjoy good global market in the future. Thus, it is good to have the resources managed on sustainable manner. In this case, developing management plan that encompasses the distribution, abundance, diversity, and economic and social uses of gum and incense bearing species including the detail vegetation map, soil and water resources interactions of the woodland to maintain sustainable production is very crucial.

10. Strategy must be devised for effective control and management of bush encroachment and livestock overgrazing to reduce their impact on natural regeneration of gum and resin bearing species.

11. An in-depth investigations into the natural and artificial propagation techniques of the potential gum and incense species identified in the study areas need to be given due considerations.

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8. Appendices

Appendix 1: The list of species that include scientific name, local name, family and growth habit of all woody species encountered at Arero district

Scientific name	Local name	Families	Habit
Grewia tembensis Fresen	Dheekka	Tilaceae	shrub
Grewia villosa	Ogomdi	Tilaceae	shrub
Boswellia neglecta S. Moore	Dakkara	Burseraceae	tree/shrub
Acacia senegal(L.)willd.	Sephansa diimaa	Fabaceae	tree/shrub
Commiphora Africana (A. Rich.)	Hammesa dhiiroo	Burseraceae	tree/shrub
Grewia bicolour Juss.	Harooressa	Tilaceae	shrub
Blepharispermum pubescens S.	Baanya	Asteraceae	shrub
Harmsia sidoides K.Schum.	Qaxxee	Sterculiaceae	shrub
Commiphora baluensis (Ehrenb.)Egle.	Agarsuu	Burseraceae	Tree
Ipomoea donaldsonii Rendle	Dhaliyyee	Convolvulaceae	shrub
Commiphora confusa Vollesen	Siltaachoo	Burseraceae	Tree
Commiphora myrrha	Qumbii	Burseracea	Tree
Boswellia micrphylla Chiov	Ilkibukisa	Burseraceae	Tree/shrub
Commiphora habessinica (Berg)	Hoomacho	Burseraceae	Tree/shrub
Lanea rivae (Chiov.) Sacleux	Handaraka	Anacardiaceae	Tree
Commiphora kua (R.Br.Ex Royle) Vollesen	Callanqaa	Burseraceae	Tree/shrub
Acacia bussei Harms ex S. jostedt	Hallo	Fabaceae	Tree
Acacia mellifer (Vahl.)Benth	Saphanse guracha	Fabaceae	Tree/shrub
Commiphora terebinthina Vollesen	Sangga igguu	Burseraceae	Tree/shrub
Commiphora boranesis	Rigga qeeroo	Burseraceae	Tree/shrub
Commiphora schimperi (Berg.)Egngl.	Hammesa qayyoo	Burseraceae	Tree/shrub
Dodonea angustifloia L.f..	Dhitacha	Sapindaceae	Tree/shrub
Vernonia cinerascens Sch. Bip	Qaxee dhaltu	Asteraceae	Shrub
Indigofera volkensii Taub	Gurbi hoola	Fabaceae	Shrub
Lanea triphylla		Anacardiaceae	Tree
Premna schimperi Engl.	Xaaxessaa	Verbenaceae	Shrub
Kirkia burgeri stannard ssp Burgerii	Bisdhuga	Simaroubaceae	Shrub
Acacia tortilis (Forssk.)Hayne	Dhadacha	Fabaceae	Tree
Sterculia stenocarpa H. Winkler	Qarari	Sterculiacea	Tree
*Delonix elata(*L.) Gamble	Sukella	Fabaceae	Tree

Acacia oerfota (Forssk.)Schweinf	Waanga	Fabaceae	Shrub
Boswellia rivae	Dakkara	Burseraceae	Tree/shrub
Erythria melanacantha Taub. Ex Harms	Waleensuu	Fabaceae	Tree
Plectranthus ignarius(Schweinf.)	Barbarressa	Laminaceae	Shrub
Maerua triphylla A.Rich.Var	Dhumayoo	Capparindaceae	Tree/shrub
Delonex baccal (Chiov.)Bak	Ballanjii	Fabaceae	Tree
Sesamothamus rivae Engl.	Lallaaftoo	Pedaliaceae	Tree
Terminalia prunioides Laws	Qoroboo	Combretaceae	Tree/shrub
Terminalia brownii Fresen	Birresa	Combretaceae	Tree
Ormocarpum trichocarpum (Taub)	Buutiyyee	Fabaceae	Shrub
Hibiscus crassinervius Hochst ex A.Rich	Bungalla	Malvaceae	Shrub

Appendix 2: The list of species that include scientific name, local name, family and growth habit of all woody species encountered at Yabello district.

Scientific name	Local name	Family	Habit
Grewia bicolor Juss.	Harooressa	Tilaceae	Shrub
Commiphora confusa Vollesen	Siltaachoo	Burseraceae	Tree
Acacia seyal Del.	Waacuu diimaa	Fabaceae	Tree
Acacia Senegal (L.)willd.	Sephansa diimaa	Fabaceae	Tree/shrub
Grewia villosa	Ogomdi	Tilaceae	Shrub
Commiphora africana (A. Rich.)	Hammesa dhiiroo	Burseraceae	Tree/shrub
Acacia mellifer (Vahl.) Benth	Saphansa gurraacha	Fabaceae	Tree/shrub
Commiphora habessinica (Berg)	Hoomacho	Burseraceae	Tree/shrub
Boswellia neglecta S. Moore	Dakkara	Burseraceae	tree/shrub
Commiphora kua (R.Br.Ex Royle) Vollesen	Callaanqaa	Burseraceae	Tree/shrub
Commiphora baluensis Engle.	Agarsuu	Burseraceae	Tree
Acacia oerfota (Forssk.) Schweinf	Waanga	Fabaceae	Shrub
Harmsia sidoides K.Schum.	Qaxxee	Sterculiaceae	shrub
Acacia bussei Harms ex S. jostedt	Hallo	Fabaceae	Tree
Acacia tortilis (Forssk.)Hayne	Dhadacha	Fabaceae	Tree
Commiphora schimperi (Berg.)Egngl.	Hammesa qayyoo	Burseraceae	Tree/shrub
Lanea rivae (Chiov.) Sacleux	Handaraka	Anacardiaceae	Tree
Dichrostachyus cinerea (L.) wight et Arm.	Jirimee	Fabaceae	Tree/shrub
Commiphora boranesis	Rigaa qeeroo	Burseraceae	Tree/shrub
Grewia tenax (Forssk.) fiori	Saarkama	Tiliaceae	Shrub
Sterculia stenocarpa H. Winkler	Qarari	Sterculiacea	Tree
Balanites aegyptica (L.) Del.	Badana Lu'oo	Balanitaceae	Tree/shrub
Boscia mossambicensi Klotzsch	Qalqalcha	Capparidaceae	Tree