Research and Development *in* Dryland Forests *of* Ethiopia

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Research and Development in DRYLAND FORESTS of Ethiopia

Proceedings of the National Workshop
Organized by
Forestry Research Center, Ethiopian Institute of Agricultural Research (EIAR) &
Center for International Forestry Research (CIFOR)

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November, 2011

Addis Ababa, Ethiopia

First published by:

Forum for Environment
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PREFACE

Ethiopia is known to have wide array of agro-ecological zones where Drylands are among the dominant agro-ecologies. Classified into super arid, arid, semi-arid and dry sub-humid, dryland ecosystems, are quiet diverse in terms of climatic, biophysical and coupled with socio-cultural phenomenon, key deriving factors for habitat differentiation. Such difference in habitat is one major factor for species diversity and endemism in drylands of Ethiopia.

Drylands, which fall within the range of UNEP's definition of desertification, cover about 47% of the landmass at global scale, 66% in Africa and over 75 70% in Ethiopia. These ecosystems in Ethiopia host seven among the nine vegetation formation, signifying their importance in terms of the flora and fauna they support. They support some of the key species that offer significant socio-economic and ecological opportunities. To name few, Drylands house diverse genera, among others, the genera A*cacia, Boswellia, Commiphora* and *Sterculia*, principal sources of high value oleo-gums and resins, whose application span from local use to some of the sophisticated industries of western countries. Drylands are home for some of the key agricultural crops including sorghum, millet, and beans. Majority of the country's Protected Areas are found in these ecosystems. They support major water bodies in the country including some of the international rivers. The Rift Valley lacks play a non replaceable role in serving the global migratory birds. Above all, most of the country's hydropower dams and irrigation systems are in these ecosystems. For centuries, Drylands in Ethiopia support millions of pastoral and agro-pastoral communities via provision of goods and services. Dryforests and the biodiversity they host is the key ingredient for livestock production, which is the mainstay of the drylanders.

Despite all the above-mentioned socio-economic and ecological importance, current ongoing professional discussion show that, Dryland ecosystems in Ethiopia are increasingly becoming vulnerable to global climate change. The extra temperature due to the frequent and extended drought and rain fall variability are hampering livelihood and ecological process. Such issues and problems call for integrated approach that leads us to outputs responding to livelihood adaptation and environmental resilience. Among others, Drylands need policy and development reformation and re-orientation. So far, the various development interventions were either not inclusive (e.g. marginalization of dryforests) or insertion of new land use systems, which are incompatible to the fragile nature of Dryland ecosystems.

The purpose of this particular proceeding is to contribute to the dialogue about the challenges and opportunities that hinder and enable sustainable Dryland ecosystems development and thereby, call for informed decisions. We hope the information in this proceeding will be relevant for policy makers, practitioner, teachers, researchers, private sectors and the public at large.

Finally, on behalf of the Forestry Research Process of the Ethiopian Institute of Agricultural Research (EIAR) and myself, I would like to forward my grateful thanks to Forestry Research Center (FRC) for organizing the workshop, Center for International Forestry Research (CIFOR) for co-organizing the event and Forum for Environment (FfE) for financing all the necessary costs to publish this book. Special thank goes to Mr Adefires Worku (FRC-EIAR) for his diligence while organizing the workshop and also for his vital contribution to this publication.

Happy reading

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OVERVIEW OF RESEARCH ACHIEVEMENTS AND GAPS ON DRYLAND FORESTS OF ETHIOPIA: THE CASE OF GUM-RESIN BEARING RESOURCES

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Abstract

Available literatures were reviewed with the objective of compiling the fragmented research findings and development interventions done so far on gum-resin bearing resources in Ethiopia. This review summarized what is known and what not, identified major policy, research and extension gaps and provided way forwards for optimal use of these vital resources. Although not up-to-date, some documents indicated that the dryland forests of Ethiopia, where gum-resin bearing species are the predominant component, constitute vast lands estimated to be between 2.5 and 3.5 million ha. There is an understanding on the distribution, diversity and overall population status of the majority of gum-resin bearing species, except for some regions of the country. So far, fiteen Commiphora, six Boswellia, twelve Acacia and two Sterculia species were identified as sources of locally used or nationally traded gum-resins. Eight types of oleo-gum resins of different botanical origins: frankincense, gum Arabic, gum talha, gum karaya, gum gumero, myrrh, opopanax and hagar were collected, used and traded at home or exported. Collection and marketing of oleo-gum-resins is found to be historic and established tradition in various regions of the country. There is also baseline information on socio-economic contribution of some of these products to both local and national economy. The participation of the private sector in this area has been increasing, leading to an improvement in export size and foreign currency earning. Despite some knowledge and understanding, still up-to-date and a national level information on current status of the resources base is lacking. There is critical knowledge gap in production, processing and storage techniques of gum-resins. Information on product quality and value added processing is lacking. Except for few, knowledge on silviculture and taxonomy for the majority of gum-resin bearing species is limited. Tree selection and other issues to improve production quantity is nearly untouched. There is only limited quantification on socio-economic contribution of the sub-sector to household and national economy. The existing poor marketing strategy, lack of specific policy/regulation, poor infrastructure, week institutional capacity, low level of awareness, inadequate private sector involvement, difficulty to credit access, illegal transborder trade, the existing harsh environment, poor links between research and extension and other related factors are identified as major bottlenecks to the development of the sub-sector.

***Key words**: dryland forests, Ethiopia, research overview oleo-gum-resins,*

1. Introduction

The wide array of altitudinal gradients, varying topography and the rift valley system coupled with the age old cultural complexity has created quiet diverse ecological conditions leading to characteristic flora and fauna with high level of endemism (EFAP, 1994). Drylands are among the major agro-ecological zones in the country. Vast areas of land in Ethiopia, approximately 55% are arid to semi-arid with marginal or little agricultural potential (NCSS, 1993; Tamire, 1997). Including the dry sub-humid areas, the total drylands of the country amounts to 860,000 km2 (75%) (Mulugeta and Demel, 2004). Owing to the climatic conditions, in these areas pastoralism and agro-pastoralism has been the principal mode of life for centuries (Ameha et al., 2008).

Various studies revealed that the ecologic and socio-economic conditions of the Ethiopian drylands are declining, jeopardizing sustainable pastoral way of life (Mulugeta *et al.*, 2003; Gemedo *et al.*, 2005; Adefires, 2006). Therefore, the forthcoming discussions outlined that (i) the complex issues in drylands of Ethiopia needs multi-disciplinary strategies capable of providing multiple outcomes addressing concurrently issues of productivity, climate change, capacity building and environmental integrity; (ii) the need to care on short and long term impacts of any introduced interventions; (iii) the need to promote development initiatives that are participatory and conservation oriented; (iv) the need for integrating the indigenous knowledge; and (v) the need for continuous monitoring and preparedness, if rigorous dryland development is sought.

Many researchers (Arnold and Perez, 2001; Kindeya, 2003; Mulugeta and Demel, 2004) believed that, if properly done, forestry based development initiatives were able to answer the above mentioned appeals. According these scientists, forests/woodland resources form an integral part of the ecological and social-cultural framework in drylands. In drylands of Ethiopia several species in the genera *Acacia*, *Boswellia*, *Commiphora* and *Streculia* which are known to hold commercially important non-timber forest products (NTFPs) such as gum-resins (Mulugeta *et al.*, 2003; Adefires *et al.*, 2007). Ethiopia is known to be one of the world leading producers of gum-resins (Mulugeta and Demel, 2004; Mulugeta and Teshale, 2006; Wubalem *et al.*, 2007). The role of gum-resins trade and its contribution to both the local and national economy is significant.

Despite the immense ecological and economic role of the gum-resin sub-sector, efforts to improve the sub-sector through research and development thus far have been limited (Kindeya, 2003; Abeje *et al.*, 2005; Mulugeta *et tal.*, 2007; Wubalem *et al.*, 2004). More importantly, as most research and development efforts were piecemeal in approach, the available information and knowledge generated were too fragmented and scattered. Lack of centralized database system in forestry sector in general and the gum-resin sub-sector in particular were believed to adversely affect planning and decision making. Therefore, the overall objective of this paper was to thoroughly review the available but fragmented literatures related to gum-resins, synthesize and compile information and thereby contribute to the knowledge transfer, and indicate observable research gaps and constraints that may be useful for future action. The information provided in this review is believed to be of use in the future planning and decision making to develop drylands of the country.

2. Description of the Study Species

The current compilation work focused on gum-resin yielding species of the genera *Acacia*, *Boswellia, Commiphora* and *Sterculaia* of the family *Fabaceae, Burseraceae* and *Sterculiaceae*. The gum-resin bearing trees are typical plants of the drier low lying semi-arid to arid areas in Ethiopia. They cover the altitudinal ranges between 100-2000 masl (Vollesen,1989). About 6 *Boswellia, over 52 Commiphora and several Acacia* species are found in Ethiopia (Vollesen, 1989; Mulugeta and Teshome, 2006). *Streculia setigera, source of gum karaya is reported mainly from northern part of the country, while S. strncarpa is found in Borana (Adefires, 2006) as occasional sources of adulterant. Various Ethno-botanical studies showed that, besides providing valuable commercial products such as oleo-gum-resins, most species of these genera are major sources of feed, wood, medicine and food for the pastoral communities (Gemedo et al., 2005; Adefires, 2006; Adefires and Dagnew, 2008). Though, there is lack of detailed data, their role in maintaining functioning ecosystem and buffering the prevailing desertification, soil amelioration, wind erosion control, and others should not be overlooked.*

3. Summary of the Findings

3.1. Resources base

Despite the long history of natural gum tapping and exporting, the culture of quantitative resource assessment and inventory is lacking. The quantity of the resource base in the country can only be obtained from the fragmented and rough approximations. For instance, different researchers showed the resources base and distribution of the gum-resin resources in various parts in Ethiopia. (Vollesen, 1989; EFAP, 1994; Girmay, 2000; Kindeya, 2003; Mulugeta *et al.*, 2003; Abeje *et al.*, 2005; Adefires, 2006; Dagnew, 2006; Adefires and Dagnew, 2008) In these literatures, the total area of woodlands and bushlands comprising gums-resins bearing species cover between 2.8 and 3.5 million ha. Ethiopia's drylands were identified as richly endowed with various species of the gum-resin bearing species (Fig. 1).

Fig.1. The vast woodland and the gum-resin bearing species it harbour

(*photo by Adefires W., 2008*)

3.2 Regional distribution of gum-resin bearing resources

The various studies made so far indicated the nation-wide distribution of gum-resin bearing resources in Ethiopia (Table 1). Such nation-wide distribution implies the existing huge opportunities to attract investment and participatory resources management and use for dryland development (Kindeya, 2003; Mulugeta *et al.*, 2003; Abeje *et al.*, 2005; Adefires, 2006; Dagnew, 2006; Gindaba *et al.*, 2007; Adefires and Mohamed, 2008). In almost all regions in Ethiopia dryland forests in general and gum-resin bearing species in particular occupies significant portion of the land mass. In Somali Region, for instance, seven out of the nine Zonal Administrations were known both in diversity and coverage of gum-resin bearing resources

(Mulugeta *et al*., 2003; Gindaba *et al*., 2007; Adefires and Dagnew, 2008; Adefires and Mohamed, 2008). However, there is a discrepancy among reports in the area coverage figures and in the presence or absence of species.

3.3. Production potential

Although very small portion is currently collected, the potential of natural gum-resin production from Ethiopia was estimated to be over 300,000 metric tons per annum (Mulugeta and Demel, 2004). In another report the potential was estimated to be 264,342 tons per annum (Mulugeta, 2005), implying some variations between sources. It was noted that such variation in estimation is due to lack of up-to-date and detailed survey of the resources base. In most cases, estimations were based on either previous reports and/or primary data, the latter of which is based on extrapolations from results obtained in small areas. Furthermore, estimations do not follow established quantitative methods except for few localities and species. For instance, looking at the works of Mulugeta *et al* (2003) and Gindaba *et al* (2007) for Liben Zone and Somali Regional State, either the total resources base in hectares or production potential in tone given for the Regions is far under estimated. It was also unlikely to get any precise information on the production potentials of other regions in the country. Besides, some of these references are too old to use compared to the fast dynamism going on in drylands of the country. There is also a gap in clear-cut information on the presence/absence of a particular dryland species in a given region. For instance, some of the reports included myrrh and opopanax in the species list of the northern part of the country, which in fact is not supported by Flora of Ethiopia and the reports of the institutions engaged in gum-resin production (Girmay, 2000).

Table 1. Frankincense, myrrh/opopanax and gum Arabic production potential in Ethiopia by Administrative Regions

Regional State	Type of oleo-gum resin	Estimated total area (ha)	Estimated potential production (tons)	Total in tons
Afar	(i) Olibanum	65,000	(i)250	**1350**
	(ii) Myrrh/opoponax		(ii) 500	
	(iii) Gum acacia		(iii) 600	
Amhara	(i) Olibanum	604,382	(i) 200,000	202,992
	(ii) Myrrh/opoponax		(ii) 1,192	
	(iii) Gum acacia		(iii)1,800	
Benishangul	(i) Olibanum	100,000	(i) 500	1200
	(ii) Myrrh/ opoponax		(ii) nd*	
	(iii) Gum acacia		(iii) 700	
SRS**	(i) Olibanum	150,000	(i) 2500	10700
	(ii) Myrrh/opoponax		(ii) 6500	
	(iii) Gum acacia		(iii) 1,700	
Gambella	(i) Olibanum	420,000	(i) nd	1100
	(ii) Myrrh/opoponax		(ii) nd	
	(iii) gum arcacia		(iii) 1,100	

Oromia	(i) Olibanum (ii) Myrrh/opoponax (iii) Gum acacia	430,000	(i) 6,000 (ii) 1,500 (iii) 10,000	17500
Tigray	(i) Olibanum (ii) Myrrh/ opoponax (iii) Gum acacia	940,000	(i) 57,700 (ii) 770 (iii) 2,100	57700
SNNP***	(i) Olibanum (ii) Myrrh/opoponax (iii) Gum acacia	70,000	(i) nd (ii) nd (iii) nd	nd
Total		**2,779,382**	**292,542**	**292,542**

Source (EFAP, 1994 and Girmy, 2000; * nd: no data; ** Somali Regional State; *** Southern National Nationalities and People)

3.4. Species diversity and population status

3.4.1. Species richness

The overall distribution of the woodland resources that hosts major gum-resin bearing species was given in Table 1. According to the reviewed literatures, Ethiopia is not only known for its vast woodlands resources base, but also for the diversity in gum-resin bearing species. Different *Commiphora, Boswellia, Acacia* and other species are naturally growing together (Fig. 2). Vollesen (1989) identified over 52 species of *Commiphora* and six species of *Boswellia* in Ethiopian drylands. Several *Acacia* species were also reported by Asfaw and Thulin (1989). However, the most commonly know gum-resin bearing species are small compared to the huge diversity of the member species. Mulugeta and Teshome (2006), Wubalem *et al.* (2007) and Adefires and Mohamed (2008), reported a total of 12 *Acacia*, 6 *Boswellia* and 17 *Commiphora* species as sources of gum arabic, frankincense, myrrh and myrrh types, respectively. The most commonly known sources of gum-resins species adopted from various sources are presented in Table 2. However, it is important to note that this list is not exhaustive and there are many potential species, although there has not been experience of collection and marketing of gum-resins from these potential species.

Fig.2. Diversity of gum-resin bearing species of *Commiphora*, *Boswellia* and *Acacia* from Afdher Zone of Somali Regional State (*photo by Adefires W., 2008*).

Table 2. List of the major gum-resin bearing species of Ethiopia.

Genus Boswellia	Genus Acacia	Genus Commiphora	Genus Streculia
Boswellia papyrifera	*Acacia senegal var.* senegal & var. kerensis	*Commiphora myrrha*	*Sterculia setigera*
Boswellia microphylla	*Acacia seyal* Del. var. seyal and fistula	*Commiphora africana*	*Sterculia stenocarpa*
Boswellia neglecta	*Acacia polyacantha*	*Commiphora habessinica*	
Boswellia ogadensis	*Acacia sieberiana*	*Commiphora truncata*	
Boswellia rivae	*Acacia drepanolobium*	*Commiphora boranensis*	
Boswellia pirrotae.	*Acacia horrida*	*Commiphora guidottii*	
	Aacia mellifera	*Commiphora erythraea*	
	Acacia etbaica	*Commiphora cyclophylla*	
Acacia oerfota		*Commiphora corrugata*	
	Acacia paoli	*Commiphora hildebrandtii*	
	Acacia stuhlmannii	*Commiphora odia Sprague*	
	Acacia dealbata	*Commiphora schimperi*	
		Commiphora kua	
		Commiphora serrulata	
		Commiphora monoica	
		Commiphora rostrata	
		Commiphora confusa	
		Commiphora terebinthina	

Sources: (Mulugeta *et al*., 2003; Adefires, 2006; Mulugeta and Teshome, 2006; Wubalem *et al*., 2007)

There is significant variation in species richness/diversity from place to place and Region to Region. *B. papryfiera* is a source of almost 90% of the export frankincense in the country and a major source of olibanum from northern Ethiopia (Tilahun 1997; Kindeya, 2003; Abeje *et al*., 2005; Mulugeta *et al*., 2007). Even if, there is no information on commercialisation of *B. pirota* frankincense, this species are also found in the northern part of the country stretching to the Nile basin system. *A. senegal, A. Polycantha* and *S. setigera* also grow in the northern part of the country.

In general, great diversity of *Acacia*, *Boswellia* and *Commiphora* resources were reported from south and south eastern lowlands of the country. In Liben Zone of Somali Region, a total of 7 gum-resin bearing species including *B. negelecta, B. rivea, B. microphyla,* and *B. ogadensis* were reported, indicating high diversity for frankincense production compared to the northern parts of the country (Mulugeta *et al.,* 2003). In Borana Zone, Oromia Region, 14 gum-resin producing species were identified as sources of currently traded gum-resins (Adefires, 2006). Somali Region has the most potential in terms of diversity of both gum-resin bearing species and product type (Mulugeta *et al*., 2003; Gindaba *et al*., 2007; Adefires and Mohamed, 2008). Unlike others, the gum-resin bearing *Acacia* species have wider ecological elasticity growing in different parts of the country (Girmay, 2000; Kindeya, 2003; Mulugeta *et al*., 2003; Adefires, 2006; Dagnew, 2006).

Fig. 3. *S. setigera* trees and its gum karaya, northern part of Ethiopia (*photo by Wubalem T., 2007*)

3.4.2. Abundance and current population structure

As depicted in various sources, it is not only the wide distribution of the gum and resin resources that encourage future investment on the sub-sector, but also the existing high abundance of some of the important species (Fig. 4). The density per ha for some of gum-resin bearing species was found to be very high. Adefires (2006) reported between 50 and 150 individuals/ha in Borana Zone for most the study species. Mulugeta *et al.* (2007) reported an average stem density/ha of 169 for *B. papyrifera* from Metema, Amhara Region. These suggest gum-resin bearing species are the predominant component of the vegetation composition in various drylands of Ethiopia. Furthermore, Mulugeta *et al.* (2003) and Adefires and Dagnew (2008) found high density of gum resin bearing species per ha for Somali Region. According to these studies, particularly those carried out in the south-eastern parts of Ethiopia, the gum and incense yielding species comprise over 60% of the stem density in *Acacia-Commiphora* woodland vegetation (Mulugeta *et al.*, 2003, Adefires, 2006; Dagnew, 2006). Indeed, analysis of floristic composition, abundance and potential productivity of the dryland vegetations clearly demonstrated the high opportunity for sustainable production of oleo-gum resins in the country (Mulugeta and Demel, 2004; Adefires, 2006).

Fig. 4. Abundance of different gum-resin bearing species (*photo by Mulugeta L. and Adefires W., 2007*)

Besides the good abundance for majority of gum-resin bearing species, the analyses of population structure in Borana Zone and Somali Region showed healthy regeneration, where many species represented by a considerable number of seedlings compared to higher class diameter. However, severe regeneration decline was observed for some of the species, such as *B. papyrifera and S. setigera* from north, and *B. ogadensis* from southeast. Due to such unhealthy population structure, these species were categorized as endangered indicating the need for immediate intervention measures. In Southern lowlands some of the *Commiphora* species showed least important value index depicting the declining population and the need for intervention (Adefires, 2006).

3.5. Type of gum-resins produced in Ethiopia

Gum arabic, frankincense/olibanum, myrrh, opoponax and hagar (Fig. 5) are the major commercial products collected from either one or more species in Ethiopia. Very importantly, some of the valuable species are represented by different varieties offering the possibility to collect different product that suite varied application and thus opportunity to find new market niches (Mulugeta and Teshale, 2006). For instance, gum arabic of commerce in Ethiopia is obtained from *A. senegal* with two varieties, var k*ersensis and senegal*. Likewise, Gum talha from *A. seyal* is collected from two varieties, var *fistula and seyal* (Muleugate and Teshome, 2006), depicting diversity of sources and hence diversity of products. Diversity of products based on local designation is also high. For instance, according to Mulugeta (2005) gum arabic from *A. senegal* is locally classified as Humera and Borana types, where Humera type is produced from variety *senegal from north and Borana type is from variety kerensis and collected from Borana, south and southeastern part of the country. The remaining different g*um acacias were collected from various other *Acacia* species and in most case either mixed with gum Arabic or traded separately.

Frankincense/olibanum is a gum-resin tapped from several species of the genus *Boswellia*, and in Ethiopia 6 *Boswellia* species produce three different types of olibanums. These are Tigray from *B. papyrifera*, Ogaden from *B. ogadensis, B. rivea,* and *B. micriphyla*, and Borana type frankincense from *B. neglecta* (Tilahun, 1997; Girmay, 2000; Kindeya, 2003; Mulugeta *et al.*, 2003; Adefires, 2006).

Fig. 5. Different types and grades of oleo-gum-resins collected and traded from Ethiopia (*photo by Mulugeta, 2005)*

Myrrh, opoponax and other myrrh type gum-resins are products from different *Commiphora* species (Girmay, 2000; Mulugeta *et al.*, 2003; Adefires, 2006; Adefires and Dagnew, 2008), several of which are either indigenous or endemic to the country (Volleson, 1989). For instance, hagar a locally known myrrh type collected from *C. erythraea* and *C. africana* is becoming among the popular traded substances in Somali Region and Borana (Mulugeta *et al.*, 2003; Adefires, 2006; Adefires and Dagnew, 2008). This product is illegally exported to either Kenya or Somali land and never transported to the central market. Gum karaya is produced from species of the genus *Sterculia* mainly from *S. setigera*. Gum karaya is found to be under developed compared to other gum-resins.

3.6. Economic contribution of gum-resin resources in Ethiopia

3.6.1 Socio-economic contribution

Natural gums and resins are among the key dryland NTFPs in Sub-Saharan Africa significantly contributing to improve the livelihoods of local communities in terms of food security, income generation and also foreign exchange earnings for national economy. Oleo-gum-resins are produced in the rural areas, traded in urban centres and used in some of the sophisticated cities in the world (Mulugeta *et al*., 2003). Production and trade of gum-resins therefore, touches the lives of a wide cross section of mankind. The gum-resins sub-sector in Ethiopia is playing a significant economic role both at local and national level (Tilahun, 1997; Girmay, 2000; Mulugeta *et al*., 2003; Abeje *et al*., 2005; Mulugeta and Teshale, 2006; Adefires, 2006; Adefires and Dagnew, 2008). According to the information from export office (http://www.ethioexport.org), the sub-sector is one of the few forest derived export commodities from which Ethiopia is earning foreign currency. Mulugeta and Demel (2004) further indicated that the direct national economic contribution of dryland vegetation in terms of generating foreign currency far outweighs that of the forest resources in the humid and sub-humid parts of Ethiopia combined. For instance, between 1996 and 2003, Ethiopia exported 16,019 tons of natural gum-resins which worth 20,473,058 USD. In 2008 alone, over 60 million birr was generated from gum-resins export (http://www.ethioexport.org), implying the increasing trend of both revenue and export. Girmay (2000) on the other hand reported in the last decade an average of 2928 tons of gums-resins were traded both on domestic and international markets each year with average annual revenue of 30.3 million Birr.

At local level gum-resin collection and trade play crucial roles mainly among the pastoral and agro-pastoral communities. For instance, the average annual cash income per household generated from collection and sale of gum-resins was estimated to be US$ 80.00 in Liben Zone (Mulugeta *et al.,* 2003). This income contributes 32.6% of the annual household subsistence, and ranks second after livestock in the overall household livelihood of the area. In Afdher, a neighboring Zone, the annual cash income generated per household from sale of true myrrh and opoponax ranged from $175.00 to $ 610 (Adefires and Dagnew, 2008). In Borana, the average contribution of gum collection and sale was $ 310.5 and 279 per house hold per annum at Arero and Yabello districts, respectively (Adefires, 2006). Different from what was indicated above, the bulk resource potential of *B. papyrifera* at Metema district in Amhara Region has no role in cash generation in terms of gum-resin for local people due to several reasons. Among others, unattractiveness of income from frankincense compared to other economic activities, property tenure issues, government policy on incense production, poor knowledge on production and processing and lack of awareness on the potential of frankincense as a source of income were identified as factors affecting involvement of the local community in this area (Mulugeta *et al*., 2007).

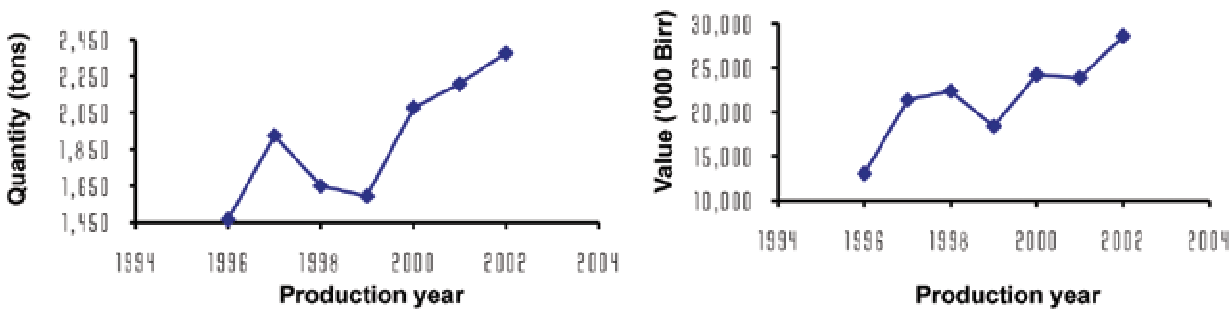
Collection and processing of gum-resins is labour-intensive activity and involves huge labour resource, thus known to offer off-farm employment opportunity for thousands of local people. From studies made in Tigray (Tilahun, 1997) and Northern Gonder Zone (Abeje, 2002) it was reported that tapping and processing of frankincense provides considerable employment opportunity for local people and others coming to the area from elsewhere in the country (Fig. 6). Tilahun (1997) indicated one-third of those involved in frankincense processing were women, indicating the role of the sub-sector in gender balancing. Men are mainly involved in tapping and collecting the incense from the forest while women undertake sorting and grading. Kindeya *et al*. (2003) calculated the net return for taper between US $ 100 to 150 per year and average income of US$ 160 per annum for women assuming ten months of off-farm employment. The sub-sector also creates considerable amount of permanent job opportunities at the gum-resin processing and exporting companies. Currently, there are 34 certified gum-resin exporting companies in Ethiopia. None of these studies are up-to-date and for sure currently the figure is different from what has been reported many years back. Thus, national assessment has to be done to verify the current contribution of the gum-resin sub-sector to household and national economy.

Fig. 6. Employment opportunity due to gum-resin production (*photo by Wubalem T. and Adefires W., 2004, 2007*).

3.6.2 Trend of harvest and trade

According to Mulugeta and Demel (2004), both trade volume and the value generated from export were steadily increasing from time to time (Fig. 7). The trade increased in value by 14% and 24% for the periods 2001-2003 and 2004-2005, respectively. Such increment was probably due to the dramatic increase in the involvement of the private sector and the existing fair market for the products. Furthermore, the recurrent drought and its consequent impact have steadily shifted the livelihood of the pastoral communities from livestock to other means such as gum-resin collection in an effort to diversify their income. Nonetheless, at world scale Ethiopia's gum/incense export share is still negligible (1%) and 28% of the total Africa's export (Mulugeta, 2005). That means the proportion between the resource base and what we are sharing from the global market is not parallel. Such a little share might be due to the limited attention given to the immense role of the gum-resin bearing species in Ethiopia. Annual trade volumes for gum Arabic from major importing countries in the 1990s was between 27,435 - 43,622 tons but is expected to reach the volume of 60,000-70,000 tons during the first decade of 2000 (Chikamai and Odera, 2002). The value of gum Arabic in the world market has also grown by 50% and 10% for the period 2001 - 2005 and 2004 – 2005, respectively, which indicates an increasing demand for the products. Global demands for natural gums and incense are growing for a number of reasons that include: consumers' preference for natural/organic products over synthetics, new innovations and expanding applications for most of these natural gums and incense, global consumer population increases and production technology availability, diversification of livelihood in reducing vulnerability and others.

Fig. 7. Export trend in quantity and value generated of natural gum-resins from Ethiopia between 1996 and 2003. (*Source: Mulugeta and Demel, 2004*).



3.7 Ecological contribution

Ethiopia is one of the most vulnerable countries to climate change. The alarming expansion of desertification is really precarious. Extreme climate events such as recurrent drought and flood are hitting the country, jeopardizing the effort to escape from the Vicious Circle of poverty. To this end, several studies worldwide proofed that forests can play double roles offering the chance to integrate different issues like combating desertification, CO_2 sequestration, biodiversity conservation, maintain environmental integrity and economic utilization (Peter, 1996; Mulugeta and Demel, 2004). Similarly, managing the woodland vegetation for production of gum-resin has been recognized for its significant contribution in ecological, economic and social integrity (Fig. 8). This is also an opportunity to contributes to UNCCC and CBD as signatory party (Mulugeta and Demel, 2004; Adefires, 2006).


Fig. 8. Various gum-resin bearing species growing in degraded landscapes (*photo by Adefires W.)*

4. Current Status of Gum-Resins Collection in Ethiopia

4.1 Frankincense (gum olibanum) production

The use of frankincense has long history in human civilisation. The first record mentioned was found on 15th century BC tomb in Egypt (Abercrombie 1985 cited in Kindeya *et al.,* 2003). The natural oil content and pleasant smell in it made frankincense desirable to burn as an incense and use as a base for perfumes and for medicinal purposes since ancient times (Kindeya *et al*., 2003). As the product is odoriferous, it is often referred to as incense, while the term olibanum is dominantly used and sometimes exchangeable with frankincense (Tilahun, 1997; Mulugeta and Demel, 2003a,b). The Tigray type olibanum is the most widely traded frankincense in Ethiopia (Girmay, 2000). The Ogaden and Borana types are gum-resins produced in the east and south-eastern parts from *B. rivae*, *B. ogadensis*, *B. neglecta* and *B. microphylla* (Girmay, 2000; Mulugeta *et al*., 2003; Adefires, 2006). Other species that yield resinous products designated as frankincense may also exist in these parts of Ethiopia, and may even include those species known from Somalia, for instance*, B. sacra* (Vollesen, 1989).

In Ethiopia, frankincense is collected both by tapping/wounding of the bark and from natural oozing. In northern parts of the country tappers make incisions in the bark of *B. Papyrifera* using a special axe, locally called 'mingaf' (Abeje *et al*., 2005). Though there is a newly introduced tapping technique for this species, still tapping is traditional (Girmay, 2000). Tapping is carried out following a specific pattern around mid-September up to the offset of the dry season, usually June (Abeje *et al*., 2005). Once the first tapping is done, the second tapping will take place after 30-40 days, and involves a moderate widening of the wound, where after the second tapping the whole process is repeated at intervals of two to three weeks until the onset of the rainy season. Wounding is done from east and west sides of the stem of the plant to facilitate faster drying of the gum by exposing wounding spots to sufficient light. Too many wounding spots affect the quality of gum produced (Girmay, 2000). The collection of gum olibanum is normally ceased during the first week of June since the plant starts producing leaves. Then the collected products will be transported to either temporary or permanent drying/sorting station and will be carefully processed until transported to the main store. The wound created during tapping is required to be healed and closed during the first week of June.

Frankincense from other *Boswellia* species is collected from natural exudates (Fig. 9) and no tapping at all (Mulugeta *et al.*, 2003; Adefires, 2006). The producers are mainly herdsmen, women and children, and they do the collection side by side with herding and other activities.

Fig. 9. Naturally oozing myrrh, incense and gum Arabic from Borana (*photo by Adefires W., 2006*).

In Tigray and Amhara, there is organised collection, whereas collection in other areas was made piece-by-piece and haphazardly. Once collected, the product will be transported to available market and/or soled to occasionally appearing buyers at village level (Adefires, 2006).

4.2. Production of gum Arabic

In a wider sense, gum Arabic refer to all gums collected from several *Acacia* species, which sometimes is referred to as "Acacia gum". Nonetheless, in Ethiopia gum Arabic in most reports refers to gum collected from *A. senegal and A. seyal*, though the two are collected and delivered separately as they are purchased on a different price and for different end uses. Still in some reports the two are referred separately as gum Arabic and gum talha (Mulugeta *et al.*, 2003), the former refers to the gum from *A. senegal* and the later to gum obtained from *A. seyal*. It has been indicated that gum talha of *A. seyal* has greater price than gum Arabic in various production areas in Ethiopia (Adefires, 2006).

Gum acacias are collected from cracks in bark of wild trees (Fig. 9), mostly in the dry seasons, with little or none in the rainy season when flowers are out (Girmy, 2000, Mulugeta *et al.*, 2003, Adefires, 2006). In most African countries, gum Arabic is regularly tapped from *A. senegal* trees which are about six years old. It was done by making narrow transverse incisions in the bark.

In about a month, tears of gum form on the surface and are gathered. Information from other countries indicated that trees begin to bear gum from 4 years of age (Duke, 1983). In Sudan and Nigeria for instance, virtually all gum from *A. senegal* is obtained by tapping. However, in Ethiopia gum Arabic is mostly produced from natural oozing. There is little experience of tapping at northern part of the country. However, very recently Forestry Research Center has adopted a tapping technique from Sudan and is undergoing an experiment under controlled condition and hoped to communicate the result very soon.

4 .3 Production of myrrh and myrrh types

The south-eastern *Acacia-Commiphora* woodlands are the richest in the diversity of the *Commiphora* species. Thirty-five (67%) of the *Commiphora* species found in Ethiopia were recorded in the species list in other African countries while 9 species are endemics to Ethiopia (Vollesen, 1989). Several species produce currently or potentially marketable oleo-gum resins (Kuchar, 1995). Myrrh, oppoponax and hagar are used to refer to the various resinous products obtained from *Commiphora* species, though distinction is often made between the three depending on the specific source species. In some literature (Thulin and Claeson, 1991) *Commiphora* gum is classified as scented/perfumery myrrh (called 'bissabol' or oppoponax) and medicinal myrrh (called 'heerabol'). Myrrh (heerabol) is a typical name for the gum obtained from *C. myrrha* and is called true myrrh (FAO, 1995). This is probably the myrrh used dominantly in medical context (Mulugeta and Demel, 2003). Generally, the chief *Commiphora* gums of economic importance in Ethiopia are myrrh, oppoponax and hagar (Girmay 2000; Mulugeta *et al*., 2003; Adefires and Dagnew, 2008).

Similar to various areas in the country, myrrh and myrrh type resins production is carried out by collecting exudates from trees in natural stands and random picking from naturally and/or accidentally exuding trees by peasants and pastoralists. Gum collection is considered secondary as it is carried out while executing other activities namely livestock production which is perceived to be more important (Adefires, 2006, Wubalem *et al*., 2007). Adefires (2006) noted that collection and post harvest management of gum and resin in Borana is almost traditional, indicating its adverse effect on the quality and quantity of gum produced and thus on the role that it could play both at local and national level. Moreover, the mixing up of gums and resins of different *Commiphora* species for increasing trade volume is a common phenomenon of adulteration, resulting in poor quality which again severely affecting marketing of gums and incenses in Borana. Thus, the need to promote and commercialize the use of such a viable resource through involvement of the local community was highly recommended.

4.4 Gum karaya

The genus *Sterculia* comprises about 300 species of which approximately 25 species are said to occur in South Africa's tropical forests (Vollsen, 1995; USAID, 2005). *S. setigera* belongs to the family *Sterculiaceae,* which is a source for important non-toxic edible gum is widely found in Ethiopia. Gum karaya sometimes known as gum Sterculia is the trade name for the gum produced from *Sterculia* species. However, in Ethiopia gum karaya is not well produced so far. India is traditionally the biggest producer and exporter of gum karaya from *S. urens*, but increasing amounts of gum enter international trade from Africa. Senegal produces gum from *S. setigera* exporting around 1000 MT per year (Wubalem *et al*., 2007). Ethiopia has potential for commercializing gum karaya product that may attract local and foreign investors, and hence contributes to the national economy. Recent observations showed that gum karaya production started in the northern parts of the country and research on resources base assessment and tapping techniques is undergoing by Forestry Research Center.

5. Quality Analyses

Except the crude idea of product type being classified based on botanical sources, there is serious knowledge gap in characterising the product quality of various sources in the country. However, there were attempt to characterise physic-chemical properties of some of the major gum-resins types. For instance, there is an understanding of the contents in Tigray type frankincense and the gum Arabic from Rift valley. There are also some workable standards mainly based on size and colour. However, there is no information for majority of the products and yet the impact of location/provenance on gum-resin quality was not investigated. This on the other hand seriously affected marketing.

Processing of gum and resin products in Ethiopia is limited only to cleaning and grading which is done manually (Wubalem *et al. 2002*; Mulugeta, 2005). According to Girmay (2000) and Kendeya (2003), sorting and grading is made in accordance to size, color and purity of the products. Five grades of frankincense from *B. papyrifera* are recognized in Ethiopia. The first three grades are exported while 4^{th} and 5^{th} grades are sold locally for domestic uses in Ethiopia. In all cases, larger and whiter lumps are valued more than the smaller, powdered and darker lumps. However, the current grading system does not correspond to the end use of the products essential oil and other chemical products. No grading is done for the Ogaden and Borana type olibanum. On the other hand, myrrh is sorted into five grades while gum Arabic & talha in most cases are only cleaned but not sorted into different grades (Mulugeta, 2005). Studies to investigate the possibilities of value added processing and quality control is generally lacking.

6. Current Status on Development and Conservation Interventions of Gum Resin Bearing Resources

In principle, the respective Regional Agriculture and Rural Development Bureaus are responsible to the management of the woodlands that harbor gum-resin bearing tree species. Thought *B. papyrifera* is important source of frankincense; the resource base of the species is dramatically decreasing. For instance, in Tigray more than 177,000 ha of *Boswellia* forests were destroyed in the last 20 years (Kindeya, 2003) and similar reports exist for Amhara Region. This also applies to most of the other gum-resin resources of the country vulnerable to both natural and anthropogenic factors. More importantly, *B. papyrifera* and some other *Commphiora* species lack natural regeneration, implying the endangerment of these species (Kindeya, 2003; Abeje *et al*., 2005; Adefires, 2006). Conversion of forest land to agriculture, over grazing, resettlement, improper tapping, fire, fuel and construction wood, drought, bush encroachment and impact of invasive species, wind and others were reported as major factors (Abeje *et al*., 2005; Mulugeta *et al*., 2007). Rijkers *et al.* (2006) for instance, indicated intensive tapping as potential threat to healthy seedling abundance. According to him, inappropriate tapping accompanied by high pressure of livestock grazing and fire, led to very low germinant densities. Severe and prolonged drought periods were also reported as contributors to the overall lack of successful seedling recruitment.

In an effort to save the species tapping regimes should include time periods in which resin harvesting is discontinued in order for trees to recover and replenish stored carbon pool. For *B. Papyrifera*, four years of rest have already greatly increased germination levels, and thus allowing yearly tapped areas a rest of 4 years was suggested (Rijkers *et al.,* 2006). In addition, seed germination must be followed by a ban on livestock grazing in order to ensure successful recruitment. Study results recommended developing a comprehensive woodland management system that guarantees sustainable productivity of *B. papyrifera*.

To better assist natural rehabilitation, closing degraded forest from free grazing, fuel wood collection and other interference has been practiced in Tigray (Mesfin *et al*., 2007). According to this particular study, comparison of net benefits in terms of Birr per ha was made for closed and open *B. papyrifera* forestlands. Sensitivity analysis showed that managing degraded *B. papyrifera* forestland as closed area always generates a higher NPV than the open one in case of changes in discount rate and prices of inputs and outputs. Thus, managing the forest through closed areas is a competitive land-use alternative that can provide greater net benefits than both open forestland and agricultural croplands (Mesfin *et al*., 2007). Furthermore, a number of nurseries in Tigray are now raising seedlings of *B. papyrifera* for reforestation (Kindeya *et al*., 2002), though the success so far was limited. For instance, in 1999 and 2000, only 4.5% and 8.7% of those planted in western Tigray have survived.

According to Hailemariam (2008), having this concern in mind, the regional BoARD with a firm stand of conservation and sustainability have proposed that the only utilization focused production system should stop before the resource completely disappears. Therefore, the office designed policy and plan concerning incense and gum development, conservation and utilization for the region. The core idea of this new approach is to enhance development of the resource through giving the land with the resource to interested legal bodies such as investors, cooperatives and other organizations on a concession basis for longer times with strict follow up from the government side rather than annually renewing production areas that could not create sense of ownership. Based on the new policy approach a total of 89 applicants (organizations, private investors and cooperatives) have got temporary permit. Some of them have submitted their management plan for five and one year and the region is on the way for the final agreement of the concession.

Table 3. Summary of past research endeavors on different issues of gum-resins resources in Ethiopia

Main issues addressed	**Author**	**Studied species**
Taxonomic account of the species	Vollesen, 1989 Gemedo *et al*., 2005; Adefires, 2006	*B. papyrifera;Commiphora* and others in Borana area
Seed germination	Tilahun, 1997	*B. papyrefera*
Opportunities and constraints	Tilahun, 1997; Abeje, 2002; Mulugeta *et al*., 2003, 2007; Adefires, 2006, Adefires and Dagnew, 2008,	*B. papyrifera*, other *Boswellias* and *Commiphora*
Resource status and ecology	Girmay, 2000; Gindaba *et al*., 2007; Adefris 2006; Adefires and Dagnew, 2008; Abeje 2002; Kendeya, 2003; Dagnew, 2006	All gum and resin trees; *B. papyrifera; A. senegal*
Socioeconomic contribution	Mulugeta *et al*., 2003; Adefires, 2006; Adefires *et al*., 2007; Abeje *et al*., 2005	All gum resin trees *B. papyrefera*
Characterization/ Chemistry	Ermias, 2003; Dagnew *et al*., 2009	*B.papyrifera frankincense, Commihporas*
		A. senegal/gum arabic
Tapping techniques	Wubalem *et al*., 2004	*B. papyrefera*
General issues	Girmay, 2000; Wubalem *et al*. 2002; Mulugeta and Demel, 2004; Mulugeta, 2005	All gum and resin bearing tree species

7. Research Gaps

From the review of past research activities on natural gum and resin resources, it can be clearly seen that the research undertakings so far are insufficient to address major concerns in the sector. For example, improving traditional tapping and developing new appropriate tapping techniques for other gum and resin bearing tree species is either scarce or completely lacking. The only attempt to improve tapping was done by Wubalem *et al.*, (2004) that improved the efficiency of tapping through reduction in tapping time by half. Such research efforts that can come up with scientifically backed recommendations on the optimum tapping intensity, suitable tapping tools, minimum size of the trees for tapping, wound sizes (width and depth), optimum tapping seasons, resting period, and related issues for many of the species is urgently required.

Lack of natural regeneration is another problem that threatens the population of some of the gum and resin bearing tree species particularly that of *B. papyrifera* (Abeje, 2002; Kendeya, 2003). Almost in all parts of the country gum and resin products are extracted from natural stands that call for successful efforts to enhance natural regeneration as well as establish plantations. However, little has been done to understand the germination ecology (Tilahun, 1997), to foster natural regeneration and establish plantations by artificial propagation (Negussie et al, 2007). Thus, research based recommendations and guidelines for enhanced natural regeneration and propagation and field establishment techniques needs to be addressed soon. There has been very little emphasis to studies on value added processing, post harvest handling and generating comprehensive marketing researches for almost all the products except few attempts. Hence, characterization works to investigate the physical and chemical properties of gum and resin products of the country and examine variation in these properties of similar products from different sources and comparison with international standards is a major study area for quality control helpful in fetching better prices from international markets.

Social researches to examine the participation of the local community, access to the resource and benefits, markets, market access and marketing channels, policy and institutional issues, and perception of the community on the production of the products are lacking except for very few studies (Mulugeta *et al*., 2007; Tatek, 2008). Such information is crucial for developing production guidelines that can ensure sustainable management and utilization of the gum and resin resources of the country. Very importantly, studies and field observations indicated that insect attack on to the tapped trees is a major concern (Abeje, 2002; Kendeya, 2003). This calls for an urgent attention to conduct pathology and entomology researches to device some control and protection strategies.

8. Recent Research Efforts/ Ongoing Research Activities

Based on the recommendation from various research findings and the current demand from the extension, private sectors, the newly established NTFPs Research Case Team in the Forestry Research Center identified thematic research area which include resources base assessment and mapping, propagation, taxonomy, biology, ecology, selection, tapping, socio-economics, value addition and protection. The case team in collaboration with other institutions is running a wide-ranging research mega-project aiming at generating comprehensive packages to promote the sustainable management and utilization of natural gum and resin resources. The other major ongoing research project is the FRAME, a joint research project between Forestry Research, Wondo Genet College of Forestry and Natural Resources, Mekelle University and Addis Ababa University from Ethiopia side and the Wageningen University, The Netherlands. The project has 4 PhD and one post doc project. There are also some projects by students, and researcher from other institutions.

9. Major Constraints in Development, Utilization and Conservation

Despite the enormous socio-economic and ecological contribution from the proper management and utilization of gum and resin resources of the country, the resource and hence the sector is reported to be in a big threat due to several interrelated factors (Abeje, 2002; Wubalem *et al.,* 2002; Mulugeta, 2005). The constraints can be grouped in to policy constraints, infrastructure and physical constraints, technological and human activity related constraints. In the following section the major constraints in development, utilization and conservation of gum and resin resources is outlined based on the available literatures.

Inadequate/insufficient research undertakings**:** As it was presented in section 7 of this review, there have been insufficient gum and resin research undertakings which were skewed to only few of the products and areas. As a result many of the major issues are not yet addressed and backed by research recommendation which is a major bottleneck for the full realization of the potential of gum and resin sector. Even the available information is in a fragmented way. This could be attributed to the prevalent shortage of trained researchers, physical facilities and budget in the Forestry Research System (Wubalem *et al*., 2002) and the hostile environment and accessibility of the areas where the resource is naturally distributed. This situation entitle the requirement of aggressive research endeavors to address priority issues to contribute to the sustainable management of the resource and improve proper utilization.

Inadequate information on the resource base and market access**:** Information on the amount, type and extent of gum and resin resources at national level is lacking which is the major problem in determining the actual production potential and planning for efficient production. Only preliminary estimations are available (Girmay, 2000; Adefires, 2006). Currently production is undertaken without a master management plan.

Poorly developed production practices**:** Gum and resin products in Ethiopia are collected from natural ooze except the case of frankincense from *B. papyrifera*. Even tapping of frankincense is not properly developed and still creating damage to the trees. The methods of post harvest handling/cleaning and storage are also not well developed. This constraint is actually merely the result of inadequate research and extension undertakings which is outlined above.

Absence of policy guidelines favorable to the gum and resin sector**:** The one year leasing of Boswellia stands to gum and resin producing enterprises (Wubalem *et al.*, 2002) and lack of supervision of the leased areas is causing damage to the resource. The short time lease system has limited the enterprises to invest on the resource for enhanced and sustainable production.

Inaccessibility/location of the resource in remote areas**:** From their very nature gum and resin bearing tree species are distributed in remote areas characterized by ragged terrain, lack of access roads and infrastructure facilities. This contributed much to the low volume and quality produced (Girmay, 2000; Wubalem *et al.,* 2002; Adefires, 2006) due to the associated hardship (harsh temperature, thirsty and disease) and difficulties to mobilize labour force, equipments and supplies as well as collection and transportation of the products.

Resource degradation**:** According to Kindeya (2003) and Abeje (2002) dry woodlands harboring gum and resin bearing tree species are under serious threat mainly as a result of clearing and conversion of woodlands to agricultural lands, government resettlement programs, human induced fire, excessive wood harvesting for fuel wood, improper harvesting/tapping of gums and resins, insect attack, windfall and overgrazing by livestock.

Lack of quality control and illegal boarder trades**:** Although there is no quantitative information on the exact amount of gum-resin, registered enterprises are complaining that lack of control on both domestic and illegal trade of gum resin products in Ethiopia is affecting the expansion of official commercialization of the product (Mulugeta, 2005).

10. Principal Exporters of Gum and Resin from Ethiopia

Organized collection of natural gums on a commercial basis is reported to have begun around 1948 (Girmay, 2000). Currently, several private organizations (Table 4) are actively involved in the business, indicating that there is an increasing trend (Girmay, 2000). For instance, Mulugeta, (2005) reported 15 exporters having a permit to export gums and resins. According to Mulugeta (2005) the private entrepreneurs share about 56% of the export and 55% of the export value. The majority of the private enterprises trade gum olibanum, principally the Tigray type olibanum, and are active in exporting than presenting their products on local markets. Nonetheless, some of the private entrepreneurs as well as NGPME present considerable share of their natural gum product on local markets. In fact, the domestic sale by NGPME is partly purchased by the private enterprises, which ultimately is exported.

Table 4. List of gum and resin exporters from Ethiopia in accordance to their share

No	Name of exporter
1	Natural Gum Processing and Marketing Enterprise
2	Guna Trading House Share
3	Abbebaye Clearing
4	Genale PLC
5	Darulea Nesrdin
6	Ambasel Trading House PVT
7	Naddish Woldu Teke
8	Bwap Exporter PLC
9	Yahia Sayid
10	Helenic Eentp
11	Yusuf Newera Animal MED.
12	Sahilu Taye
13	Tirgo Ali Abdulahi
14	Hasen Ali Abdulahi
15	Obah Hassen Arie

11. Conclusion and Recommendations

Various fragmented documents were reviewed to come up with the current conclusion. According to the currently available information, Ethiopia was shown to have large oleo-gum resin resources base still to be tapped. The huge diversity of gum bearing species, their wide distribution across many Administrative Regions and the present age old experience of gum tapping make the country peculiar. The potential of the gum-resin sub-sector to generate income for local subsistence in particular and national economy at large was proved positive, indicating the need to work out for more. Many of the research outputs depicted the significant safety net role of gum collection and sale mainly during slag-periods and for the pastoral and agro-pastoral communities in Drylands of the country by means of offering alternative options. The role of the sector to combat desertification and ecological degradation is also much emphasized. However, there still exists a critical lack of quantitative and up-to-date data that enable effective planning. Most of the available information are either too old or based on work on small area making specific generalization difficult. There is also a severe threat on the woodland resources of the country which need attention.

The reviewed literatures clearly showed that investing in the sub-sector is a feasible option. It also noted that global demand is increasing indicating the opportunity behind to gain better return. However, the lesson learnt showed that Ethiopian gum sector has still many weaknesses compared to the large potential of the resource base. The following recommendations are forwarded for policy directions and future planning to maximize the benefit from the sub-sector. The first most important measures should be giving attention to the economic, ecological and social potential of the gum-resin sub sector and improve poorly developed infrastructure at major producing areas. Second, research must come up with comprehensive technology, knowledge and information packages that suite to each gum-resin producing species and area. Hence, the currently under going efforts by different parties should be supported and should continue. Research must also be set up around production zones so that confusion as to the resources distribution will be solved. The current week organization set up of forestry extension, education and research must also be optimized and capacity of support organizations should be developed. Production and market information system management must be in place and should not be haphazard. The need to accelerate private sector involvement is the area should continue, however, must be harmonized with development and sustainable management of the resources base. There must also be promotional campaign that could help boost both the image of Ethiopian gum-resins, which should be supported with value added processing issues like organic certification. Inline with this implementation of international standard for quality control should be in place. The issue of the current leasing system in *Boswellia* woodland should also be improved for it to be profitable and also to encourage restoration of the resources base. It is also necessary to think of promoting commercial farms through improving availability of resources base including land, labour and market availability.

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OVERVIEWS OF RESEARCH APPROACH, ACHIEVEMENTS AND FUTURE RESEARCH DIRECTION WITH CROP AND LIVESTOCK IN DRYLANDS OF ETHIOPIA

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Abstract

The dryland areas of Ethiopia cover a wide range of agroecologies and farming systems and are becoming increasingly important for agricultural production. Therefore, there is a need to understand the ecological, economic, and social importance for devising effective research strategies for developing these areas. In this paper the area coverage, agroecologies, farming systems, potentials, constraints, research approach, the key technologies developed so far and impacts on production towards food security in the drylands are synthesized.

***Key words**: Dryland, farming systems, technologies generated so far*

1. Introduction

The drylands areas have wide and diversified farming systems in terms of geographical area coverage and extent. They cover about 66.6 % of the total landmass of the country (MoARD 2005). This includes the eastern part of the country that covers the whole of areas of both the Afar and Somali regional states with predominantly pastoral and agropastoral production system; the central part covering Central Rift Valley around Alem Tena, Bulbula, Dera to Sire, Meiso and Asebot plain and many partseast Shewa in the Oromia regional state; the south and southeastern part that include Negelle Borena, Yabelo to Moyale, Elkere, Delo, Bulbula area and many parts of south Omo; and the northern drylands: Almost the whole of Tigray region except some areas in western part; The Amhara region including most parts of south and north wello zone, the Oromia zone within the Amhara region and substantial parts of north and south Gonder zone. Map which show the detailed dryland areas geographical coverage and agroecologies is presented in Fig.1.

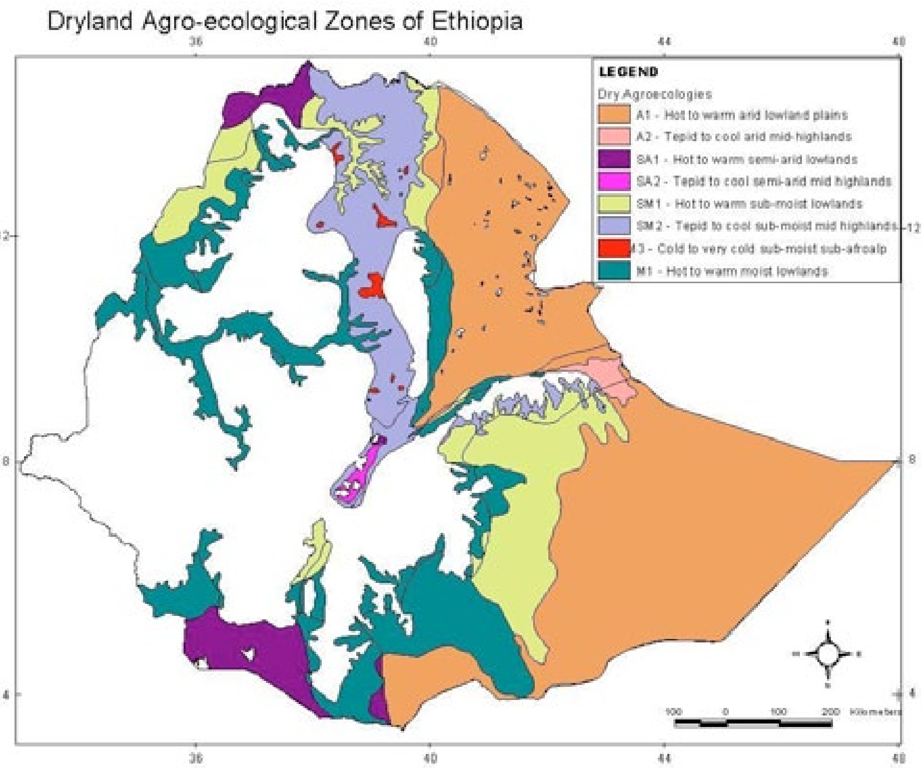

Fig. 1. Dry land Agroecological Zones of Ethiopia

The details of dryland areas, farming systems, constraints and potentials is indicted in Table 1. From this table it could be observed that the drylands have wide areas with different production systems, with different potentials and constrains indicating that research and development in these areas should be based on agroecology and system approach and not commodity approach as it is now in the new EIAR system. Furthermore, it is important to know the details of the diversity of drylands as indicated in subsequent sections.

Table 1. Summary of the farming systems, crop and livestock species, potentials, constraints, area coverage and location of the dryland Agroecology (Kidane, 2003).

Agroecology	Farming system, crop/livestock species, potentials, constraints, area coverage and location
Arid	Farming Systems: pastoral and agropastoralism, livestock species include sheep, goats, camel, donkeys, and major crops: cotton, sesame, millet, tobacco, and sorghum. Major constraints: water stress, low soil fertility, over grazing and desertification, salinity, wind erosion, termite, lack of infrastructure, marketing. Potential: livestock production, irrigated agriculture, wildlife and tourism, salt mining forestry and incense production. Area coverage and location: is located over large areas of Afar, Somalia, parts of east Shewa and southern most parts of Borena.
Semi-arid	Farming system: livestock/crop mixed type farming. Livestock species include sheep, goats, camel, donkeys, and major crops: include short cycle drought resistant crops including cotton, sesame, millet, tef, sorghum, horticulture crops, tobacco, sorghum, haricot bean and maize with supplemental irrigation. Constraints: open overgrazing, low input agriculture, land degradation, intense and erratic rainfall, water stress, low soil fertility, deforestation, salinity, wind erosion. Potential: livestock production, rainfed crop production, afforestation, mechanized and irrigated particularly in the valley bottoms and rift valley area and is located over the northern half of western Tigray, lake Koka in eastern Shewa, south Omo and pocket areas above Moyale in Borena area, both sides of rift valley lakes
Dry-Sub-moist	Farming systems: crop/livestock mixed type farming, livestock species include same as above, crops: highly diversified and major grown in the area include sorghum, tef, maize, barley, wheat, millet, haricot beans, chickpea, faba bean, field pea, safflower, sunflower and several horticultural crops. Constraints: water stress low soil fertility, open overgrazing, low input agriculture, land degradation, deforestation. Potential: relatively higher potential for rainfed crop production, livestock production, afforestation, incense production. Area coverage and location: located in most parts of the highlands of the north Shewa, south and north Wello, Wag Hemera, north and south Gonder in the Amhara region, some parts of eastern, western, eastern and central Tigray region, rift valley areas around south and west extending east and western Hararghe, east Shewa lowlands of Arsi, pocket areas around north Shewa, around Sheno area.

Drylands have wide altitudes ranging from below sea level (-126 m) in the Afar depression in the northeast to 2400 m elevation in the northern highlands. Thus, they include highlands, mid-altitude and lowlands areas. The farming systems are also complex and highly diversified. Crop, livestock and forestry production systems are highly integrated varying within short distances. This indicates the need of integrated approach to develop sustainable production system (Kidane, 2005).

Although there is no good census about the population and other socioeconomic data of the dryland areas, it is estimated that more than 1/3 of the populations in Ethiopia live in the drylands. It is also important that the population of these areas is continually increasing because people are moving from the highlands to the prevalent dryland areas in the lowlands due to over population rise leading to land degradation in the highlands. Because of the ongoing settlement program of the government to these areas, these people are environmental refuges settling in the fertile lowland dryland areas and come with their inappropriate traditional management and farming systems and are causing land degradation. The dryland management is becoming increasingly important, which should be realized by researchers and policy makers and consideration of strengthening the research and development effort in the dryland areas is crucial for sustainable utilization of dryland resources.

The drylands including the pastoral and agro pastoral areas that are naturally rich in various resource bases. The habitat of drylands is home to various types of domestic and wild animals. Rangelands for example, are important in providing forage for livestock and wildlife. Range eco-systems supply minerals, soil, plant, water, wildlife, wind, radiant energy, fish, gums, resins, free seeds and aesthetics. Drylands are also sources of water, energy and mineral resources: There are water sources with high potential for consumption, irrigation and as sources of energy in the form of rivers (Awash, Wabi Shebele, Genale, Dawa, Baro, Omo, etc.), lakes in the rift valley (Awassa, Shalla, Abijata, Chamo, Rudolf, etc.), as well as potential ground water resources. The lowlands are also rich sources of solar and wind energy, and geothermal and fossil fuels such as gas. Many mineral deposits such as limestone, marble, salt, potash sulphur, gold, etc., are also found in dryland areas.

Drylands are the center of origin and diversity of many cultivated crops. They are the main centers of sorghum, finger millet, field peas, chickpea, cowpea, perennial cotton, safflower, castor bean, and sesame and others (Source-). The dryland areas of the country are also rich in natural vegetation. It continues to play an essential role in the country's ecology and economy. Natural vegetation provides food, fodder, fuel and building materials, and helps to protect the soil from erosion and restores its fertility.

Dryland areas of Ethiopia are endowed with a wealth of plant and wild animals with high potential to produce herbal drugs and plant derived medicines. In fact, the woodlands of Ethiopia are also sources of several medicinal plants, particularly those in the genera *Acacia, Boswellia* and *Commiphora.* Traditional medicines are also obtained from wild animals in Ethiopia, e,g., hyena, wild pig, civet and the like. The use of traditional medicine is growing as modern medicine has become very expensive and beyond the reach of most people. The value and role of traditional health care systems will not diminish in the future because they are both culturally viable and expected to remain affordable. It is estimated that 80% of the people in Ethiopia rely on some form of traditional medicine for their primary health care needs, and drylands play a significant role in this line.

The bio-diversity of the dryland areas is not limited to genetic resources that can be farmed, and for medicinal and veterinary use, but are also very rich in wildlife diversities, which are known for attraction for tourism purposes. To this end, most of the 277 wild species of mammals, 861 species of avian are found in the rangelands. This is quite an important precondition for developing the tourism industry of Ethiopia and to improve the contribution of the tourism subsector to the national economy (Source..).

Livestock is a living bank for farmers in the dryland agro-ecology. It serves as insurance during the crop failure, as a source of food, and other socio-economic functions. Drylands are centre of animal diversification. The Borana, Jijiga cattle, black head Ogaden sheep, the Afar goat, the Somali goat, etc., are distinct breeds of livestock. Their conservation to prevent the erosion of genetic diversity through such things as crossbreeding, diseases, etc., and utilisation deserves full understanding of the dryland eco-system (Source.._.

Despite of all these resources, researchers, policy makers and development workers largely misunderstand the prospects of drylands for agricultural development. They are commonly called "low potential" rather than "low rainfall" areas. As a result, dryland areas were largely neglected in agricultural development in Ethiopia. Technology for these areas has been limited or lacking. Yet paradoxically, the future of the expansion of Ethiopia's food production is in these areas. As a result, the government of Ethiopia took a positive move and established the dryland agriculture at directorate level to cater research and development in the drylands. This is in line with its policy of solving the urgent and current pressing need of achieving food security, alleviating poverty and enhancing the natural resource base in the whole country particularly in dryland areas. In order to fulfill this urgent task the dryland sector was given mandates and responsibilities that are discussed in the following sections.

2. Technological Options for Drylands in Ethiopia with Focus to Climate Change Adaptation

Numerous crop technologies have been generated over the past years through a network of research institutions in the country dedicated to addressing the problems of climate change and rainfed agriculture. These include the development of crop species and cultivars, water harvesting, fertility, agronomic management practices, and others. Some of these technologies have been refined on farmer's field. These include drought tolerant/resistant, early maturing and heat tolerant crop species and varieties. The technologies developed in the crop improvement programs included food crops such as cereals mainly sorghum (6 varieties), maize (4 varieties), tef (5 varieties); grain legumes, haricot bean (4 varieties), a pigeon pea, cow peas (3 varieties), oil crops (sesame, groundnut), and fibber crop varieties. Haramaya University has also released 2 potato, 2 sweet potatoes, 1 faba bean, 1 field pea high and 1wheat varieties. All of these developed varieties are yielding under the ongoing climate change (Kindie, personal communication). However, these improved crop species and varieties has brought about only a limited impact in increasing the food production and achievements of food security in areas where there is high climate variability and change.

The major problem with these improved varieties of seeds is lack of enough quantity, and reasonable quality seeds and getting the seeds at the right time and place to the farming communities. Publicly financed seed firms (Ethiopian Seed Enterprise) or Private Seed Enterprise that produce and market seed to farmers has been established in the country. However, these Seed Enterprises could not adequately respond to the needs of farmers and cover only 25% of the total demand. As the result of this, the end-users cannot benefit from the improved technology (seed). Consequently the production and marketing of most cereals and leguminous seeds important in the semi-arid areas of the country for climate change and variability of the country have been limited. In addition, the performance of improved varieties was not verified on operational scale on farmers' field with the participation of the farmers. Agronomic practices such as water, soil fertility and other management practices was either lacking or not included. The emphasis was only on few basic food crops for subsistence and not on high value market oriented crops.

There are some soil water conservation, fertility improvement, integrated management practices that combine water harvesting, use of fertility improvement, appropriate agronomic practices such timely land preparation, weeding and use of improves varieties, etc., that can improve crop production. This paper gives only few key technologies which show the importance of integrated approach in improving crop production on sustainable basis in the drylands and use of natural resource management with improved germplasm.

3. Soil Water Conservation and Fertility Management

Lack of soil water is the bottleneck to successful crop production in the dryland areas. Several research activities were carried out to develop soil management practices, which store and conserve as much rain water as possible by reducing runoff and improving infiltration opportunity time and increase the water storage capacity of the soil profile. Tied ridges have been found to be very efficient in storing the rain water and lead to substantial grain yield increase in some of the major dryland crops including sorghum, and maize (Table 2). The average grain yield increase was very high up to 145 % for sorghum and about 125 % for maize compared to the traditional practice depending on soil type, slope, rainfall and the crop grown in some of the dryland areas, Kobbo and Melkassa. Similar grain and biomass increase of sorghum was also obtained in both Alemaya and Meiso areas (Hiluf, 2005).

Table 2. Effect of soil conservation methods (tied ridges) on grain yield of sorghum, maize in the semi-arid areas of Ethiopia (Kobo and Melkassa)

Soil conservation method	**Average grain yield t ha^{-1}**		
	Kobo	**Melkassa**	**Mean**
Sorghum			
Flat planting (control)	1.6	0.80	1.20
Tied ridges planting in furrow	2.9 (81%)	3.0 (150%)	2.95 (145%)
Maize			
Flat planting (control)	1.2	-	1.2
Tied ridges planting in furrow	2.7 (125%)	-	2.7 (125)

Ridge height = 35 cm; Ridge spacing 75 cm for sorghum and maize; Ridges tied at 5 m interval; Numbers in parenthesis are % grain yield increase over control; Source (Kidane and Rezene,1989).

4. Soil Water Conservation Practices with Improved Agronomic Practices Using Improved Crop Varieties

Soil water conservation should be integrated with other improved agronomic practices so that the soil water retained could be used effectively. Weeds should be controlled as early as possible to avoid completion. Water harvesting techniques should also be used with improved crop management practices to use the harvested water more efficiently and improve crop yield (Table 3).

Table 3. Water harvesting plus improved agronomic practices on maize grain yield

Treatments	**Yield (t ha-1)**
Broadcasting, no fertilizer, late weeding 6 weeks after emergence, flat planting (check)	1.3
Row planting, no fertilizer, late weeding 6 weeks after emergence, flat planting	1.7 (37)
No fertilizer, Late weeding 6 weeks after emergence, tied ridges	1.9 (46)
No fertilizer, early weeding 3 weeks after planting, tied ridges	2.3 (73)
40 N 46 P2O5, early weeding 3 weeks after planting, tied ridges	2.9 (117)

Numbers in parenthesis indicate percent of grain yield increase over the check, farmer's practice; Source: Kidane, 2003.

It is important to note that the achievements of farm yields much closer to experimental potential is unlikely to result from a single piece of technology in isolation. But it will require an additive approach that builds on the complementarities of improved variety and agronomic practices (Table 4). While this does not mean that progress in raising productivity will not be feasible without applying the whole package, it does imply the need to consider each item as a component of a technology rather than a stand-alone.

Table 4. Summary of Innovations in Maize yield and Their Impact on Grain Yield Kenya

Component	**Content**	**Yield t ha^{-1}**
Basic	Local variety	0.6
Improved variety	With a small increase in plant population	0.7
Improved fertility	40 kg N/ha 15 kg P/ha	1.1
Time of planting	Moved to near optimum to the area	1.3
Weeding	A second weeding	1.4
Plant population	Increased from 25,000 to 35,000 plants/ha	1.5
Further improvement to fertility	Fertilizer increased by an additional 50 kg N and 20 Kg P ha^{-1}	2.1
Changed to hybrid seed improved timing of operations	Use of hybrid planted within two weeks of start of the rains and weeded within one month of planting	2.8
Improved pest control	Appropriate action to control stem borer and other pests	
Additional improvement to fertility	Addition of 50 kg N/ha and 30 kg P/ha	4.0

(Source)

Mixed and intercropping is widely practiced in traditional agriculture in semi-arid areas of East Africa to diversify and increase production. Thus substantial yield increase was found by intercropping cereals (such as sorghum) with different grain legumes (mung bean, cow pea, pigeon pea, hyacinth bean, and chickpea). The results indicated that sorghum yield increased particularly when it was intercropped with mung bean and cowpea. The other important finding is that striga infestation was lower with the intercropping of both cow peas and mung bean. Striga is parasitic weed constraining the production of important food crop in drylands of Eastearn Africa (Table 5).

Table 5. Effect of intercropping and planting pattern of mung bean with sorghum on striga infestation and grain yield of sorghum in semi-arid of Ethiopia

Treatment	**Grain yield t ha^{-1}**		**Stand count/plot**
	Sorghum	**Mung bean**	
Pure sorghum (2-8-76)	1.8	-	29.5
Sorghum (2-8-76) + mug bean (22-7-76)	0.9	0.7	7.0
Sorghum (2-8-76) + mug bean (22-7-76), but re-move on (2-8-76	1.5	-	11.5
Sorghum + mung bean planted at the same time (2-8-76)	1.3	0.4	9.5

Source (Kidane, 1993)

5. Assessment of Existing Technologies, Practices and Policies in Dryland Crop Production

During the last two decades of research, plant breeding has been the predominant discipline with other disciplines providing a supporting role. This stress on what we call cultivar only strategy that resulted from the successes of the Green revolution (Wheat and rice) in the predominantly irrigated regions of Asia, South America, and North (Africa) and other breeding success in the agriculture of developed countries (Kidane, 2003). One common characteristic of the regions where breeding has been successful was the moderate to high utilization of improved agronomic practices, including water control and chemical-fertilizer utilization and improved variety. In the United States for example, where sorghum yields tripled in 30 years from, 1.2 metric tons per hectare in 1950 to more than 3.8 in 1980, the genetic contribution was estimated to be from 28 to 39 percent (Miller and Kebede, 1984, not mentioned in the reference list). Over 60 percent of these very large yield gains in the United States were due to improved agronomic practices, especially fertilization, herbicides, and water control. The new cultivars are generally more responsive. Thus, the technological-development strategy needs to include both breeding and improved agronomy. This is because, crop productivity is a function of not only the genetic potential of a crop, but also of the agroclimatic, topographic, and the soil environment in which the crop is grown. Both the genetic potential and the physical environment can be modified. With the Ethiopian dryland context, however, it is the environment (low soil water and fertility and the associated water and nutrient stress) that limits crop yield. This is especially true, in the dryland areas where there is highly variable ecology and farming systems and climate and ignoring management factors avoids the heart of the problem.

The research on cropping systems in dryland areas was very weak. The research themes so far tackled at the research center level on cropping systems inter-cropping, for instance include species comparison, planting configuration, and planting schedule. The aspects which are untouched are genotype evaluation for inter-cropping, nutrient requirement, weed control, physiological aspects, response to different moisture regimes, diseases and pest control aspects and erosion control, etc. This drawback should be addressed to improve crop production in the dry areas. The major problems to be highlighted here is that policy makers should try to improve the input system supply, and the research approach in the dryland areas should change from commodity to system and integrated approach. This can improve the contribution of NARS to improve food security and livelihood and improve capacity to deal with climate change threats.

6. Livestock Production in the Drylands

Ethiopia has the highest number of livestock in Africa and it is the tenth largest in the world. Livestock in Ethiopia in general and in the dryland areas in particular are the principal capital of the farmer. The sector if properly managed and utilized has potential for economic development. This sector is the main stay for dryland people particularly the pastoralists and agro-pastoralists who are the main victims of drought and climate change. Livestock production gives opportunities for economic and social development that goes beyond the objectives of food security. Livestock production is therefore, economically, socially and politically important sector in the country's agricultural system. The question now is how can it adapt to the ongoing climate change and variability and improve production (PADS 2003). The approach used in development and improving livestock production includes the following activities:

i. Documentation of indigenous knowledge and practice for livestock production including:

- Livestock are bred for their resilience to drought and diseases, rather than their productivity.
- Herd species diversification: is common, with many herd owners rearing a variety of different stocks to reduce overall vulnerability to drought and disease.
- Keeping large herd size at the beginning of the drought to increase the likelyhood of the herd to survive at the end of drought period.
- Human and livestock movement as a response to seasonal variations in forage availability. Pastoralists exercise conservation of grazing resources for dry season for mitigating feed shortages.
- In the dry seasons, when milk yields decline or are insufficient for subsistence, pastoralists depend on livestock and agricultural produce. They sell their sheep, goats and cattle, especially males and unproductive females to purchase grain for home consumption. As the degree of severity of drought

increases, the pressure for selling their breeding stock rises.

- The pastoralist select drought and heat tolerant livestock species as drought copping mechanism.
- Change of livestock types and stock diversification is also another strategy used in adapting to climate change and drought.
- Conservation of dry season grazing reserves.
- Reduction of watering frequency.

ii. Technologies available for improving livestock production in relation to climate change and variability are:

A) Solving the feed problem - Some of research results have been documented and synthesized and are ready for use. In relation to this there is information on available germplasm. The major genera of tropical grass and forage legumes held in three international *ex situ* collections by the CGIAR are documented for use of researcher's development agents and the herders.

- Germplasm of indigenous forage genera from dryland areas available from the ILRI gene bank is also available for use.
- Large germplasm collections of multipurpose crops maintained in the CGIAR genetic resources centers
- List of promising herbaceous legumes and fodder tree species for use in dryland areas are available.
- Drought resistant and short crops which could be used to provide fodder in the agropastoral areas have been developed.

B) Introduction of drought resistant and heat tolerant livestock species - Recently drought resistant and highly productive small ruminants have been introduced for the dryland areas and are performing well and could be used to improve production and available for the traditional herders.

C) Development works conducted to improving livestock production in the dry areas - Through previous development projects infrastructure - roads, markets, water, veterinary clinics, interregional trade in over 27% of the southern and eastern rangelands have been established. The project established service cooperatives, upgraded wells, trained herders in animal health, installed a range monitoring system, and transferred fattening ranches to the pastoral community.

Government has also established breeding centers for genetic resource conservation.

1. Feed shortage is one of the major constraints in livestock production in Ethiopia and several activities were carried out to address this problem in order to improve food security by the NARS and other institutions in relation to climate change. These include natural pasture improvement, backyard forage introduction and development, integration of forage legumes into cereal production systems and various forms of utilization of feed resources for livestock production. The natural forage was improved through area closure allowing the natural pasture to regenerate and enrichment plantation was also carried out to fill the gap between natural vegetation.
2. Highly degraded areas were selected and enclosed in many areas particularly in dryland areas to allow the natural pasture to rehabilitate and revegatate. Then drought resistant herbaceous legumes and grass species have been promoted to improve the fodder quality. The community members have been organized into group and formulated bylaws and regulation within the context of the regional state land use guideline. To this effect communities have got a considerable benefit from harvest of grass to feed their animals, sell out to earn cash and long grass (senbelet) which is used for roofing while constructing houses (CRS, 2005 not includeded in the list of refereces).

Several leguminous shrubs which are drought resistant forage crops such as pigeon pea, saltbush, *Senna artemisioides* and *Opuntia* (Beles) were also grown in watershed areas of many woredas in the semi-arid areas of Tigray (GTZ, 2009 not includeded in the list of references). This forage crops can grow on as little rainfall as 200 mm. They are nutritious perennial forage shrub for small ruminants and cattle. They provide protein and minerals needed by ruminants. These forage crops are very effective in soil and water, and soil fertility improvement and rehabilitate degraded areas as proved in most watershed areas.

7. Conclusion and the Way Forward

The dryland areas cover wide and diversified agroecologies and farming systems and are important agricultural production systems. The major problems are water stress and low soil fertility associated with the ongoing natural resource degradation and climate variability. These are leading to environmental crisis and food insecurity, poverty, malnutrition and the like. Therefore, the way forward should be integrated approach combining agricultural production with natural resources conservation and management and should not be in a commodity approach which deals each sector in isolation. It should also focus in developing technologies to adapt to the ongoing climate variability and change to improve production on sustainable bases and achieve food security and alleviate poverty our countries national goal.

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ENABLING ENVIRONMENTS FOR FORESTRY RESEARCH IN ETHIOPIA

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Abstract

Forest research contributes significantly to the development and management of forest resources. The first Forestry Research Institute in Ethiopia was established in 1961 in the Faculty of Science, Addis Ababa University. However, it was disbanded and fully absorbed by the Faculty in 1967. Forestry Research Center and the then Wood Utilization Research Center were established in 1975 and 1979, respectively. However, both research centers were transferred to the then EARO in 1997 and merged. Though the institutional arrenegment history of forestry research in Ethiopia was weak, over the years, it has achieved significant technologies in plantation forestry, agroforestry, tree seed technology, natural forest management, wood utilization, non timber forest products utilization and management, etc. These technologies and information have been disseminated to forest development and forest products utilization sectors. Many problems have been discovered in the analysis of Ethiopian Institute of Aagriculture Rresearch (EIAR)-Bissness Process reengineering (BPR)- As it Is (AS IS) status quo. Therefore, major features of forestry BPR are: projects rather than fragmented survey, experiment and trails (SETs), projects that emanate from customers need rather than researchers own interest, peer review rather than the redundant and several stages of AS IS Review, etc. The research projects are coordinated under 4 national case teams. The main challenges of forestry research sector at EIAR are Staff turnover and lack of trained manpower and lack of adequate laboratory facilities. Other institutions involved in forestry research in Ethiopia are regional research institutes, higher learning institutes and Non-governmental organizations. Forest research institutions in Ethiopia, are affected by the low political profile of the sector as a whole which is manifested by institutions' lack of autonomy, vulnerability to arbitrary and frequent changes in structure, weak voice of the research community, and declining public spending. Hence, there is an urgency and need for major changes in forest research institutions if they are to be more effective in delivering quality and relevant products and services.

Key words: *Forestry research, forest management, staff turnover*

1. Introduction

Agriculture is the dominant sector of the Ethiopian economy accounting for about 45 % of the GDP and 76 % of export revenue. It is estimated to provide livelihood for 85 % of the total population, including the predominantly subsistent farm families who, on average, have a holding of 1.5 ha even less per family to cultivate. These farmers occupy about 90 % of agricultural outputs, including most food crops (cereals, pulses and oilseeds), coffee, and virtually all livestock (Yonas *et al*., 2008).

Forests and the benefits they provide in the form of wood, food, income, and watershed protection have an important and critical role in enabling people to secure a stable and adequate food supply. Deforestation and land degradation, however, are impairing the capacity of forests and the land to contribute to food security, and to provide other benefits, such as fuel wood and fodder. Ethiopians are facing rapid deforestation and degradation of land resources. The increasing population has resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction materials (Badege, 2001). Agricultural productivity is severely threatened by land degradation involving both soil erosion and declining soil fertility in the highlands. This threat stems from the depletion and degradation of the vegetation cover of the country, especially forests, and exploitative farming practices. The clearing of forestland is driven by the demand for crop and grazing land and for fuel wood, both spurred by high rates of population growth. With a decline in fuel wood availability, animal dung and crop residues are increasingly used as household fuel instead of serving as natural fertilizers for the soil; thereby further depressing agricultural yields (EFAP, 1994).

The major reasons of deforestation are clearing of forests and woodlands for cultivating crops and cutting of trees and shrubs for various purposes, notably for fuel wood, charcoal, construction material, etc. The fact that plantation forestry has been very far from meeting the demand for wood for various purposes indicates the inevitability of deforestation. The underlying causes of deforestation are, however, closely linked with the vicious cycle of mutually reinforcing factors, i.e. poverty, population growth, poor economic growth and the state of the environment (Yonas *et al*., 2008).

Although forestry is contributing to the national economy and the global environment, the Ethiopian government gives very little attention to this resource. Therefore, the existing structure, budget outlay, staffing and facilities are inadequate, to say the least, for the minimum of operations required to manage the existing forest resources of the country (Mersha, 2007). Lack of proper reporting on the contribution of forestry to the national economy emanate from several aspects that may include: unawareness by all concerned about the importance of forestry and their essential contributions to sustainable development, lack of enough trained personnel in the field, lack of proper forest resource management and product control. The absence of reliable documentation on the contributions of forestry is a major constraint to estimate its real contribution to the national economy. Therefore, forestry's contribution is not only underestimated, but often reported as part of agriculture. Forests provide diverse products and services that have direct value (use vale) and indirect value (non-use value). If the use and non-use values, which is called total economic value are quantified and valued, the contributions of forestry to the national economy could have been considerable (Demel and Mulugeta, 2005).

2. Forestry Research: History and Current Status

Forest research in developing countries, like Ethiopia, can contribute significantly to the development and management of forest resources. The first Forestry Research Institute (FRI) was established in 1961 through the financial support of GTZ and US-point four. The Institute was housed in the Faculty of Science, Addis Ababa University. However, it was disbanded and fully absorbed by the Faculty in 1967 since it was unable to maintain strong programs and qualified research staff. From 1965 to 1975 there were few forest research activities at Alemaya University but there was no institution charged to lead the research activities (Amare *et al*., 1990). Some forest research activities were also practiced in the SIDA-supported development program since the commencement of Chilalo Arsi Development Unit (CADU) Project in 1965. In 1978, the then Wondo Genet Forestry Resources Institute, now Wondo Genet College of Forestry and Natural Resources were established.

Forestry Research Center (FRC), and the then Wood Utilization Research Center (WUARC), were established in 1975 and 1979, respectively, under the Forestry and Wildlife Conservation Development Authority (FaWCDA). The centers were incorporated in the then Ministry of Natural Resources Development and Environmental Protection in 1992 and again re-transferred to the Ministry of Agriculture in 1995. In addition to these centers, higher learning, local and international institutions were also actively engaged in undertaking forest research (EFAP 1994, Demel, 2004).

Realizing the need to undertake systematic and coordinated research, the Federal Government of Ethiopia reorganized the National Agricultural Research System and established the then Ethiopian Agricultural Research Organization (EARO) in 1997 by proclamation (Negarit Gazeta, 1997). The forest research program at EARO has received equal status with other research sectors. As a result, FRC and the WUARC and other agricultural research centers had been transferred to EARO. According to the proclamation, EARO shall be responsible for generating, improving and adapting technologies and co-coordinating, encouraging and assisting research activities in order to fulfill the current and long term agricultural technology requirements of the country (EARO, 2000).

Forest research, one of the research sectors of Ethiopian Institute of Agricultural Research (EIAR), is actively involved in conducting and building capacity for research. Over the years, it has achieved significant technologies in plantation forestry, agroforestry, tree seed technology, natural forest management, wood utilization, non timber forest products utilization and management, etc. These technologies and information have been disseminated to forest development and forest products utilization sectors.

2.1 Limitations of the research activities

The forestry research activities have limitations that include lack of broadness, organization of the different activities, consideration of social and extension activities. Thus, research topics addressed are limited in scope and consider AEZ and few indigenous trees. Most research activities focused on biophysical aspect and the social aspect was not sufficiently addressed. The research did not also sufficiently entertain policy, economics and the market issues. The research activities done so far were mostly very much fragmented, and dissemination of research output was not that strong.

2.2 Business Process and Reengineering (BPR) and current status of forestry research process in EIAR

Although forestry research has been there for the last 30 years in Ethiopia, no significant impact that can influence the lives of its people has been witnessed. Past research efforts lacked coordination, inclusiveness, responsiveness to demand scientific profoundness. These and many other problems have been discovered in the analysis of EIAR- BPR-AS IS status quo. Therefore, the major features of the new TO BE in forestry research are: projects rather than fragmented SETs (studies, experiments and trials), projects emanate from customers need rather than researchers own interest, peer review rather than the redundant and several stages of AS IS review, process flow based end-to-end forestry technology generation and delivery process, etc. Currently, forestry process is organized in 4 national research case teams, namely Plantation and Agroforestry, Natural Forest, Non-timber Forest Products and Forest Products Utilization. The main challenges of forestry research sector at EIAR are staff turnover and lack of trained manpower and lack of adequate laboratory facilities.

2.3 Forestry research in other institutions of the country

Other institutions other than EIAR, involved in forestry research in Ethiopia are regional research institutes, higher learning institutes and Non-governmental organizations. Regional agricultural research institutes conducting forestry research are: Amhara Region Agricultural Research Institute (Forestry Directorate); Oromiya Regiona Agricultural Research Institute (Natural Resource Process); Tigray Region Agricultural Research Institute (Natural Resource Process); SNNP Region Agricultural Research Institute; Somali Region Pastoral and Agro pastoral Research Institute; and Gambela Region Agricultural Research Institute.

Among Higher Learning Institutions (HLIs) conducting forestry research Wondo Genet College of Forestry and Natural Resources is the only forestry higher learning institute in Ethiopia. It trains foresters at BSc and MSc academic level at present with total annual intake capacity of approximately 400 for undergraduate and 15 for post graduate students. The college has more or less similar research and educational capacity as that of forestry research at EIAR (Demel and Mulugeta, 2005). Other HLIs teaching forestry and conducting forestry related research include Addis Ababa University, Haramaya University, Jimma University, Mekele University, and Ambo University. Although they are not conducting research, Technical and Vocational Agricultural Training Institutions (TVAT) were established under the Ministry of Agriculture and Rural Development (MoARD) in 2002 to meet the demand of farmers training centres in 18,000 farmer's centres in the different regions of Ethiopia. Currently there are a total of twenty-five TVAT colleges, four at federal and twenty-one at regional administrative regions. The training is at diploma (10+3) level where students are trained in the field of Agriculture and Natural Resources Management in which Forest and Soil and Water Conservation is the major components (Mersha, 2007).

Non Governmental Organizations conducting forestry related research include Farm Africa, Forum

For Environment, Ethiopian Development Research Institute, GTZ and Non-Timber Forest Products Research and Development Project. These institutions have also some capacity for forestry research, extension and development in the country.

3. Challenges in Forestry Research

Forestry research institutions in Ethiopia, as in most of the rest of Africa, continue to be affected by the low political profile of the sector as a whole which is manifested by institutions' lack of autonomy, vulnerability to arbitrary and frequent changes in structure, weak voice of the research community, and declining public spending. The limited funds made available often do not match activities and have high annual variations (KFPE, 2001). Generally, there is low morale among research staff leading to very high staff turnover as trained and seasoned researchers leave in search of greener pastures leaving forest research institutions behind with junior and less skilled new recruits (Sall, 2004).

The overall impact of weak forestry research systems in Ethiopia, and ultimately in Africa, translates into low research output and low research uptake or impact (Kowero *et al.*, 2001). The limited output that exists often has unclear relevance to development, duplicates previous work and is of poor quality as evidenced by low publication rate of research in these institutions. Although forest is one of the major resources for meeting the social, economical and ecological demand of the country and the universe, currently in Ethiopia governmental policies have caused this sector to lose its focus. It has been exposed to frequent restructuring and instability with dramatic effect on the employees of the sector. Recently, institutional merging between natural resources, forestry and agriculture and the shifts from one sector to another are harming the forestry and natural resources sector because of competitions and bias of resource allocation, human resources development and program priorities. This result has affected the attractiveness of the forestry and natural resources fields of studies and employment for the last ten years (Mersha, 2007).

Currently, the forestry sector at the federal level has a very low organizational profile in the Ministry of Agriculture and Rural Development. Budget allocations and staff resources are often inadequate to monitor forest resources effectively and to ensure sustainable management. The trend towards decentralisation and devolution of forest management responsibilities to the local governments could not be effective due to low capacity of the sector at all levels. The current capacity of the sector is constrained especially at the regional level due to the absence of an appropriate management structure, the inadequate allocation of budget and the high level of encroachment for expanding agricultural land and illegal settlements (Yonas *et al*., 2008).

Forestry research takes 10 to 15 years, for example, to complete provenance trial and many more years for well performing provenance to find its way into the planting site. These long lags make forest research especially susceptible to frequent restructuring and virtually render it ineffective. Many researchers have left in the past partly because of unpredictable and arbitrary changes. Research facility, which is usually expensive, is another important issue to be considered. During restructuring and changes, in most cases, years of efforts in building capacity is lost and to build it again is costly in terms of both money and time. Frequent restructuring, therefore, can be devastating to the longer-term development of a viable organizational base for forestry research.

4. Experience of Forestry Research and Institutional set up of Other Countries

The most common case of consolidation among African forest research organisations has been the adoption of a single structure called a National Forest Research Institute. The motivation behind this development is to address institutional instabilities, including the attendant staff instabilities, lowering of the transactions costs of forest research across otherwise disparate agencies, and to streamline the allocation of limited resources, thereby improving the focus of the research—spatially and otherwise. In recent years, many countries in Africa have adopted this model, including but not limited to; Forest Research Institute of Malawi (FRIM), Tanzanian Forest Research Institute (TAFORI), Kenyan Forest Research Institute (KEFRI), Forest Research Institute of Nigeria (FRIN), and Forest Research Institute of Ghana (FORIG).

5. Outcomes from the Establishment of an Autonomous Forestry Research Institute

There is an urgency and need for major changes in forest research institutions if they are to be more effective in delivering quality and relevant products and services. Forestry researchers need support and training to work with society in identifying research issues and solving development problems. This will bring them current with the dynamic social, cultural, technological and economic conditions. This would not only make research saleable, it would also promote the role of forestry in social and economic development and raise the profile of the researcher in society. Forestry research institutions have to be prepared for a competitive research funding environment to access global resources and reduce dependency on public funding (Yonas *et al.*, 2008). To address the multifaceted issues of forestry in Ethiopia, to meet the demand for bioenergy, to contribute to the protection and environmental rehabilitation of the rapidly degrading forest resources, to improve availability of quality germplasm, and increase the production of forest products for the rural and industrial development, to make use of the upcoming new global opportunities like carbon trading, the country needs an autonomous or semi-autonomous Ethiopian Forest Research Institute (EFRI). Such a model will not only make it possible to acquire the critical mass of staff and facilities to respond to the seemingly overwhelming research challenge in the country, but also will ensure stability and incremental development of the research system.

Moreover, the autonomous and strong research institute will coordinate research activities conducted by different actors of the country, so that duplication of efforts will be avoided. Sufficient and well-developed human resources in research and development are the cornerstone of advancement in scientific knowledge, technological progress, enhancing the quality of life, ensuring the welfare of Ethiopians and contributing to the country's competitiveness.

6. Conclusion

The challenges of the forestry sector and professionals involved in forestry are to arrest/retard destruction of forest resources, expand the forest resources base to meet demand for energy, construction, wood-based industries and non-timber forest products, keep sustainable balance between utilisation and conservation of forests to improve the quality of human life, harness forest resources to urgently needed socio-economic development and design mechanisms to enhance the production of timber and non-timber forest products for export and reduce/substitute imports of forest products. These can be achieved having strong research institution, capable to generate forestry technologies and knowledge to development, utilization and conservations sector of the country. In the final analysis, the idea of establishing a Forestry Research Institute and strengthening the national forest research system is long overdue. A study supported by FAO/UNDP and conducted by Davidson, as far back as 1988 already emphasized this and provided detailed recommendation on the issue (Davidson, 1988). Convincing decision-makers outside the forest sector of the value of a strong forest research system may be more challenging than ever. But the storm is gathering, a quick and meaningful action needs to be taken now to make a solid case for forestry and plead with policy makers. In all history, may be now is a historical moment for foresters to pull together and make a stand. The window of opportunity is fast closing, maybe it is now or never (Yonas *et al*., 2009). Therefore, breakthrough measures should be taken in the country in upgrading the forestry research sector with appropriate manpower, budget and facilities.

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SUSTAINABLE MANAGEMENT OF BIODIVERSITY: IMPLICATION FOR ADAPTATION TO AND MITIGATION OF CLIMATE CHANGE IN DRY LANDS OF ETHIOPIA

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Abstract

This paper summarizes the current state of resources diversity in drylands of Ethiopia, its potential for food security and environmental resilience and the need for its sustainable management. The reviewed literatures indicated that Ethiopia ranks fifth in species diversity in the Region with a remarkable endemism. Ethiopia's plant and animal biodiversity wealth is considered to be one of the most important features of its varied environment and the age-old socio-economic practices. Dryland ecosystems are the dominant agro-ecologies in the country. Although they are not exhaustively explored and documented, studies revealed that the level of species diversity and endemism in these ecosystems cannot be overlooked. Current findings for instance, indicated that the Ogaden lowland is still sources of unnamed species, either new to the world or to the Flora of Ethiopia. A major driving force for biological diversification in drylands is the relative aridity and the significant variations between sites due to difference in topography, geology, variations in the most limiting factors and seasonal pattern of rainfall, fires and herbivore pressure within each aridity zone. The resulting patchy nature of habitats is thus determinants of the distribution of living organisms, leading to its diversification. Dryland ecosystems in Ethiopia are therefore, renowned biodiversity hotspot and home for various ecologically, economically and socially important species. These ecosystems hosts uniquely adapted species and genetic traits, which in this era of climate change might be crucial both for current local level adaptation and also asset for future developments. The wealth of biodiversity in drylands is a major source of livelihood, particularly for the most vulnerable pastoral and agro-pastoral communities. For instance, the role of the woodland resources and the biodiversity it hosts is the major sources of fodder, food, wood, income, herbal medicine, energy, shelter, employment and other cultural values. Furthermore, the overall role of dryland biodiversity in delivering key environmental services such as maintaining functioning ecosystems and enhancing the resilience of the environment after shock and buffering the ever alarming desertification is tremendous. Despite the enormous ecological, economic and socio-cultural benefits of dryland biodiversity, these vital resources are prone to severe pressure due to rapid land use changes and over utilization. The government and citizens of Ethiopia should therefore, worry about these ecosystems and the resources therein as drylands are soul home for millions of pastoral and agro-pastoral communities, are place where major hydro-dames of the country are situated, support most of the national and transboundary rivers, hosts majority of the National Parks and ecotourism areas, main destination for government led resettlement programmes, land donors for the flourishing commercial farming and major production areas for some of the forest export articles. More importantly, drylands in Ethiopia are politically sensitive and also are areas viewed by professional and key decision makers as present and future hope of the country. In addition, as the country is signatory to the various international agreements, it is mandatory and judicious to further explore and harness the resources thereof and develop feasible mechanisms to realize sustainable management of these ecosystems and thereby promote conservation based and accountable resources utilization in this parts of the country.

***Key words**: Biodiversity, climate change, desertification, Dryland, food security, sustainable use*

1. Introduction

It is widely acknowledged that most of the world's biodiversity is found in Third World countries. Likewise, Africa's plant and animal biodiversity wealth is considered to be one of the most important and feature of its environment. Africa is home to eight of the 34 internationally recognized biodiversity hotspots in the world. These include the Cape Floristic Region, Coastal Forests of Eastern Africa, Eastern Afromontane, Guinean Forests of West Africa, the Horn of Africa, Madagascar and the Indian Ocean Islands, Maputaland-Pondoland-Albany and the Succulent Karoo (Millennium Ecosystem Assessment, 2005). Among the eight world's hotspots, three of them are found in the

Horn of Africa. Ethiopia is the fifth and 25th largest country in diversity of species in the Region and world, respectively. Wide range of ecological variation coupled with the corresponding diverse socio-cultural practices has made Ethiopia one of the diversity rich countries in the world (Tadesse, 2003).

Africa is also known for its diverse agro-ecological zones. Among others, dryland ecosystems are the predominant agro-ecologies in various countries in the region (UNDP, 2008; Mulugeta, 2009). Owing to the climatic condition, for centuries, drylands in Africa have been home for millions of the pastoral and agro-pastoral communities (Ameha *et al.*, 2008). Although the diversity of species in most drylands in Africa is quantitatively lower compared to other ecosystems in moist areas, there are exceptions to this where drylands host one of the significant biological diversity. For instance, areas with harsh climates including the Namib Desert in Namibia and the Karoo in the west of South Africa and Ogdane in southeastern Ethiopia are acknowledged for their significant diversity (Vollesen, 1989).

Due to the geological history, broad latitudinal spread and altitudinal ranges, Ethiopia spans a remarkable number of the world's broad ecological regions. Among others, drylands which host one of the largest plant and animal diversity are the dominant agro-ecology in Ethiopia (Vollesen, 1989; Gemedo, 2004). Such a huge biological and biophysical diversity is the basic asset and pillar on which the livelihoods of millions of pastoralists, agro-pastoralists, farmers and urban residents depend on and continue to depend. More importantly, due to the harsh ecological conditions within dryland ecosystems, it requires species to become resilient or tolerant to drought, salinity, pest and diseases, fire and herbivore pressure and to be able to grow readily and set seeds within a very short time frame (Campbell, 1996). Particularly, in this era of climate change, such unique genetic traits are not only important to populations living in drylands, but also for those who are living far from these ecosystems.

Various plant and animal species in the drylands in Ethiopia are valuable sources of cash income, employment, food, feed, wood, medicine, shelter and cultural values (Gemedo *et al.*, 2005; Adefires, 2006; Mulugeta, 2009; Getachew et al., 2009). For instance, dry forests are source for various high value NTFPs, mainly in the form of gum-resins, wild foods such as honey, fruits, seeds, leafs, bush meat, bamboo, spices and medicinal plants which are the major means of livelihood (Mulugeta and Demel, 2004; Abeje *et al.*, 2005; Adefires and Dagnew, 2008). Furthermore, the different array of environmental services obtained due to the existences of dryland biodiversity cannot be overlooked. These regions are soul home for pastoral and agro-pastoral communities. They are places where our major hydro-dames are situated; support most of the national and transboardering rivers; hosts the majority of the National Parks and ecotourism areas, almost soul areas for Government led resettlement programmes, land donors for the flourishing commercial farming, and are major production areas for some of the forest export articles.

The Government and citizens of Ethiopia should care about dryland ecosystems and the biodiversity therein because most of the highlands of the country are irreversibly degraded and no more sufficient to support the agriculture led industrialization policy of the country. On the other hand dryland ecosystems are viewed as the present and future hope of the country. However, though remnants of healthy biodiversity and indigenous knowledge still exist, drylands in Ethiopia are also facing increasing threats of further degradation. Globally, it was reported an estimated 60 percent of drylands is already degraded resulting in an estimated annual economic loss of USD 42 billion world-wide (SBSTTA, 1999). Though not as such quantitatively estimated, the situation in Ethiopia is also not different. Cognizant of this the Government of Ethiopia is signatory to various Conventions, Protocols and Agreements and are responsible to accrue in the various initiatives and plan for sustainable management of dryland biodiversity. Thus, it is a timely and judicious to further explore and develop mechanisms to sustainably manage dryland biodiversity in the country. The objective of the current paper is to present evidence that portray the overall diversity in drylands and its potential for food security and if managed properly its role in environmental resilience in drylands of Ethiopia. It also highlights the urgent need for sustainable management of these vital resources and the major constraints and challenges hindering its realization. Finally, various suggestions and way forwards were given on what need to be done to better harness dryland biodiversity in food security while contributing to a functioning ecosystems.

2. Dryland Ecosystems, Global Perspectives

2.1. Definition and extent

The term dryland in this paper is used to cover hyper-arid, arid, semi-arid and dry sub-humid ecosystems in the world. All drylands have at least one feature in common and this is aridity (SBSTTA, 1999). Aridity as widely used in the scientific literature and is based on the ratio of P/PET (where P is the area's mean annual precipitation and PET is the mean potential evapo-transpiration). In other words, drylands could be defined as "hyper arid, arid, semi-arid and dry sub-humid areas of the world where the aridity index falls within the range between 0.05 to 0.65" (UNCCD, 1997). This ratio is referred to as aridity index and is used to classify drylands as hyper-arid (ratio less than 0.05), arid (0.05 to 0.20), semi-arid (0.20 to 0.50) and dry sub-humid areas (0.50 to 0.65) (Tamire, 1997; SBSTTA, 1999).

Drylands cover approximately 40 percent of the Earth's land surface from all the continents (Edouard, 2000). In Ethiopia, drylands cover nearly 75 % of the total landmass of the country where 55% of this total is arid and semi-arid (Tamrie, 1997; Mulugeta, 2005). Table 1 shows the extents of the different dryland categories in Ethiopia. This statistics clearly show the looming threat due to advancing desertification in the country.

Table 1. Estimates of land areas affected by desertification in Ethiopia.

Bioclimatic zone	Area (10^6 km^2)*
Hyperarid	53-55
Arid	300-310
Semiarid	207-250
Dry Sub-humid	300
Total	860 – 915

Source (Le Houerou, 1996; Tamire, 1997 cited in Mulugata and Demel, 2004)

2.3. Where are the world's drylands?

Dryland ecosystems cover extensive land areas stretching across more than one third of the earth's land surface. They are found in all continents in both the northern and southern hemispheres, and are home to about one quarter of the earth's population (UNCCD, 1997). The map bellow shows the distribution of drylands in the world. As indicated in Fig 1., the vast land mass in Africa and Asia is drylands. Thus, the two continents alone share 64% of the drylands of the globe. In Ethiopia drylands are prevalent mainly in the northern, eastern, central, southern and southeastern lowlands of the country (Fig. 2).

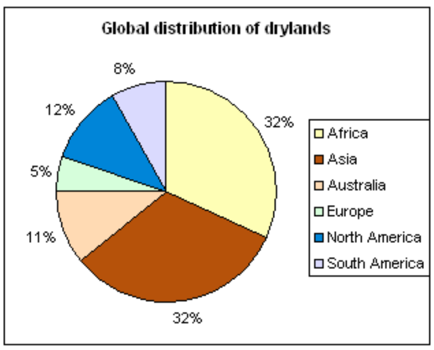

Fig. 1. Global distribution of drylands, sources, Earth Trends (2003), Country Profiles accessed on-line at http://earthtrends.wri.org, November, 2009.

Drylands have a very wide and diversified resources base and are inhabited by various animals and plants that are progenitors of many food, fiber and medicinal plant species. However, these days, besides the continuous resettlement programmes undergoing, such a resources base in drylands has increasingly attracted commercial agricultural development in the country. In the past, regardless of the complexity of these ecosystems, their potential and uniqueness as important components of the country's biodiversity and their role for economic development was overlooked. In Ethiopia, attitudinally drylands found between -126 to 2400 masl (Tamire, 1997). As indicated bellow, the distribution of dryland agro-ecological zones covers mainly the eastern, south eastern, southern, the Rift system and northwest of the country.

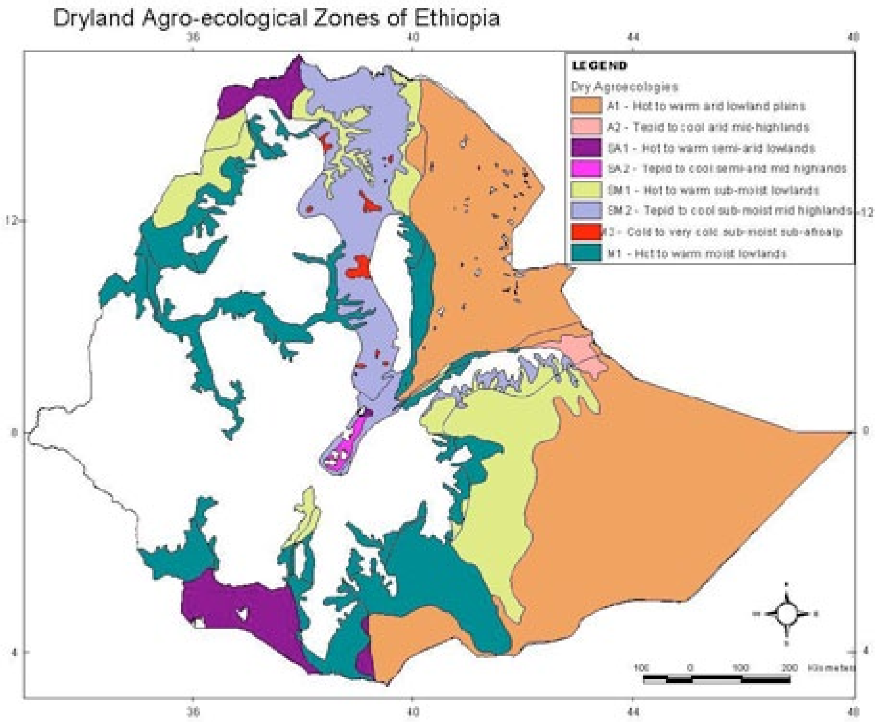

Fig. 2. Dry land Agro-ecological Zones of Ethiopia

2.4. Dryland biodiversity

The United Nations Convention on Biological Diversity defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (UNDP, 2008). The total number of species in the world is estimated to be between 30 – 50 million, of which about 1.4 million have been formally described (Edouard, 2000). Ethiopia owns between 6500 to 7000 plant species; making the country the fifth and 25^{th} largest in biological diversity within the Region and the globe, respectively (Hedberg and Edwards, 1995). Dryland ecosystems in the world are among the major ecosystems known for their immense biological diversity. According to IUCN and WWF, for instance, there are 234 Centres of Plant Diversity (CPD) worldwide, of which 42 are within drylands, implying the significances of these ecosystems in terms of their biodiversity. According to this classification to qualify as a CPD, a mainland area must contain at least 1000 vascular plants over a diverse range of habitats, and at least 10 percent of these must be endemic species (Myers *et al*., 2000). On top of these, the plants and their gene pools must also be highly valued by indigenous and other people for their contributions to human subsistence, economic welfare, religious and cultural practices, and ecological importance.

Although the numbers of species in drylands of the world including those in Ethiopia are not exhaustively documented, the level of species diversity and endemism in some of these ecosystems cannot be under estimated. Of course, various facts in the world showed that species diversity in most of the dryland regions is not as rich as in high forest regions. However, there are exceptions in the case of Ethiopian drylands. For instance, the vast arid landmass in Ogaden is known for its highest species diversity and as the same time for its endemism even compared to some of the humid forest belts in the country (Vollesen, 1989). This also supports the assertion of Vivero et al. (2005), who stated that, Ogaden is floristically the richest in endemism in Ethiopia. Concurrent to this very recently, Mats Thulin of Uppsala University and his colleagues discovered unnamed species "*Acacia fumosa*", implying the importance of the area for further investigation. The same report further concluded that six of the seven endangered endemic plant species of *Acacia-Commiphora* woodland ecosystem in Ethiopia are found in Ogaden. Examples of some threatened rare species in Ogaden are; *Ammodorcas clarkei*, and *Cordeauxia edulis* (Vollesen, 1989). More importantly, various studies indicated that drylands are home to a relatively high number of endemic species - plants and animals uniquely adapted to the variable and extreme conditions of these areas, indication of the potential it hosts. Other reports also indicated that the world's major food crop such as wheat, barley, sorghum, millet, and cotton have all originated from dryland ecosystems (Kidane, 2006), even more signifying the actual and potential roles of dryland ecosystems and the biodiversity for food security and development in Ethiopia.

2.5. What are the driving forces of diversification in drylands?

Dryland ecosystems cover a variety of terrestrial biomes (i.e., arid steppe, grasslands, tropical and sub-tropical savannahs, dry forest ecosystems and coastal areas) which are extremely heterogeneous. A major driving force of biological diversification in dryland environment is the relative aridity (Edouard, 2000). Within each aridity zone, significant variations between sites are introduced by topography, geology and by variations in the most limiting factors such as water and soil nutrients. The resulting patchy nature of habitats determines the distribution of living organisms. In addition to the habitat differentiation seasonal pattern of rainfall, fires and herbivore pressure are also among the driving factors. Types and intensities of environmental stresses combined to determine the main selection pressures in drylands: low and highly variable rainfall in time and space; recurrent but unpredictable droughts that may persist for several consecutive years; high temperatures; inherently low soil fertility; high incidence of salinity; prevailing herbivore pressure; and fires. These stresses have selected for a large diversity of adaptive traits. The seasonal pattern of rainfall, for example, has selected for plant and animal species and micro-organisms able to develop rapidly and complete their life cycle in a very short period of time. Some species have mechanisms to escape drought whereas other species have appropriate organs to resist drought. Plant species in dryland for example, have large below ground systems to store water and nutrient or have corky bark to insulate living cells from desiccation and fire burning (Medina *et al.*, 1992; SBSTTA, 1999).

3. Why Drylands?

3.1 Peculiarity

As mentioned earlier, 75% of land mass in the country is considered to be dryland zone. These ecosystems have immense scientific, ecological, economic and social value (Mulugeta *et al., 2003; Gemedo, 2004; Kidane, 2006; Adefires and Dagnew, 2008). However, they* cover rain shadow areas and in most cases are victims of the uncertain climate extremes. In drylands, the climate, temperature, rainfall and soil types vary considerably with different altitudes and such diversity can be sensed within a short distance in a given locality. Drylands in Ethiopia also contain some of the quickly transforming and fragile landscapes; least protected and threatened native species in the country. Consequently, many economically, ecologically and socially preferred indigenous species are subjected to threat. Some are also concentrated in small refuges and some with reduced regeneration. For *Boswellia papyrifera* from north and *Cordeauxia edulis* from eastern lowlands bearing commercial commodities were recently joined the IUCN Red List), accessed on November, 2009 at http://incensemaking.com/monographs/frankincense.htm. Drylands, although they are not as species-rich as humid regions, yet they are home to many endemic species uniquely adapted to arid conditions. But much of this natural biodiversity is fragile, and held in a delicate balance that is easily affected by natural and human-induced environmental changes. For instance, Abeje *et al., (2005) and Adefires (2006) revealed that* some of the species in drylands remained with limited resilience, and are progressively disappearing at least in their regeneration and abundances. High moisture stress, water scarcity and vulnerability of drylands to over-exploitation and inappropriate land use, were some of the typical characteristics of dryland threats. Mainly, the recurrent drought that may persist for several consecutive years is the rule, not an exception. Although strongly modified from their original states, the remaining dryland communities and species are of major significance, representing all that remains of a unique and diverse ecological zone and its potential for future restoration and dryland development.

3.2 The role of dryland ecosystems in food security

Dryland ecosystems throughout the world support some of the poorest world's communities, the majority of them are dependent on natural habitats and biological resources (CCD Secretariat, 1997). It is estimated that these ecosystems cover one third of the earth's total land surface and about half of this area is economically productive used either as range, agricultural land, forest/protected land or settlement areas (CCD Secretariat, 1997). In the world, drylands are the habitat and source of livelihood for about one quarter of the earth's population (Medina and Huber, 1992). Likewise, in Ethiopia drylands are the sole habitats for 12% of the country's total population with majority leading pastoral and agro-pastoral livelihood and where the biodiversity therein is the major asset to depend on (Ameha *et al*., 2008).

Drylands, which are currently being threatened by advancing desertification and inappropriate land use, have been the major deriving engines for the economic development of the country. To mention some among others, these eco-regions are important production zones of livestock, crop and various forest products in Ethiopia (Kidane, 2006). For instance, according to the study by Ameha and his group (Ameha *et al.,* 2008), arid and semi-arid rangelands that serve as the resource base for livestock production system in Ethiopia covers about 62% of the national land area, encompass 40% of the livestock population of the country and employs approximately 27% of the population (Sara and Mike, 2009). Majority of the rural populations in Ethiopia are involved in some way with animal husbandry, whose role included: provision of draft power, food, cash, transportation, fuel and social prestige (especially in pastoral areas). At national level, livestock and livestock products provide about 10% of Ethiopia's foreign exchange earnings, with hides and skins constituting about 90% of this, and where such foreign currency obtained from the livestock sector is very much dependent on the range land/biodiversity (Gemedo, 2004; Ameha *et al.,* 2008).

Dryland zones are also the main production places for many of the country's major food crops such as wheat, teff, sorghum, maize and millet. The emerging commercial farms including the rampantly growing bio-fuel projects are targeting and undergoing in these parts of the country. Considering the water resources of Ethiopia, drylands supports some of the national and transbordering major perennial rivers namely the Blue Nile, Awash, Wabeshebele, Web, Genale, Dawa, Baro, Omo, Tekeze, etc., although most of them are emerging from the highlands of the country. Thus the role of dryland ecosystems in supporting these rivers and the economic, ecological and social role of these rivers to the country in general and local livelihood in particular is tremendous. Coming to the energy sector, it was noted that the Government of Ethiopia is striving to fulfill power demand and billions was already allocated for the construction of various hydropower generation projects. And most of the major and recently under construction dams including Tekeze, Tana Beles and the three Gilgel Gibe projects are situated in these drylands, implying the role of these ecosystems in sustaining the energy sector and thereby energy and food security. Above all, many citizens believes that, the vast landmass along the abovementioned major rivers could be the hope for future science-based and mechanized agriculture to up lift the country from the current poverty tragedy. Drylands are also the main "land donors" for the voluntary Government led resettlement programme as means to rescue the most vulnerable and chronically food insecure households. Thus, there is no way to overlook the economic, ecological and social value of these ecosystems in Ethiopia in particular and in the Horn in general (Gemedo, 2004; Mulugeta *et al.,* 2004; Adefires, 2006).

Generally, the processes through which the natural environment provides resources useful to people are known as 'ecosystem services' and are integral to life in drylands. The role of dryland ecosystems from food security and environmental resilience perspectives can be summarized as follow:

1. Provisioning of goods, including products from ecosystems such as food, feed, wood, fibre, fresh water, and genetic resources. The use of edible fruits as sources of food, parts of plants as sources of medicine and gum resin collection and trade for income generation by people living in drylands.
2. Regulating services, including the regulation of, for example, hydrological cycles, the climate cycle and some human diseases. In drylands, for example, the growing of trees like *Faidherbia albida* and *Moringa stenopetala* as agro-forestry tree was reported to boost the number of microorganisms essential for making soil nutrients available to crops and also the improved nutrient status of the soil helps reduce erosion and help other species to better establish and thereby enhance biodiversity.
3. Cultural and religious services, including spiritual enrichment, cognitive development, knowledge systems, social relations and aesthetic values. The use of frankincense and myrrh for treating various ailments for instance has an age-old "cultural and religious value" to people living in and out of dryland areas of Ethiopia. Various NTFPs collection and marketing besides their role for consumptions, saving, insurance and buffering, also are major sources of women and school children as means of social integrity (Adefires, 2009).
4. Supporting services, including services necessary for all other ecosystems such as biomass production, production of atmospheric oxygen, water and soil retention, and habitat maintenance. For example, native trees in arid regions are known to create cooler temperatures compared to the open surrounding desert by increasing the availability of nutrients for other plants and by increasing the abundance and diversity of animals.

3.2.1 The case of dryland forests

3.2.1.1 Significances to the national economy

Studies have shown that the potential of forestry in supporting the industry sector development is immense (Yonas *et al*., 2009; Mulugeta, 2009). Forests in general have an important role to play in alleviating poverty worldwide in two senses. First, they serve as a vital safety net function (as gap filler, including their service as a source of petty cash) providing people with goods and services they are unable to afford in the market place and thus helping rural people avoid poverty, or helping those who are poor to mitigate their plight (Campbell *et al*., 2002). Second, forests have untapped potential to actually uplift some of the rural people out of poverty (Kindeya, 2003; Mulugeta *et al*., 2003; Adefires, 2006; Adefires, 2009). More importantly, forest trees are perennial crops that are relatively less affected by soil and weather conditions compared to cereal crops and hence, supply the various products in more or less stable manner.

In Ethiopia, drylands hosts one of the vast forest resources that have multiple benefits. According to EFA (1994) there is over 3.5 million ha of woodland resources in these ecosystems. These vegetation formations are dominated by ecologically and socio-economically important species of the genera *Acacia, Boswellia, Commiphora* and *Sterculia*, principal sources of tradable oleo-gum resins which had a demand that range from local to international (Kindeya, 2003; Adefires, 2006; Mulugeta *et al*, 2003). According to Mulugeta and Demel (2004) though there still lack of as such reliable data at national scale, there is an estimated of over 300,000 metric tons production potential of oleo-gum resins from dryland forests in Ethiopia, implying the huge opportunity to be tapped by mainstreaming these resources in the development agendas. Gums and gum resins play significant economic roles both at local and national scale in Ethiopia (Mulugeta *et al*., 2003; Abeje *et al*., 2005). In fact, they are among the few forest export commodities that the county owns, and by this virtue generate significant foreign currency. According to Mulugeta (2005), the direct contribution of dryland forest to the national economy far outweighs the forests of the humid and sub-humid combined (Mulugeta, 2009). For instance based on the information from the export promotion agency and custom authority between 1991 and 2000 E.C. the country were able to produces and export 28,601 tons of different oleo-gum resins and earned over 3656 million Birr (equivalent to 31 million USD) (Table 2). These figures however, does not exclude the unrecorded but large volumes of parallel trans-border trades with neighboring countries such as Somalia and Kenya and also the huge amount supplied to the domestic market. In line to this report, FAO (1995) reported that half of the myrrh exported from Somalia is assumed to originate from Ethiopia.

Table 2. Exports of natural gums and resins from Ethiopia, data from 1991 to 2000 E.C. (source: Ethiopian Export Promotion Agency & Ethiopian Custom Authority)

Year (E.C)	Quantity in tons	Value in 000 Birr
1991	1663	16,734
1993	2138	24,357
1995	2304	28,127
1997	3791	42,536
1999	3976	50,285
Total	**28601**	**365,864**

4.2.1.2 Contribution to the household economy

Income generation: based on the study done at South Africa (Shakeleton *et al.*, 2007), indigenous forests and savannas, along with plantation forests, offer numerous benefits to rural communities. This paper concludes that a large proportion of the population makes use of forests and the resources from them. These are vital components of local livelihoods, which probably prevent people from slipping into deeper poverty. Likewise, various studies made in Ethiopia indicated that, besides the contribution to the national economy, perhaps the most important economic contribution of dryland forests is to the local people. For instance, these studies witnessed the diverse at the local level economic significance of gums and gum resins (Kindeya, 2003; Abeje *et al.,* 2005; Mulugeta *et al*., 2003; Adefires and Dagnew, 2008). Among others, they provide cash income, employment opportunity and emergency food as direct benefit, and indirectly contribute to household livelihoods by supporting other land uses principally animal husbandry. According to a study made at Liben, Somali Region, the income contribution to the household subsistence from collection and sale of oleo-gum resins is 33%, an income estimated to cover one-third of the annual subsistence and is the second livelihood activity next to livestock production (Mulugeta *et al*., 2003). According to Adefires (2006) who studied the socio-economic contribution of the gum-resin sub-sector at Borana zone, the average annual contribution from collection and sale of various types of gum-resins is found to be 2670 and 2400 birr per household at Arero and Yabello Weredas, respectively.

In Borana, though there is no exhaustive data on forest products flow to household livelihood, the role of forest products in day- to-day livelihood of the woodland poor is significant. For the majority of the household, gum-resin is a hanging in business, i.e., a livelihood strategy where the households engaged in livelihood activities for their subsistence or consumption (Adefires, 2009). However, for few households the sub-sector is a means for stepping up, i.e. a livelihood strategy where the household used the gum business as means to diversify income and even shift to other business sectors. Further study by Adefires and Dagnew (2008) at Afdher, Somali reported the annual cash income generated per household from sale of true myrrh and opopanax ranged from 210 to 7320 birr per season. Similar to the study in Liben (Mulugeta *et al.,* 2003) in economic terms, gum and resin collection business in Afdher ranked second after livestock. Such an economic contribution signifies its critical role to local people living in fragile arid and semi-arid lands as an effort to diversify their economy, and thus potentially minimize risks associated with frequent crop and fodder failures and cannot be overlooked. In conclusion, the following may be stated about the potential for ole-gum resin production from drylands in Ethiopia. The resource base is almost certainly vastly under-exploited but under heavy pressure from shifting cultivators, commercial cultivation, fuelwood collectors and charcoal makers, resettlements and expansion of desertification.

Employment: the other form of livelihood from the dryland forest and the biodiversity therein, is the opportunity of getting seasonal employment. According to Abeje *et al.* (2005), the total number of seasonal workers engaged in tapping and grading of gum-resins in Ethiopia ranged between 20,000 and 30,000 per year. In a country with limited access to seasonal employment such an opportunity to hire a considerable number of the citizen is worthy to mention. The scenario show that, if problems solved and the sector further develop by giving due attention to it, one can imagine the number of vacancies to be generated.

Food: In Ethiopia, the number of wild and semi-wild edible plant species is estimated at well over 480 (Zemede and Mesifn, 2001; Getachew *et al.,* 2009). Studies (e.g., Zemede and Mesfin, 2001) documented the occurrence of wild edible species in different areas of the country. The direct and indirect role of dryland biodiversity as food source is also reported to be important. In these regions, intractable problems of food insecurity, poverty and malnutrition are widespread with suffering among women and children being especially acute. Various reports (e.g., Gemedo *et al.,* 2005; Adefires, 2006) indicated that the year round dependence of the woodland poor on various NTFPs as food sources, mainly during slage-periods. According to Zemede and Mesfin (2001) Ethiopia is not only rich in edible plant diversity, but also with the knowledge to manage and use the various plant species. According to these authors, the use of wild species in native diet is a wide spread tradition. Particularly, the pastoral and agro-pastoral communities has long list of edible species, classified as sources of supplementary, famine food, etc. In general, it was recalled that food from the wild can make supplemental, seasonal and emergency contribution to household food supplies, thereby contributing to food security significantly. Unfortunately, the importance of wild fruits as a food supplement and means of survival during times of drought and famine has largely been overlooked by the research and development community.

Green pharmacy: more than 80 percent of the people living in Africa and in Ethiopia are believed to depend on plant- based medicines to satisfy their health-care requirements (Kebu, 2006). Particularly, in most of the dryland parts of the country, access to modern health centers is much limited and millions yet depend on herbal medicines (Gemedo *et al.,* 2005; Tigist et al., 2006). In this regard, some of the Africa's plant species have contributed immensely to the world's pharmaceutical industry. Noteworthy among these are Ancistrocladus korupensis (Cameroon), *Pausinystalia yohimbe* (Nigeria, Cameroon and Rwanda) and *Catharanthus roseus* (Madagascar), *Commiphora myrrha* (Ethiopia, Somalia) which are being used in pharmaceutical research in industrialized countries (Zemede and Mesifen, 2001; Mulugeta and Demel, 2004). In Ethiopia indigenous peoples' and rural communities' knowledge and use of various plant species has substantial base for future investment in developing various drug. For instance, the Borana elders use various species to cure ailments including some of the major diseases in the country (Adefires, 2006).

Honey and Beeswax: Beekeeping is a traditional important off farm activity to harvest honey for many rural people in Ethiopia. Ethiopia is the leader in Eastern Africa in bee product business development and far exceeds other countries in Africa in terms of volumes of honey and beeswax harvested and traded (Taddele and Nejdan, 2008). Ethiopia is the World's 10th biggest honey producer and the 4th largest beeswax producer after China, Mexico and Turkey. The country reportedly has the largest bee population in Africa with over 10 million bee colonies, out of which about 7.5 million are confined in hives and the remaining exist in the forest. The current honey production of the country is estimated at 24,600 tons per year. Ethiopia is also the 5th biggest wax exporters to the world market. The annual production of wax is estimated at 3200 tones, without considering beeswax wasted in the remote areas. Owing to its varied flora and fauna in Africa, Ethiopia is highly suitable for sustaining a large number of bee colonies, where the share of dryland vegetations in supporting these colonies is reportedly significant (Taddele and Nejdan, 2008).

4.3 Dryland biodiversity and pastoralism

Dryland ecosystems are historical supporters of the livelihoods of millions of pastoralist communities (Gemedo, 2004). However, the currently forgoing discussion show that there are two opinions as far as pastoralism is concerned. The first is that, though it is not evidence-based, many policy makers in East Africa have preconceptions about the value of pastoralism as a land-use system believing it is economically inefficient and environmentally destructive (Sabine, 2004; Ameha *et al.,* 2008). The second group who understand and argue pastoralism as effective and efficient ways of livelihood means to adapt to the negative impacts of climate change in such a marginal environments emphasize that not only there is no consensus on what is a dynamic economic model of pastoralism, no mechanism exist to inform government decision making of its comparative advantages over alternative land uses, as the existing national statistics are inadequate and inaccurate. These groups justify that direct values of pastoralism including production of milk, beef and hides for subsistence and live livestock for export are rarely included in the national accounts. Indirect values of pastoralism including income from tourism, sustainable land use and risk management in disequilibrium environments, biodiversity conservation and improved agricultural returns are also too rarely captured in national statistics or recognized by policy makers. Consequently pastoralism is undervalued and policy makers promote to change or replace, which in one way or another create a vicious circle of impoverishment, conflict and environmental degradation in dryland areas.

According to various studies, pastoralism in Ethiopia is a diverse and dynamic livelihood system integrating livestock husbandry with other activities including agriculture and forest management. While their dependence on the drylands makes them vulnerable to the ecological effects of climate change, their economic benefits from pastoral livestock production are manifold. For instance, pastoral natural resource management makes an important contribution to the sustainable use of arid and semi-arid rangelands. By using livestock and livestock products pastoralists fulfill a crucial role for food and livelihood security. Above all, pastoralists' adaptive capacity provides a unique opportunity to prepare for, and manage the associated shocks and stresses such as drought and flood (Sabine, 2004). Further authors (e.g. Coppock, 1994; Gemedo *et al.,* 2003; Overseas Development Institute, 2006) asserted the system is able to generate significant returns from dryland environments. Considering its role to the national economy, it was reported that majority of the exportable life animals come from these parts of the country. Furthermore, drylands are also major sources of milk, meat and draft animals for the highlands of the country. Thus, if well managed and supported with technology, particularly in this era of climate uncertainty, such a livelihood strategy is a rational use of the marginal ecosystems such as drylands. With this regard, the role of dryland plant biodiversity in supporting the livestock and the communities therein is manifold. For instance, dryland forests are the primary sources of browse, medicine and shade for the livestock. Furthermore, the biodiversity plays great role in keeping functioning ecosystems helping sustainable livestock production. In conclusion, the role of dryland in supporting livestock production and thereby to food security is rather huge.

4.4 Dryland biodiversity and ecotourism

Drylands are not only diverse in terms of plant and animal species and the landscape diversity, but also center for cultural diversities and ethnicities. They harbor majority (77%) of the protected areas that are known to exist in Ethiopia (Tadele, 2005; Menassie, 2009). More than half of the oldest and established national parks including the Awash, Nech Sare, Omo, Gambella and many game reserves and sanctuaries are situated in drylands with huge potential for promoting ecotourism development in the country. According to Tadele (2005), ecotourism is rampantly emerging in Ethiopian drylands and becoming livelihood for hundreds of thousand communities living around or in protected areas. Thus, the role of dryland biodiversity as a major supporter of the wildlife and its potential for tourist attraction cannot be over looked.

5. The Need for Conserving Dryland Biodiversity

5.1 Ecological perspectives

5.1.1 Climate change and desertification adaptation and mitigation

Warming of the climate system is now "unequivocal". Human-induced climate change is observable and having a discernible influence on physical, biological and social systems throughout the world including Ethiopia (IPCC, 2007). Ethiopia is also a country of contrasts (EPA, 2007). It boasts an incredible diversity of ecosystems, natural resources, emerging economic activities, types of settlements, diversity in ethnicity and culture. Yet, it is characterized by conditions of widespread poverty and human insecurity (World Bank, 2004). Climate change represents one of the major threat and challenge to this country in particular because majority of the citizens have a limited capacity to adapt to climate variability and change (IPCC, 2007).

More frequent and prolonged droughts can seriously reduced crop and livestock productivity and thus affect food security (Mulugeta and Demel, 2004; Gemedo *et al*., 2005; Ameha *et al., 2008). According to these authors,* Ethiopia has been trying hard in cereal-crop based agricultural production and many assumed this would assure food security (PASDEP, 2006). However, though the production base (land) including marginal lands is increasingly cultivated, the overall food security remains precarious. More frustrating, studies (e.g., Eriksen and Rosentrater, 2008) show that for the region as a whole and Ethiopia in particular, net productivity reductions of more than 10 percent are possible in the case of maize and other major crops such as sorghum, millet, sugar cane and wheat with the upcoming climate change scenario. Particularly, those people making living in marginal areas will be most severely impacted due to climate change and desertification than those in more humid areas. According to Shakleton *et al* (2007), on the other hand, there is a growing recognition of the need to manage and integrate dryland biodiversity i.e. NTFPs, not only for its own sake but also because biodiversity helps to sustain the provision of 'ecosystem services' on which people and the well being of ecosystems depend, thus enhance adaptation and mitigation.

In Ethiopia, besides the substantial economic significance of dryland biodiversity, several species of *Acacia, Boswellia* and *Commiphora* could be managed to provide, concurrently, multiple ecological services that will enable the country to fight against desertification which also comply with the international conventions. These vegetation resources also contribute to the conservation and enhancement of biodiversity and improve soil fertility. Given the increasing recognition that many dryland plant species develop extensive below ground biomass, current estimates of C-sequestration in drylands are probably vastly underestimated. In the Sahel, for example, tree below ground biomass has been shown to be as high as the above ground biomass, with roots extending to 70 m away from the trunk or as deep as 30 m (Jonsson, 1995). This is yet another manifestation of dryland adaptation and thereby contributes to climate change mitigation. More importantly, each such species in drylands has developed its own way of coping with variable water availability and temperature extremes, an opportunity for the future choice. For example, some cacti have few or no leaves to reduce water loss through transpiration, while others have succulent tissues that store water. Above all, the regulatory services of keeping once ecosystem biodiversity are worth to mention. For instance, greater biodiversity contributes in regulating hydrological cycle, climate cycle, nutrient cycle and etc (Medina and Huber, 1992). Besides its regulatory services, the existence of biological diversity has supportive services to other ecosystems. Higher biological diversity also regulates occurrences of accidents due to some of the human disease outbreaks by way of balancing nature. Above all, the future of our major water bodies in drylands far depends on how these ecosystems are maintained.

In light of the abovementioned premises, sustainably managing dryland ecosystems in general and biodiversity therein in particular is thus, rule of the game not an option.

5.1.2 Keeping nation's commitments

Investing in environmentally sound technologies to attend the risk of land degradation and biodiversity lose is not only economically rewarding but also creates a socially and environmentally responsible image that enhances reputation. In Ethiopia, conservation of biodiversity and arresting alarming desertification in particular and maintaining functioning ecosystem in general is our responsibility (CBD Secretariat, 1992; CCD Secretariat, 1997). Likewise, Ethiopia is signatory to various international agreements, i.e., CBD, UNCCD, MDG, and many more. As part of these responsibilities, we need to sustainably manage our biodiversity and integrity of ecosystems. We are also responsible to ensure developing the most neglected communities (example, the vulnerable pastoral communities) through innovative technologies and ensure disseminating the new knowledge generated. In this regards, dryland ecosystems which are home for various endemic, and yet threatened species and landscapes and the indigenous people are believed to be the most exposed to negative impacts of climate change and alarming desertification. In this case, the role of dryland biodiversity in efforts to maintain ecosystems and rehabilitate the fragile once cannot be over looked.

5.2 Economic perspectives

There is a general misconception that drylands are resources poor ecosystems. However, today various studies verified that various drylands are resource full (Mulugeta *et al.,* 2003; Adefires, 2006; Kidane, 2006). The reason behind such misconception is that, only few attempts have been made to assess and place economic values on the goods and services provided by dryland ecosystems. Of course, trying to place a monetary value on dryland biodiversity's "goods and services" is not easy.

5.2.1 Special features of dry land biodiversity

The heterogeneity of habitats, inter and intra species diversity, diversity of micro-organisms, presence of wild relatives of globally important domesticated species, traditionally adapted land use systems, and indigenous knowledge are some of the important features of drylands. Although species richness is higher in tropical forests than in many drylands, within–species diversity is probably much higher in drylands than in forest ecosystems and this may be because of isolation of populations due to the heterogeneity of habitats. Thus, dryland biodiversity has distinguishable features. For instance, the variation within and between species diversity and the unique traits that most dryland species provide will be option to develop drought and disease resistant varieties.

Diversity of habitats: drylands are known for its diversity of habitats. Such habitat diversity is one of the major factors for within and between species differentiation.

Wild relatives of domesticated species: historically, drylands have been the living basis for mankind. As per the existing knowledge, the first human ancestors (i.e., Lucy and Ardi) originated in the savannah grasslands of eastern Africa, the lowlands of Afar. Likewise, the origins of many of the earth's most important food crops were originated from and still exist in drylands. For example, maize, beans, tomato and potatoes originate from the drylands of Mexico, Peru, Bolivia and Chile. Millet and sorghum, and various species of wheat and rice come from the African drylands (UNDP, 2008). Though, there are only limited studies, Ethiopian drylands are hoped to continue providing new species that will be harnessed to the future food security agendas. Particularly, in this era of globalization, the traditional food products from dryland regions are increasingly becoming commercialized.

Micro-organisms: The world micro-organisms is notoriously poorly documented. The level of biodiversity is unknown. The importance of micro-organisms, however, is well appreciated in food, agriculture and pharmaceutical circles. Their ecological role is also crucial. In the particularly difficult environment of drylands, micro-organisms play a major role in key ecological processes that sustain the functioning of these ecosystems. In response to the inherently low soil moisture and nutrients in dryland soils, there exist a great diversity of symbiotic associations between plants and micro-organisms. Also, some free-living organisms contribute significantly to the nitrogen balance of dryland ecosystems (Medina and Huber, 1992). More importantly, the finding of micro-organisms living in the Eartale, the lack of fire and with different traits by Ethiopian scientist is a new scientific finding widely appreciated by the global scientific community.

Agro-biodiversity in drylands: agricultural biodiversity is a vital subset of biodiversity. It is the result of the careful selection, domestication and inventive development of farmers whose food and livelihood security depends on the sustained management of this biodiversity. Promotion of crop genetic diversity is part of farmer's coping strategies for mitigating weather unpredictability; it also reduces the so-called "hunger period" by spreading availability of food products over time. For example, Mulvany (1999) investigated farmers' crop variety ranking criteria in Kenya and reports the use of the following criteria: early maturity (drought escaping), drought tolerant, stable and if possible high yield, pest/disease and weed tolerance, and socioeconomic criteria - e.g. variety for market production or household consumption.

Diversity of farming systems: the last three decades farming systems research have shown the tremendous diversity and vitality of many traditional cropping systems in drylands, as elsewhere. We now have a better appreciation of why farmers continue to nurture biodiversity despite the pressures to convert to mechanized mono-cropping. The reasons have to do with risk management, balancing long term ecological sustainability. Another major farming strategy in drylands is the deliberate preservation of valued trees and shrubs in crop fields, a traditional agroforestry system known as parklands. In West Africa, for example, Faidherbia albida parklands in semi arid and sub-humid areas are known to have sustained continuous cropping for generations without fallow periods.

5.3 Socio-cultural perspectives

The role of dryland biodiversity in cultural and religious services, including spiritual enrichment, cognitive development, knowledge systems, social relations and aesthetic values is immense (Mulugeta *et al.,* 2003; Gemedo *et al.*, 2005; Adefires et al., 2006). Various species including the gum-resins bearing and many others are known to provide "cultural and religious services" to people living in dryland areas of Ethiopia through their use in traditional costumes and cultural activities involving medicine, handicrafts and religion. For instance, the role of cash income obtained through collection and sale gum-resins in Borana pastoral communities festive and social integrity is very high. Particularly women use the money they got from the sale of these commodities to buy gifts during the visit of relatives and to participate on various traditional ceremonies (Adefires *et al.,* in press)

5.4 Political perspective

Majority of drylands in Ethiopia have been in continuous and historical civil wars. Thus, though there are some seen changes, dryland areas are yet far underdeveloped. On the other hand, there is rampant growth of population in these areas of the country, exerting severe pressure on the limited resources base and thus potential sources of conflicts. Arresting not only economic and ecological but also conflicts and other political issues are important and the need for developing the areas and building the capacity of the local communities, particularly those of pastoral and agro-pastoral communities to the level they are able to manage livelihood and abuses is crucial (FDRE, 2006). In this case, the role of dryland biodiversity as an alternative to induce rapid development in such areas with limited option is significant.

6. Major Threats of Dryland Biodiversity

6.1 Desertification, climate change and biodiversity lose

The physical processes of land degradation, biodiversity evolution or extinction, and climate change are intimately inter-twined, especially in drylands (Lean, 1995). Land degradation reduces natural vegetation cover, and affects productivity of crops, livestock and wildlife. Soil micro-organisms are also affected through soil erosion. The loss of biodiversity likewise undermines the environmental health of drylands and makes them more prone to further degradation (Tamire, 1997). The vicious cycle fuels increased soil erosion, which causes increase in sedimentation of rivers and lakes, contributing to the degradation of international waters and affects biodiversity in rivers, lakes and coastal ecosystems.

Desertification, which is the land degradation process that occurs in the drylands, is also related to climate in many ways. Degradation of vegetation cover decreases carbon sequestration capacity of drylands, thus increasing emissions of carbon dioxide into the atmosphere. But carbon storage capacity of drylands is poorly documented. Another link between desertification and climate is through the effect of dryland dust on atmospheric composition. Arid lands are significant contributors of dust. Reduction of vegetation cover caused by land degradation increases these effects. Periodic burning of savannah landscape has also been shown to have implications for atmospheric chemistry. Thus ecological processes in drylands influence local and global climate. Climate change in turn affects drylands biodiversity by influencing species distribution range, water supplies, heat extremes, the humidity and temperature of soils and thus the albedo.

The predicted global climate warming and desertification are expected to have profound impacts on global biodiversity at levels that may compromise the sustainability of human development on the planet. Climate warming will cause, inter alia, higher evaporation rates and lower rainfall both of which are major determinants of dryland ecological processes and species survival. Simulation models of climate change predict shifts in species distribution and reduced productivity in drylands (Sala and Chapin, 2000). Globally, each one-degree rise in temperature is expected to displace the adaptation of terrestrial species some 125 km towards the poles, or 150 meters in altitude. Approximately 30 percent of the earth's vegetation could experience a shift as a result of climate change. The yield decrease may even be as high as 11% and 38% in some localities more severely affected. The maize crop yield in Asia and Latin America may shrink by between 10 and 65 per cent. The expected impact on wild biodiversity is much less known or analyzed (see paper on Vulnerability and Adaptation in this series).

6.2 Pressure on natural resources

In a very challenging paper entitled "There is more to biodiversity than the tropical rainforests", Readford *et al*. (1990) pointed out that much of the publicity concerning threats to global ecosystems and biodiversity has centered on tropical rainforests. While the authors concede that there is no doubt of the importance of moist tropical forests in terms of biodiversity, they also voiced concern that the almost exclusive attention to rainforests may act as blinders, limiting the vision of major conservation stakeholders: donor agencies, governmental bodies, etc. This would in turn lead to the neglect of other ecosystems. One such neglected ecosystem is the world drylands. Similarly, in Ethiopia, whoever is looking for more land for resettlement, commercial farming, dam construction and etc., is the dryland ecosystems the first most areas considered as 'land donors'. Various studies show that, since the past few decades, the population growth in drylands is incredible. Beside, the resettlement programme of the government, the saturation of highlands and the alarming employment opportunities due to expansion of the commercial farming and changing infrastructures have attracted hundreds of thousands of people to drylands. These again, dramatically increased over use of natural resources.

The other important factor is unwise use of the resources. For instance, the restless tapping of *B. papyrifera* in northern part of the country accompanied by other factors has resulted in week or no regeneration of the species which ultimately threatened the perpetuation of this particular species (Abeje *et al,* 2005). The same was reported on *Cordeuxia edulis* from Somali Region. The currently ongoing continued large scale conversion of the lowland Bamboo, in Benishangul Gumuz is an alarm for decision makers and professional to look for a win-win before it is too late. The impact of charcoal and expansion of farmland in the rift systems is the main threat to the *Acacia* woodland.

6.3 Invasive alien species and bush encroachment

An invasive alien species (IAS) are defined as a species that is non-native (or alien) to the ecosystem, introduced either deliberately or unintentionally, where they have the ability to establish, invade, out compete native species, take over the new environments, and whose introduction causes or is likely to cause economic/environmental harm or harm to human and animal health and thereby affect livelihood. Currently, over six IAS species were identified as emerging issues in the country. These include *Prosopis juliflora, Parthenium hysterophorus, Lantana camara, Eccornia crasipes* and *Straiga* species. Sadly, almost all of these species are dominantly growing in dry lands exerting considerable impacts on dry land biodiversity. For instance, Adefires et al. (2008) reported 76 species from non-infested plots compared to the 31 species in the *Prosopis* infested sites from Afar Region, implying the adverse impact on native diversity. Further, native bush encroachers are also becoming serious threats to native diversity in drylands of Ethiopia. According to Gemedo (2004), for instance, the different *Acacia* species such as *A. drepanolobium, A. melifera* and *A. oerfota* are some of the major bush encroachers causing severe impact on native species diversity in Borana.

6.4 Low recognition by professional and decision makers

The sub-group on biodiversity of the CBD's international panel of experts noted that the scientific community and international agencies that spearheaded efforts to raise awareness about rainforest biodiversity are conspicuously absent from the dryland debate. The report revealed that, the existing low awareness about the importance of drylands vis-à-vis biodiversity and livelihoods as one of the major reasons why this ecosystem has received inadequate attention. In Ethiopia, except the fragmented efforts in these past few years, drylands were far from any development and conservation efforts. The values of these ecosystems are yet not get full recognition and most of the development activities are ongoing in the expenses of the biodiversity these ecosystems are hosting. Today, most of the vast commercial mono-crop projects are implemented by converting the dryland forests without taking into account their huge ecological and socio-economic importance.

6.5 Poor infrastructure and facilities development

As it was mentioned earlier, majority of the drylands region in Ethiopia remained under developed. Even though there are changes, there still exists poor access to road, technology, market, information, and other facilities like health centers, education and credits. These on the other hand, play significant role in exerting pressure on sustainable management and use of the resources base.

7. What Opportunities Do We Have to Develop Drylands?

The challenges of food insecurity and ecological stress will continue to be greatest in the drylands due to the vagaries of climate, pervasiveness of risk, complexity of poverty, and a degrading natural resource base. Although, these are problems leading to food and feed insecurity and overall natural resource degradation there are also tremendous opportunities to develop the drylands in a relatively short period of time.

7.1 Mainstreaming NTFPs harvest and trade

Ethiopia is one of the world's major exporters of gum-resins (Kindeya, 2003; Mulugeta, 2005). Though there are some efforts to substitute the gum-resins products in certain domains of utilization in the advanced industries, it appears more doubtful whether synthetics will ever seriously threaten the market for these natural commodities in the global markets. Thus, instead of the employed reasoning, one might admittedly make use of a far more optimistic view for future market prospects of gum-resin resources of the country. These is because, there is in fact a possibility that present world-wide trends which favor utilization of healthy 'ecological' products, which may lead to increased future demand for such a perfectly natural product (Mulugeta and Demel, 2004). This means, being the owner of over 3 million hectare of woodland dominated with diverse gum-resin bearing species and the possibility to increase production several times compared to what is extracted today, and the existence of established tapping and marketing experiences, Ethiopia will remain one of the lead exporter of the organic oleo-gum resins to the world's market, implying the possibility to promote greater economic gain while contributing to keep ecosystem integrity through adopting tree based land use (Mulugeta *et al.,* 2003; Adefires *et al.,* in press).

7.2 Promoting community based ecotourism

Protected areas have long been a major pillar of biodiversity conservation strategies. In Africa, for example, about 9 percent of the total land area is designated as protected area (Tadele, 2005; Menassie, 2009). Drylands have a slightly higher share than moist forests. About 16 percent of Africa's population lives within 20 km of designated protected areas and population growth in these buffer zones have been found to be higher than elsewhere. This is indicative of the importance of these sites for local people's livelihoods. Likewise, dryland forest in Ethiopia hosts one of the diverse wildlife population and best known species that are endangered worldwide, the symbols of which include the elephant and the impressive large herds of herbivores in eastern and southern Africa (Tadele, 2005). Majority of the protected areas in the country are found in the dryland ecosystems. The relative isolation, remoteness and sparse populations of many dryland areas are being turned into assets by expanding tourism driven by the increasing affluence and free time and high mobility enjoyed by a large segment of the global population. In association with the existing indigenous living style of the pastoral and agro-pastoral communities that attracted huge attention, the wild life sector harbored in drylands of Ethiopia could be important sources of income generation through promoting conservation campaigns, game hunting and ecotourism.

7.3. Dryland biodiversity as carbon sinks

Afforestation depends on land productivity, but rather than producing a crop it generates a service benefiting the global environment; trees effectively sequester carbon and also produce renewable energy in the form of fuelwood. These mitigate global climate change, for which dryland afforestation can be rewarded through the rapidly growing "carbon trading" under the Clean Development Mechanism (CDM) of the Kyoto Protocol and REED (Reducing Emissions from Deforestation and forest degradation in a developing countries). Though drylands are less efficient compared to non-drylands in carbon sequestration, their potential for further carbon sequestration is high, due to their large area coverage (Mulugeta and Demel, 2004). Drylands are a major repository for the world's biodiversity and therefore, constitute a major focus point for the UN Convention on Biodiversity. Because of their vastness, drylands have the potential to be a significant sink for carbon.

8. Conclusion and Way Forwards

The extent of drylands in Ethiopia is increasing from time to time. The role of these ecoregion in the country cannot be overlooked. Dryland ecosystems harbor wider ranges of plant and animal diversity with significant endemism. They are home for majority of the internationally recognized protected areas and thereby host the last remaining populations of some of the important and threatened species. As it was recognized very well, food security/insecurity, sustainable biodiversity and landscape management has multidimensional linkages. Particularly the pastoral and agro-pastoral communities, their livestock and the wildlife population residing in these ecoregions are much susceptible to the ever changing climate and expanding desertification. In these ecosystems, therefore, the role of biodiversity is multi-dimensional. It provides food, feed, shelter, medicine, income, energy, cultural value and thereby enhances community adaptation and resilience. Biodiversity also plays multi roles in mitigating climate variability, arresting desertification, sequestering carbon, maintaining hydrologic cycle and thus supporting steady environmental functioning. Further, various studies indicate dryland ecosystems contain highly resilient species adapted to the seasonal pattern of rainfall and recurrent droughts. These attributes/traits on the other hand have rather wider significance in the context of predicted global warming. Drylands in Ethiopia also perceived as major land donors for future mechanized agriculture as the highlands are ever degrading and cannot support such activities. Even now, they are becoming the major destination of large scale commercial framings. They are almost the soul suitable places for the Government led huge investment on the renewable hydro-electric generation. However, the various studies depicted that, to be able to significantly benefits from the multi-spectrum of dryland ecosystems, it needs sustainable management of the water shade and the biodiversity therein.

However, drylands in Ethiopia are subjected to severe and alarmingly degradation as they have been neglected both in conservation and sustainable use efforts for many years in the back. On the other hand, the diminishing of the dryland's biological diversity has consequences far more profound than other, sometimes more widely recognized, environmental dilemmas. Because the loss is irreversible as for instance, species that are lost are lost forever and the potential impact on the human condition, on the fabric of the Earth's living systems, and on the process of evolution is immense. It is therefore, important to thoroughly study and provide a definitive picture of the overall biodiversity status, trends, its potential use and management interventions needed. Nevertheless, addressing potential and actual biodiversity loss, through documentation, advocacy, capacity building, and improvement of the enabling environment, and highlighting and encouraging instances where biodiversity is healthy and managed sustainably should be rule of the game now onwards. It is necessary that the focused initiatives be embarked on to mitigate the ever-worsening levels of dry forests and woodlands degradation. Such efforts need to be implemented at regional and local levels and international communities and partners need to be more sensitive to the present situation and come to the support of the governments and the affected people.

More specifically, the following interventions shall be implemented to elucidate the issues in drylands of Ethiopia:

- Raising community and agency awareness. A significant barrier to achieving conservation gains in many dryland areas is low public awareness and appreciation of the indigenous biota, the threats they face, and the potential for their recovery.
- Strengthening sustainable political, social and economic situations.
- Continuing commencing scientific research to come up with a comprehensive information on the current status of the biodiversity, the resources base, the trend, the potential and actual economic, ecological and social values of these resources base and thereby develop a management guideline.
- Improve research-extension-farmer (community) linkages and co-operation.
- Improve stakeholders participation in research, extension, training, awareness and education programmes (e.g., gender, youth, indigenous communities).
- Strengthening the indigenous institutions and community empowerment for them to be able to re-introduce wise management of resources.
- Improve knowledge of drylands and the indigenous communities including traditional agricultural practices. Studies show that only native institutions are capable of imparting the understanding of biological diversity among the general public and the proficiency among professionals that will result in effective conservation. Thus, it is especially important that development agencies support nongovernmental organizations, educational institutions, museums, and libraries in developing countries, and foster effective operation of the government agencies legally charged with managing resources.
- The need for closing the gap between science and policy and cross-disciplinary approaches, participatory approach from problem identification through planning to monitoring and evaluation of outcomes and impacts

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LINKAGES, MUTUAL BENEFITS AND FUTURE OPPORTUNITIES OF SUSTAINABLE DRYLAND FOREST MANAGEMENT AND ECOTOURISM: EXPERIENCES OF THE DRYLAND ECOSYSTEMS IN ETHIOPIA

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Abstract

The dryland ecosystems that cover extensive portion (71.5%) of Ethiopia's land mass are endowed with vast arrays of natural resources, and biodiversity and associated scenic beauty. They are centers of cultural diversities and ethnicities. They contain rich and unique assemblages of plants and animals. As a result, they harbor the majority (77%) of the protected areas that are known to exist in Ethiopia. These resources are the basis for developing and promoting ecotourism and other related nature-based tourism that play significant role in food security. However, they are not exploited for the same as done in neighboring countries. Instead, the natural resource base in Ethiopia in general and dryland ecosystems in particular are under serious threat. Hence, it's time to look for appropriate and timely interventions from all stakeholders before the damage to the remaining dryland forest and other natural resources proceeds beyond the possibility of their rehabilitation. One option in this regard is ecotourism. As experiences obtained in central rift valley regions of Ethiopia and other developing nations, ecotourism and other forms of nature-based tourism could become the driving force in achieving the growth of local, regional and national economies. It generates vital off-farm incomes to local communities through employment, promoting small-scale business opportunities, sale of local produce and artifacts thereby retaining significant proportion of the labour force that would otherwise be engaged in deforestation and resources degradation. Therefore, the objective of this paper is to examine the role of ecotourism for sustainable management of dryland biodiversities and its contribution in maintaining food security using experiences gained from the dryland ecosystems in Ethiopia and other parts of Africa.

Key words: *biodiversity, dryland, Ecotourism, management*

1. Introduction

The name "drylands" also called as "marginal lands", "low potential lands" doesn't seem to describe the actual and potential benefits they are rendering to communities. They are rarely figured as important resources for a developing country in their natural state. However, they are among the most biodiverse areas of the world in terms of species per square meter (ECO, 2000). Due to the particular adaptations to extreme environmental conditions, dryland ecosystems harbor a distinctive biological diversity, with many endemic species and genetic variants that occur nowhere else in the world. The origins of many of the earth's most important food crops are found in drylands. For example, maize, beans, tomato and potatoes originate from the drylands of Mexico, Peru, Bolivia and Chile. Millet and sorghum, and various species of wheat and rice come from the African drylands (IUCN, 2007).

Dryland ecosystems including dry sub-humid, semi-arid, arid and hyper arid areas occupy approximately 50% of the earth's terrestrial surface. They encompass diverse habitats such as deserts, forests and woodlands, savannas and steppes, wetlands, lakes and rivers. They are home for more than 35% of the world's population in which, over 90% of them live in developing countries that provided with the necessary goods and services (IUCN, 2007). In Africa, the drylands are home to 45% of the continents populations. Excluding deserts, they comprise 43% of Africa's surface area. According to UNEP's definition of desertification the dryland areas in Ethiopia constitutes 71.5% of the country's total land area (Tamire, 1997). One component of these dryland ecosystems having enormous socio-economic and ecological importance in Ethiopia is the dryland forest ecosystems.

Drylands play significant roles in livelihood diversification of both rural and urban households providing wood, food, animal feed, human health care and environmental conservation. They also harbor various wildlife resources, scenic landscapes which are the main assets in attracting visitors to such destinations. Despite such roles, the dryland forest and the associated natural resources in dryland ecosystems of Ethiopia have been subjected to severe exploitation and degradation. Rapid growth of population coupled with the development of agriculture and settlement expansion, grazing pressure, sever exploitation of forests for obtaining basic and non wood forest products, as well as improper forest management are drivers of such degradation. As a result, environmental problems including soil erosion, loss of biodiversity, land degradation, changes in rivers regimes, increased siltation of dams and lakes, recurrent drought, and acute shortage of basic forest products have been experienced and natural hazards are occurring with increasing frequency (EFAP, 1993). This calls for appropriate and timely interventions from all stakeholders before the damage to the remaining dryland forest resources proceeds beyond the possibility of their rehabilitation.

Several past efforts like enclosing degraded areas, establishment of protected areas including national parks and others have been exercised by the government of Ethiopia. Yet, the efforts made have low level of achievements. One reason for this could be, inefficient economic incentives generated from most developmental strategies and poor participation of local communities. However, it is well understood that the future of natural resources conservation and development will be secured only when the resources are managed in a way that they generate benefits to improve livelihoods of communities so they are not forced to deplete their resources for survival reasons. Realities in Ethiopia as well proved that, natural resources could be conserved as far as they render benefits to local communities which they are bound. Hence, new integrated conservation-development approaches should be sought that integrates economic gains from natural resources conservation while maintaining them for ecological and other benefits. Ecotourism which is one form of nature-based tourism when carefully planned and implemented, is one of those approaches that possess enormous potential to link economic incentives with significant natural resource conservation in such dryland ecosystems of a country.

2. Ecotourism and Nature-Based Tourism

As the name implies, "nature-based tourism' is defined as any type of tourism that relies on attractions directly related to the natural environment (Valentine, 1992). It involves educational and interpretation of the natural environment and manage to be ecologically sustainable. It encompasses a diverse range of other forms of tourism including ecotourism, adventure tourism, wildlife tourism and others that their experiences rely on natural attractions. The nature-based tourism itself is sub component of the broader category of sustainable tourism. In this regard, the rift valley region and other dryland ecosystems in Ethiopia proved to have huge potential for the development of such nature-based tourism including ecotourism. The Bishangari and Wenny (eco) loges are few instances of such nature-based tourism in central rift valley regions of Ethiopia that have been established on the basis of existing natural attractions and scenic beauty.

Fig. 1. Position of nature based tourism, ecotourism within the broader category of sustainable tourism. Source: http:www.tq.com.au accessed 28 November 2009 (slightly modified).

2.1 Concepts and evolution of ecotourism

The origin of the term "Ecotourism", also known as ecological tourism is not entirely clear. There is no as such clear and exact reference with regard to the use of the term 'ecotourism'. However, one of the first to use it appears to have been Hetzer in 1965, who identified four 'pillars' or principles of responsible tourism: minimizing environmental impacts, respecting host cultures, maximizing the benefits to local people, and maximizing tourists satisfaction (Orams, 1995 cited in Weavers, 2001). The first of these happen to be the most distinguishing characteristics of "ecological tourism" or "Ecotourism" (Fennell, 1998; 2002). So far, there is no one agreed definition describing what constitutes the term 'ecotourism'. It has been defined variously depending on the context of country of implementation, major expected outputs and interests' of authors involved. However, the majority of definitions given to ecotourism focus mainly on description of the three major contributions of ecotourism i.e. its role towards conservation of natural resources of an area, benefiting host communities and satisfaction of ecotourists involved in the experience. Originally, the term 'ecotourism' was defined as: "travelling to relatively undisturbed or uncontaminated areas with the specific objectives of studying, admiring, and enjoying, its wild plants and animals, as well as any existing cultural manifestations found in these areas" (Ceballos-Lascurain, 1987 Cited in Diamantis, 2004).

Ecotourism, the new environmental paradigm emerged between 1970s and 1980s within the womb of an environmental movement (Honey, 1999). It has developed as a consequence of growing environmental concern coupled with an emerging discontent with mass tourism which has in general sense believed to ignore the social and ecological elements of destination regions. At the same time, less developed countries began to realize that nature-based tourism offers a means of earning foreign exchange and providing a less destructive use of resources than other alternatives such as logging and agriculture. By the mid 1980s many countries have identified ecotourism as means of achieving both conservation and development goals.

Following the general trend that happened in other parts of the world, the concept and idea of developing ecotourism has become in effect for the first time in Ethiopia during the late 1990s. It was first initiated by FARM-Africa eco-tourism project called Bishangari Tented camp which itself was part of a forest conservation project. However, this tented camp ecotourism project didn't last long, mainly because of the emerging difficulties in the relationship with the local communities and also the difficulties in getting the required license for promoting ecotourism. From the year 2000 onwards, the license for the same exact site with its ecotourism concept was given to private owners to undertake an eco-based tourism by the name 'Bishangari ecolodge'. Since then, the owners of Bishangari ecolodge integrate development with natural resources conservation using concepts of ecotourism. This is one best example to show that economic success lies not only with pure exploitation of natural resources of an area, but also through conservation of such resources and maintaining environmental sustainability. Following this, other ecotourism projects like the Adaba-dodolla, Wenhi community based ecotourism and privately owned ecolodge like 'Wenny ecolodge' have been developed. Recently, many more ecotourism projects are also being initiated and implemented (Tadele, 2005).

3. Dryland Ecosystems and Major Attractions in Ethiopia

3.1 Dryland forest resources, wildlife and national parks

Being an integral part of the forest resources of Ethiopia, the dryland ecosystems encompass the dryland forest ecosystems dominated by *Acacia -Commiphora* woodland, savanna grassland and the associated wildlife resources, scenic beauty, many lakes and cultural diversities. These dryland forests are highly valued for various goods and services they render to the local community and the society at large. They have a considerable ecological and economic significance in terms of safeguarding the fragile ecosystem and contributing to both regional and national economy (Getachew, 1999). They have significant role in the conservation of biodiversity, environmental protection, soil and water conservation and maintenance and improvement of microclimate.

The savanna and woodland forests resources of the dryland ecosystems in Ethiopia host vast diversity of big and small mammals, amphibians, reptiles, birds making them an attractive center for the development of nature-based tourism. As a result, the rift valley region and other dryland ecosystems in Ethiopia encompasses many of the national parks such as Awash, Abijata-Shalla, Nech-sar, Mago, Omo the recently established Maze, Chebera-Churchura, Kafeta-Sheraro, Alatish, Geralle each being unique in its own. Many of the wildlife sanctuaries including Yabello, Babile Elephant, Senkile Swayne's Hartebeest are also part of these dryland ecosystems. They also contain most of the wildlife reserves namely Mille-Sardo, Gewane, Alledeghi, Awash west, Chew-bahr and Tama signifying the current and future potential of these dryland ecosystems for developing ecotourism and other related nature-based tourism. Below are list and locations of the national parks, sanctuaries and wildlife reserves (Fig. 2).

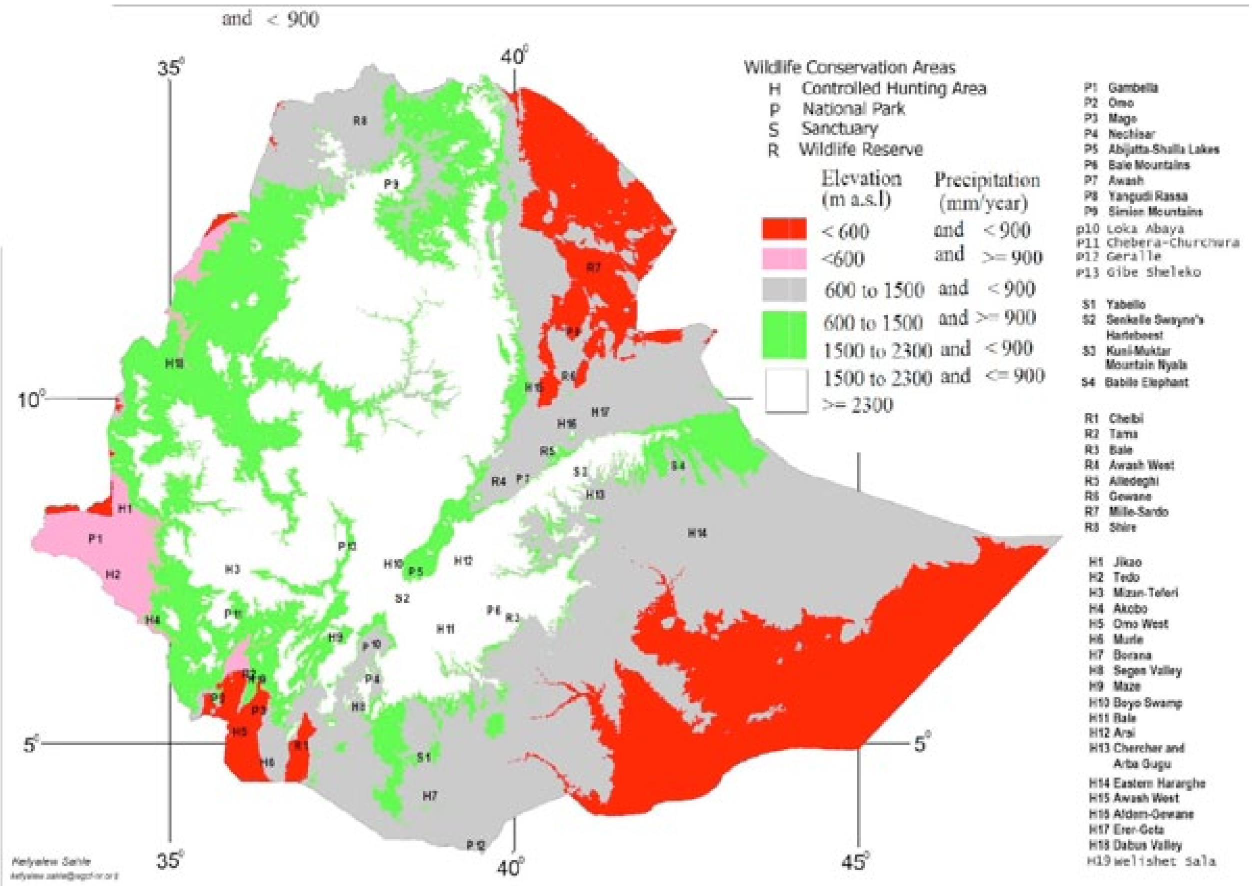

Fig. 2. Map showing distribution and location of protected areas in drylands of Ethiopia
(Source: Digital-Elevation-Model-Ethiopia (DEM) – NASA (STRM), World climate for rainfall, Geo-processed by K. Sahele in Nov. 2009)

3.2 Lakes

Most lakes found in Ethiopia are located along the rift valley which itself is part of the dryland ecosystems. In addition to the Debre-Zeit crater lakes, which are on the western margin of the central rift valley, there are eight major lakes following the descending Ethiopian rift valley to the south. These lakes are not just accumulation of water, but are resources endowed with several economic significances such as fish, birds, crocodiles and some with mineral resources. The lakes hold enormous fish resources. The lakes in these dryland ecosystems happen to be breeding spots for numerous precious birds, which are both endemic and common ones. In fact, Ethiopia's rift valley is known to be one of the biggest bird sanctuaries in Africa. Above all, these lakes are found to have greater potential for developing ecotourism and are partially being exploited for the same recently.

One can find huge concentrations of privately and government owned hotels, beach resorts and (eco) lodges within the central rift valley regions of Ethiopia in response to these varieties of attractions (Fig. 2). Many more new ones are also under construction within Langano catchment. However, it's not possible to say that all are promoting nature-based type of tourism experiences though they built on the basis of existing natural attractions. Only two of the existing (eco) lodges namely, Bishangari and Wenny are known so far to provide nature-based type of tourism experiences. Hence, they played a lot towards conservation of natural resources of the area. But it can be witnessed that, they all played significant role in providing employment opportunities for local people, and encouraging some community members to develop their own small business centers (Table 2). The key issue in this regard is how best these tourism service providers might be coordinated to enhance their benefits for local communities, the environment and natural resources conservation.

Table 1. List of major attractions, existing and future possible ecotourism and other nature-based tourism activities

List of major attractions of dryland ecosystem in Ethiopia	**Existing and possible nature-based and ecotourism activities**
Woodland vegetation	☞ Bush walking ☞ Scientific study ☞ Observing wildflowers and other plants
Wildlife Resources (mammals, birds, reptiles, amphibians, etc.)	☞ Observing animals ☞ Bird watching ☞ Hippo spotting ☞ Scientific study ☞ Nature photography
Scenic beauty	☞ Trekking ☞ Landscape viewing ☞ Nature photography
Lakes	☞ Boat cruising ☞ Fish angling (fish catch and release) ☞ Bird watching ☞ Swimming ☞ Diving
Rivers and water falls	☞ Rafting
Ethnicity and cultural diversities	☞ Heritage tours ☞ Visits to cultural villages

Table 2. Operational beach resorts, hotels and (eco) lodges in the central rift valley areas of Ethiopia

No	Name	Type	Ownership	Employment opportunity provided		
				Total	**% of locals**	**Remark**
1	Abule-bassuma	Lodge	Gov-private	?	?	NF recently
2	Wabishebelle	Hotel	Gov	62	83.8	1 temporary
3	Langano-vacation club	Hotel-resort	Private	90	70	Planned number for January 2010
4	Getu Asfaw	Hotel	Private	41	63	All are temporary & name might change
5	Langano lodge	Lodge	Private	14	64	Temporary
6	Karkaro-beach resort	Beach-resort	Private	13	61.5	
7	Ros-Ethiopia		Private	47	85	Temporary and the name might change
8	Saban-beach resort	Beach resort	Private	120	98	
9	Bekele Molla	Hotel	Private	108	56.5	18 are temporary
10	Bishangari ecolodge	Ecolodge	Private	43	95.4	
11	Wenny ecolodge	Ecolodge	Private	27	92.6	

Abbreviations used: Gov-private = Government private, NF = not functional

Data source: Respective hotels, resorts and (eco) lodges on visit made in November, 2009.

4. Activities in Ecotourism and Other Nature-Based Tourism

The type of activities or experiences in nature-based tourism and ecotourism heavily depend on the type of attractions an environment can provide. As indicated above, the dryland ecosystems in Ethiopia are centers for most of the protected areas including national parks, wildlife reserves and sanctuaries. They are also known for their outstanding landscape scenery. The greater diversified people of Ethiopia are also found in the drylands. As a result they are centre of cultural and ethnic tour. Such rich, diversified natural and cultural assets of these dryland ecosystems provide an immense opportunity for developing various forms of nature-based and ecotourism experiences. Below are some of list of existing attractions and possible nature-based and ecotourism activities that can be developed in the future though some have been implemented in existing ecolodges.

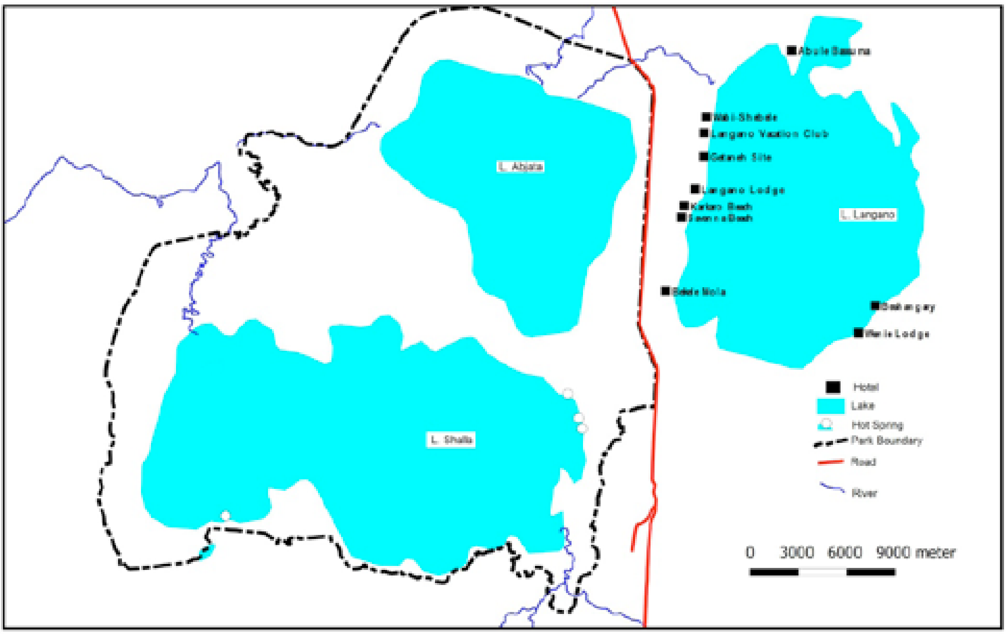

Fig. 3. Map showing Abijata-Shalla national park and the neighboring tourist service providers (active attraction sites).

5. Benefits of Ecotourism and its roles in food security

5.1 General

Ecotourism has widely been acknowledged for the wide varieties of benefits rendering to people at local level, enhancing the development of regional and national economy of a country, and contributing to the conservation of natural resources of an area.

5.2 Ecotourism, job opportunities and roles in food security

Direct employment opportunities generated by ecotourism-related jobs is sometimes one of the most significant benefits for local communities, providing alternative off-farm income source to rural farmers, women and young people. Often, in dryland ecosystems, the job opportunities generated because of ecotourism are better secured and provide continuous income source as compared to other livelihood strategies like agriculture which is affected by recurrent drought. In such environment, the rainfall is sporadic, scarce making agricultural productivity less reliable as compared to ecotourism driven employment opportunities. Other than the direct employment opportunities rendered, many local businesses centers have been started up, offering goods and services to visitors where there are tourism and ecotourism activities making the multiplier effect considerable.

Even though it is at its initial stage, study conducted in central rift valley area indicate that ecotourism seen to play a vital role in the development of local, regional and national economies. For instance, two of the privately owned eco (lodes) that are engaged in providing nature-based tourism experiences namely Bishangari and Wenny have provided a direct employment opportunity to 62 household heads of local communities. According to Tadele (2005), each household in the central rift valley area of Ethiopia on the average supports eight family members increasing the number of direct beneficiaries to nearly 496. The same study conducted by interviewing 98 households noted that 14% of them expressed that they are generating incomes through ecotourism-related activities like, sale of crafts, fish and provision of services to tourists. The income generated in relation to ecotourism is used in purchase of food items for feeding family members playing a role in food security, paying children school fees, health care thereby alleviating poverty and leading to overall livelihood improvements.

Though minimal at present and more future efforts are expected, participation of ecolodges owners in the development of social facilities like construction of access roads that assist farmers in bringing their produces to markets for higher prices, provision of construction materials, books for schools and pure water for surrounding local community plays significant role in improving the household economy and hence improving the living standards of the people at local levels. These in turn have an overall effect in improving the economy of people at household, local, regional and national levels.

5.3 Ecotourism and its role in natural resources conservation

As indicated above, there are wide ranges of benefits accrued from an already developed ecotourism, one of which is natural resources conservation. There are different direct and indirect ways through which ecotourism would contribute towards conservation of natural resources of a given area. Directly, in order for ecotourism to exist it needs the existence of those natural and cultural attractions of a given locality. As a result, such resources will be conserved directly for the survival of ecotourism itself. A study conducted in the central rift valley regions of Ethiopia showed that in Langano catchment where ecotourism has been exercised, a marked difference has been observed in terms of woody plant species diversity between areas with and without ecotourism. Areas with ecotourism found to support highest diversity (richness), density and evenness of woody plant species (Tadele, 2005; Fig. 4). For instance, a total of 24 species representing at least 16 families were recorded in area with ecotourism and 8 species representing at least 6 families were recorded in area without ecotourism. The other direct means is that, once ecotourism has been developed, the money generated from it would be re-invested on the conservation of these resources.

A. B.

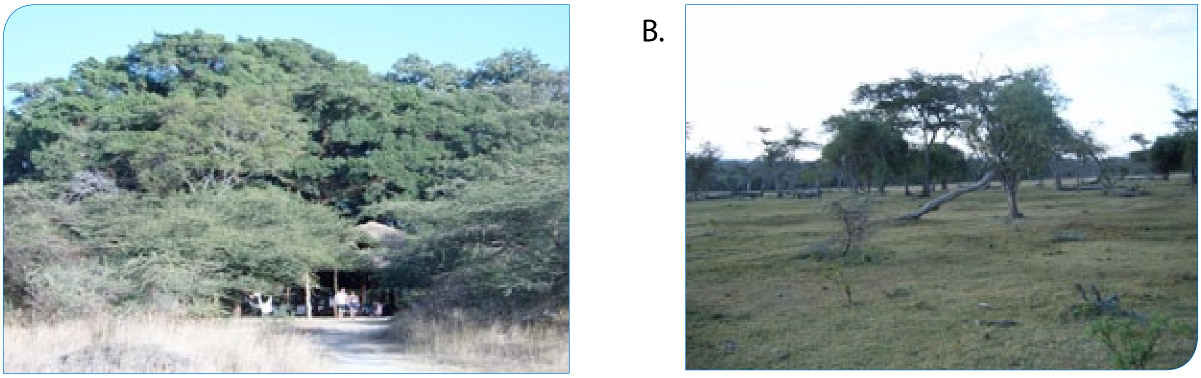

Fig. 4. Showing pictures (A) taken from area with ecotourism and (B) taken from areas without ecotourism at Bishangari site. (Photos by Tadele Z.)

The economic benefits generated from ecotourism include enterance fees, licenses and concessions; fee for specific activities and various forms of taxes often generate substantial funds to support conservation and management of natural environments. Tourists' expenditures on lodging, transportation, food, guides, and souvenirs are important sources of income for local communities.

Indirectly, ecotourism has an educational and interpretation component whereby both host communities and ecotourists will be made aware of the importance of conserving the environment and its resources. Besides, the employment opportunities provided to local people as a result of ecotourism initiates and encourage them to become conservation supporters. It has also been observed that, members of the communities who are employed in ecotourism centers will acquire skills of tour guiding, food preparation and foreign languages because of the training opportunities provided to them. Such skills are long-lasting in terms of opening up further employment opportunities in other tourism related businesses. Moreover, the employment opportunities provided in relation to ecotourism would play paramount importance in retaining significant proportion of the labor force of local communities that would otherwise be engaged in charcoal production through mining of the acacia woodland resources. Hence, pressure exerted on the remaining dryland forest resources will decline because of reduction in such activities leading to deforestation.

If it was possible to quantify the benefits achieved through ecotourism in the form of environmental protection, natural resources conservation (soil, water, and biodiversity) in terms of monetary basis, the value achieved could have surpassed the majority of other sectors of the economy. More recent studies undertaken in this regard, showed that the value attained due to ecotourism are much higher than other forms of land uses. A study undertaken in Amboseli National Park (Kenya) showed that the income generated due to ecotourism is 18-20 times higher than if the park was used for agricultural purposes. The park is also estimated to be worth 18 times the annual income of a fully developed commercial beef industry. Others estimated that the total net return for a park such as Amboseli in utilizing tourism to be 50 times more per hectare per year than the most optimistic agricultural returns (Wearing and Neil, 1999).

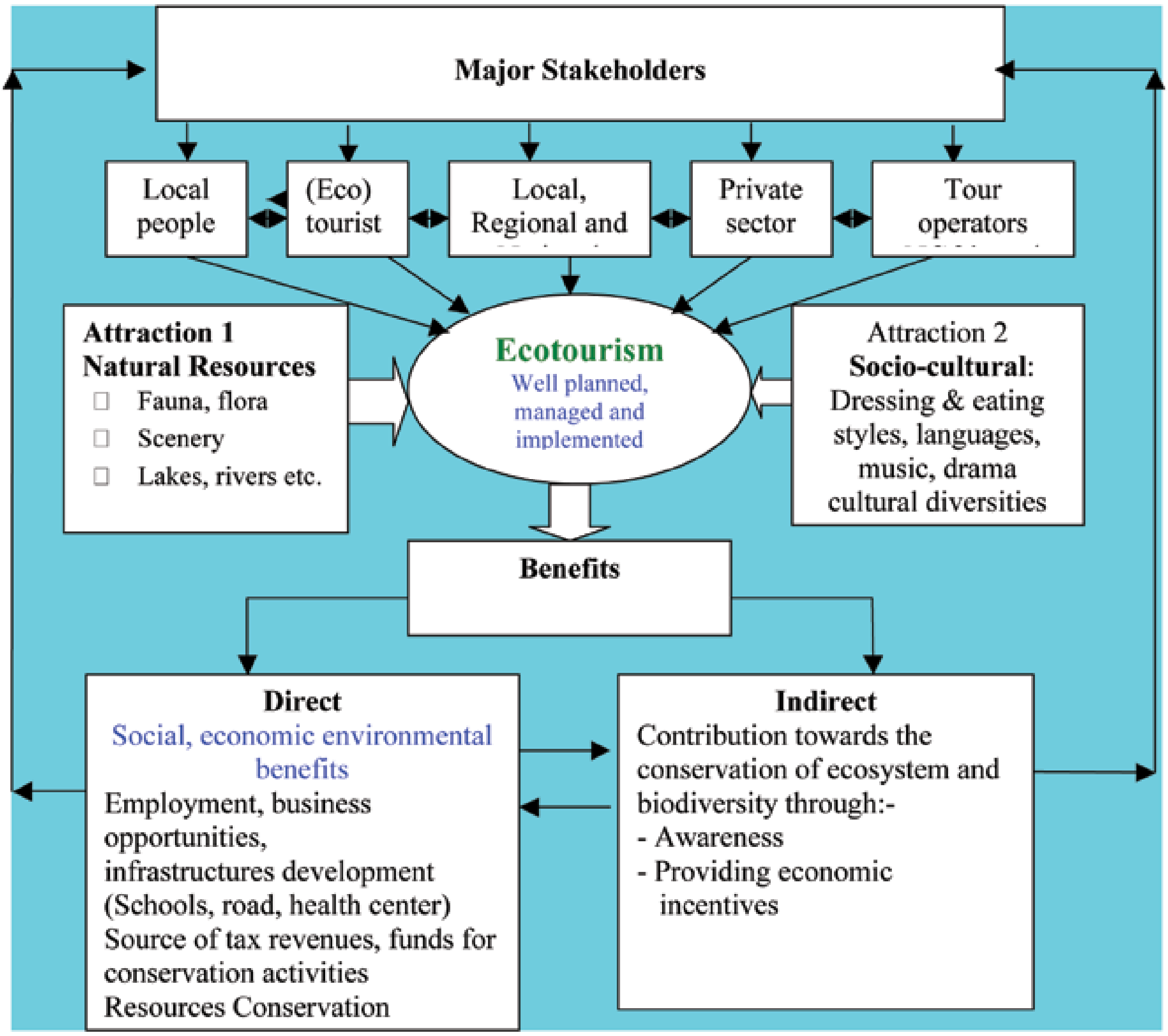

Fig. 5. Ecotourism: major linkages with attractions, key stakeholders and benefits generated. Slightly modified from (Tadele, 2005).

Another study undertaken in Uganda where there is ecotourism activity in relation to mountain gorillas, the value of the land with ecotourism is found to be 18 times higher than if it was to be used for agriculture. Such studies clearly show the potential that ecotourism can have in developing the economies of developing world, especially in sub-Saharan African countries where there are about 440 protected areas covering about 2,600,000 square hectares. (Africa Recovery, 1999). These all show the potentials that ecotourism would contribute in enhancing the development of local households, regional and national economies without degrading existing natural resources. Ultimately, it is such improvements for local host communities that make ecotourism socially and economically acceptable, and not just a marketing ploy. As it can be seen above on the Fig. 5, ecotourism has the potential to encourage multi-stakeholder participation thereby enhancing those positive qualities in terms of cultural exchange, bringing the necessary attitudinal change and understanding of each other.

5.4 Other characteristics and principles of ecotourism favoring natural and cultural resources conservation of destination areas

There are other characteristics and principles of ecotourism that favor conservation of natural and socio-cultural resources. One of these principles of ecotourism is to minimize the perceived negative impacts of conventional (mass) tourism. Unlike in mass tourism, ecotourism by nature is small in scale. This is to mean that only small numbers of visitors are involved in ecotourism experiences. It considers the carrying capacity of attractions, tourism service facilities of destination areas while expecting some amount of income on sustainable basis. As it can be seen in west of Lake Langano where there is mass tourism, there is no limit with regard to numbers of tourists as the main objective in such tourism activity is profit maximization. Not only ecotourism is small scale in its nature, it also involves those people who are ecologically and socially conscious and has no or little impacts on attractions of surroundings. In addition to these, those who involve in such ecotourism experiences in the central rift valley area are from high income group with the majority being foreigners (67%) (Tadele, 2005). As a result, it plays significant role in enhancing the national economy through generation of foreign currency.

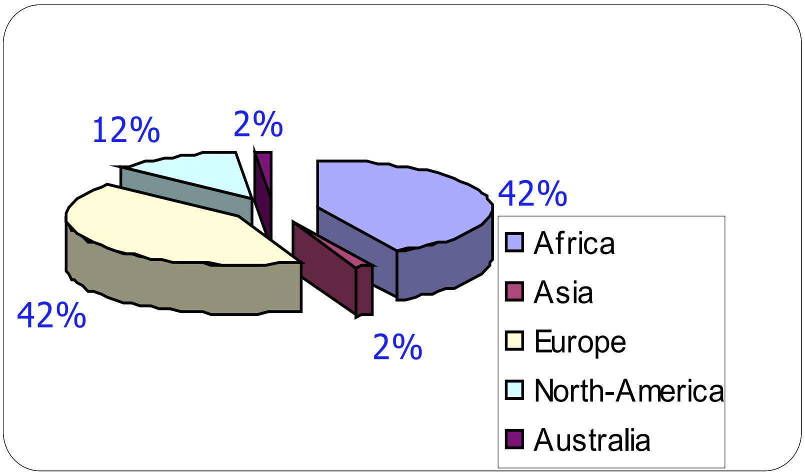

Fig. 6. Origin and proportion by continents of (eco) tourists during 2002-2004 years) (Source: Tadele, 2005)

The other feature of ecotourism that favor conservation of resources is the nature of the experiences/activities themselves. Activities in ecotourism are non-consumptive, meaning they don't involve exploitation of resources. As a result, attractions are always there while providing ecotourists with the opportunity of enjoyment. Such activities include bird watching, wildlife viewing, photography, scientific investigation and others (Table 2) which all are recently implemented in (eco) lodges that promote nature-based tourism experiences.

6. Wildlife Contribution in Dryland Ecosystem of Ethiopia

The drylands that cover extensive portion of Ethiopia's land mass are endowed with rich and unique assemblages of plants and animals. As a result, they harbor most (77%) of the protected areas of the country that can be a base for developing and promoting ecotourism. Hence, ecotourism and other forms of nature-based tourism could become the driving force in achieving the growth of local, regional and national economy of Ethiopia. Wildlife based tourism can bring vital off-farm incomes to local communities through employment, and purchase of local produce and artifacts (Menassie, 2009) hence playing roles to national economies.

Wild animals exert significant influences on food production systems which may be positive or negative. Positive influences include the role of wild animals as seed dispersal and pollination agents as well as use of wild animal droppings as fertilizers. Many species of birds and mammals such as bats, monkeys, baboons and squirrels are known to spread fruit trees by their feeding action. A study in the Cote d'Ivoire found that sites where elephants had vanished long ago lacked saplings of certain tree species which are known to be dispersed by elephants (Alexandra, 1978)

Though drylands have experienced significant problems in their role to attract greater number of tourists, they still are part of the main tourist destinations in Ethiopia. The greater diversified people of Ethiopia are also found in the drylands. As a result, they are centre of cultural and ethnic tour. They are also ports of entry for visitors. According to Minassie (2009), 15% of tourists enter to the country through the drylands.

6.1 The role of wildlife and ecotourism in food security

Though, civilization and agricultural development over millennia has drastically reduced people's dependence on bushmeat (meat of wild animals), it was one of the main sources of food and virtually the sole source of animal protein for people in pre-historic times across the world. However, the reality in Africa is that for the greater majority of rural people, bushmeat represents a vital dietary item for a complex combination of reasons dictated by lack of alternate sources, financial limitations, preference and cultural values. For such people, wild animals constitute a valuable food resource which cannot be easily withdrawn or replaced without causing wide-ranging socio-economic imbalances.

In countries such as Botswana and Zaire, much of the meat consumed is bushmeat and in the majority of West African states, bushmeat is the preferred meat and has a higher retail value than domestic meat in urban markets. Similarly, many places in Ethiopia particularly in marginal areas, people use the meet of wild animals. For instance, the meat of White Eared Kob is sources of protein for people living in remote parts of Gamebella region. The meat is hanged and sun-dried even for later use. In North-Gonder, Alatish, the meat of Warthog is an important source of protein for local community (Girma and Afework, 2008; Fig. 7).

Fig. 7. Poachers and meat of Warthog they killed in Alatish. (Source: Girma and Afework, 2008).

In addition to being a highly preferred food item in many areas of Africa, wild animal foods are life-saving reserves in times of food shortage and hunger. The importance of caterpillars, beetles and termites as key sources of food in times of famine is particularly well documented for communities in the Central African sub-region.

The contribution of wildlife to food security and nutritional well-being in Africa is also manifested in the spiritual, cultural and medicinal values placed on wild animals by rural African communities. Many such communities still depend on wild animals and their products, used alone or with herbs, for medication and the treatment of a wide variety of ailments ranging from mental and physical illnesses to ante-natal care; while a wide range of wild animal species have spiritual and cultural associations (Ntiamoa-Baidu, 1987, 1992).

Table 3. The role of wildlife for food security

Direct Contribution		**Indirect Contribution**	
Food from wild animals		**Household income**	
Bushmeat	Smoked, fresh, salted, biltong	Employment	Hunters Traders; Helpers Chop bar workers. Services linked to the tourist industry, Craft workers, Wildlife officers
Eggs	birds, turtles	**Macro-economy**	
			Tourist Industry, Sport hunting, game viewing, Local (hunting permits/taxes), Export trade (live animals), Export trade (skins, hides, trophy)
Insects			
adults; larvae	Roasted, dried, boiled		
Honey		**Influence on Health**	
Flavorings			Wild animals parts/products medicines, Use of wild animals in drug development, Spiritual & mental health, Cultural & religious values
		Influence on Agricultural systems	
			Seed dispersal, pollination and pests

Source (Ntiamoa-Baidu, 1997)

The magnitude of exploitation and consumption, however varies from country to country and is determined not only by its availability, but is also influenced by governmental controls on hunting, socio-economic status and cultural prohibitions. In areas where wildlife still exists, people collect, hunt or purchase and eat bushmeat for a variety of reasons. Some people depend on bushmeat for their animal protein supply because they have no other sources or cannot afford alternative sources. Others eat bushmeat as a matter of preference or as a luxury item/delicacy to be eaten on special occasions. Some recent data are available on bushmeat consumption in individual households and communities in a few areas of Africa. For instance, a survey conducted in 1987 in Bukavu, Zaire indicated that 72% of the population in the town consumed bushmeat regularly and the yearly bushmeat consumption of the town was estimated to be about 400 tons (Keita, 1993). Bush meat consumption in Côte d'Ivoire was estimated to be 83,000 tons in 1990, valued at US$117,000,000 (Feer, 1993).

Bushmeat production estimates published by FAO for selected countries are reproduced in Table 5, which also gives the contribution of bushmeat to daily protein intake. These estimates are based on very limited data and have value for comparisons between different countries rather than as absolute production figures. In the same vein, the figures for bushmeat consumption do not reflect the real situation that pertains in many rural African communities. Thus, the need for more studies in this area cannot be over-emphasized (Ntiamoa-Baidu, 1997).

Trade of bushmeat and wildlife products as well as wildlife based industries contribute significantly to both national and household food security through the generation of financial resources which can be used directly to purchase food or to develop and improve food production systems. The main contribution of wildlife to African macro-economies comes from wildlife-based tourism, recreation and associated industries. There is a point of view that the greater proportion of income from tourism in African countries goes to foreign owned airlines and hotels. However, it is also obvious that the tourist industry in Africa offers employment to a significant number of local people, thereby contributing to household income and access to food.

Apart from the income generated through direct employment in wildlife based ventures, wildlife also contributes directly to household income through hunting, trade in bushmeat, trophies, skins and hides, as well as sale of live animals and craftwork based on wild animal products. Bushmeat is often used as an item of barter for carbohydrate food resources and essential household items. Markets for bushmeat and other wild animal products help to fuel rural economies and provide income sources for the rural communities, who often have very few other avenues for earning cash income and for whom income from wild products is essential for the provision of everyday needs. Hunting and bushmeat trade involves several levels of participants, from hunters to middlemen and meat processors and therefore, provides income not only for hunters but a wide cross-section of both rural and urban communities. Even among communities where the main occupation is farming, income from hunting/collection of wild animals and wild animal products often represent a substantial proportion of the household income which cannot be easily removed without causing significant hardships. A large proportion of rural populations in Africa live on the edge of poverty and have to struggle to survive. Under such conditions even small incomes such as that derived from seasonal collection of snails by women could determine whether or not a child continues school, since without this there would be no money to pay school fees.

Table 4. Bushmeat production and consumption in selected African countries

Country	Estimated Bushmeat production				Protein consumption (g/day)		
	1980	1985	1990	1994	Total Protein	Animal Protein	Bushmeat
Botswana	5	5	5	5	71.3	21.5	1.9
Cameroon	33	40	44	46	52.3	11.1	0.2
Congo	10.2	10.6	11	11.8	51.3	21.6	1.4
Ethiopia	52	62	72	74	-	-	-
Gabon	18.5	18.5	18.5	18.5	-	-	-
Ghana	44	57	57	57	46.3	13.2	3.4
Côte d’Ivoire	13	13	13	13	53.1	13	1.3
Kenya	8.5	9.1	9.6	9.9	-	-	-
Namibia	2.6	3.1	3.6	4	-	-	-
Nigeria	100	100	100	100	47	6.5	0.5
South Africa	10	10	-	-	77.1	27.9	0.1
Sudan	6	6.5	7.5	7.7	60.6	25.1	1.7
Tanzania	8.5	11	12.2	12.8	55.3	11.3	0.2

Source (FAO, 1995)

Wildlife based tourism is particularly well developed in eastern and southern Africa where the industry contributes significantly to national incomes and is a key foreign currency earner in a number of countries and maintain food security. Kenya is cited as the most successful African country in terms of tourism development and the industry earns approximately US$ 600 million a year, an income exceeded only by that from coffee. Using a computer model based on projected number of visitors to the Amboseli National Park in Kenya over a 15 years period, Thresher (1991) argues convincingly that it is more profitable to both the nation and individual households to protect game animals for tourism than for consumptive uses. For individual landowners participating in a group ranch scheme and who received benefits from the state after cost deductions, income derived from the maintenance of a lion on their ranch as tourist resource was $91,000 as compared with $600 paid out as hunting fees if the lion was sold.

7. Conclusion and Recommendations

The dryland ecosystems constituting extensive portion (7.5 %) of Ethiopia's land mass hosted the majority (77%) of the protected areas in the country signifying their current and future potentials for developing ecotourism and other related nature-based tourism. Though there are some past and current efforts to make use of these resources, they are however, not well exploited for the same to their capacities. Instead, they are threatened because of the intensified pressure exerted on them. Accurate data on major natural and socio-cultural attractions, wildlife utilization aspects and extent of their damage are also lacking. Hence, we are at constant move to look for viable strategies which are economical and sustainable in conserving, and developing the natural resource base of the country. One option in this regard is ecotourism. Ecotourism is one form of sustainable tourism that has been emerged in recent times to avert the negative impacts associated to conventional tourism. It is more recently (in the late 1990s) that the concepts and idea of developing ecotourism in Ethiopia has been emerged which may be traced back to the establishment of Bishangari ecolodge in the Langano catchment of central rift valley region.

Because of the very recent nature of ecotourism in Ethiopia, much remains to be studied about the current and anticipated future potentials of ecotourism in relation to environment and associated resources, the various benefits rendering to host communities as well as the negative impacts associated to it. In light of these, the following are recommendations on the basis of overall experiences gained so far in dryland ecosystems especially central rift valley regions of Ethiopia.

- Both the regional and national governments should take the lead in facilitating coordination of tourism service providers to enhance their roles in benefiting local communities and natural resources conservation which seems not been done yet.
- It is time to consider options of organizing communities in an effort to develop their own community based ecotourism centers so that benefits accrued from it directly and fully goes to themselves? This could serve as an incentive in initiating local communities to become conservation allies.
- Collaborative work among local people and community leaders, government, NGO's and private investors is needed to ensure sustainability of ecotourism or the tourism industry as a whole.
- Further research has to be done to deal with the impacts (both positive and negative) that ecotourism would bring to destination areas.
- It is also worthy to look for other alternative income sources for people living in such dryland ecosystem in an effort to reduce pressure on existing natural resources.

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A PRELIMINARY PHYSICOCHEMICAL STUDY ON THE MEANINGFULNESS OF GRADING IN BOSWELLIA PAPYRIFERA (DEL.) HOECHST (FRANKINCENSE) TRADE

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Abstract

Based on their origin, three types of frankincense are distinguished in Ethiopia. These are the Tigray type, the Ogaden type and the Borena type. The study samples were from the Tigray, Ogaden and Borena types of frankincense. The samples were collected from Nazareth where the grading system is processed. The Tigray type frankincense sample is separated into 7 (seven) grades. Prior to the process of grading Tigray 5 is picked out of the collected raw material and set aside for domestic sale. The next step is to separate by color grade 4 (dark-normal and brown-special) from the bulk containing grade 1, 2, and 3. The mixture of grades 1, 2, and 3, then, are subjected to separation by using sieves of different mesh size. Those granules that could not go through 6 mm mesh pore are classified as grade 1. The filtrate is again treated with a sieve of 4 mm mesh size; the residue is grade 2, and the powder that passed through the 4 mm mesh is grade 3. Further, grade 1 is screened as 1A (white) and 1B which is not as white as 1A. The Borena type has a color of black and it has a sticky property. The size of Borena type frankincense is not uniform. The Ogaden type frankincense has impurities. It has been mixed with stone and dust. It has a brown color. And like the Borena type the Ogaden type has not been graded and it does not have a uniform size. Three experiments were designed to find out if the 7 (seven) grades of Tigray type were chemically different and also are the Ogaden and Borena types. The three experiments were TLC, GC-MS, and evaporation durations determinations. As the spots on the TLC plates indicated there are similarities and also some differences. The first samples Tigray 1A, 2 and 3 were found to be the same. The 4 normal (4N) and 4 special (4S) showed some similarities with the samples described above with a difference in RF values. These two samples have a more polar compound than the other group of samples. Tigray 1B has polar compounds than the first three samples but not as significant as the two Tigray 4 types. The Tigray 5 (the bark) has similar spot with Tigray 1A, 2 and 3 samples. This tells us that this sample has the same composition of substances as the first three samples. The GC-MS experiments gave more or less similar features. The GC-MS spectra showed that the two samples (4N and 4S) have the same compounds with the other four samples which are traditionally believed to have been quality samples. Tigray 4 samples not only showed same features with the others but also with better compositions. The Tigray 5 type is the one which is not exported for industrial or medicinal applications. But as seen with the TLC and GC-MS chromatography and spectra, respectively, it has similarity with the top three grade samples which were always quoted with higher prices. Hence this base-line investigation suggested that the whole exercise of grading seemed to have been a futile effort. As to Grade 4 (4N and 4S), this study came up with a strong suggestion that an importer would benefit by investing on them. Further detailed chemical study would warrant a justifiable scientific benchmarking in regards to completing chemo-taxonomical studies, and towards banking data for well informed advices to stakeholders. On the other hand the Borena and Ogaden types' study unequivocally proved them to be very different from the Tigray type and also between themselves. Overall, the study conducted so far, resulted in motivating chemists and other professionals to carry out comprehensive biophysical and chemical studies in order to deliver appropriate and useful scientific information to producers, exporters and importers.

***Key words**: composition, grading, Frankincense;*

1. Introduction

Frankincense was an important trade item for many cultures, mainly among the Egyptians, Greeks, Romans, Chinese, Babylonians, Assyrians and Ethiopia. Incense is burnt in many churches worldwide (FAO, 1995). The Babylonians, Assyrians and Egyptians burned frankincense in their temples as an offering to the gods during religious rites. The ancient Egyptians also ground the remains of burned frankincense to create kohl, the black substance they used for eyeliner. It is also used for smoking houses particularly during coffee ceremonies (Wubalem et al., 2004)). Frankincense is used as an oil extract in a number of application such as modern perfumery, traditional medicine, pharmaceuticals, fumigation powders, fabrication of adhesives, painting and chewing gum industries. The Greeks and Romans used the aromatic resin as incense, whereas the Chinese valued frankincense for its medicinal properties. Frankincense was used as a remedy for various ailments including leprosy and gonorrhea. These findings illustrated well that frankincense has applications for a variety of uses (Darlen, 2008).

The perfume industry uses frankincense as one of its ingredients. Since frankincense can take up to six hours to evaporate it is often used in perfume to increase the longevity of the fragrance. Its natural woody fragrance can also enhance scents resulting from fruity or spicy blends (Darlen, 2008). Practitioners of aromatherapy use frankincense in both essential oil and incense form. The aroma of frankincense is soothing and can help to calm the mind and relieve stress. A person can add a few drops of frankincense essential oil to the bath or burn the incense to enjoy the pleasant scent. In aromatherapy, practitioners use frankincense to clear the head as well as rejuvenate the mind and body (Darlen, 2008).

Frankincense oil is sometimes used as an ingredient in creams or lotions. It is beneficial for normal and oily skin tones while reviving dry or aging skin. It can help clear spots and reduce the appearance of scars. Frankincense oil can also soothe and speed healing of skin wounds and inflammation. Frankincense oil can also be used to relieve the symptoms of respiratory ailments such as bronchitis, asthma and colds. The aromatic steam helps clear the lungs, making breathing easier. Frankincense works as a massage oil to relieve the pain and stiffness of aching muscles and increase blood flow. The oil can also be massaged into the temples and/or neck to relieve tension headache (Darlen, 2008). Despite the enormous importance of frankincense production in Ethiopia very few attempts have been made to promote sustainable production, processing, marketing, development and quality management of this natural resource.

^{13}C NMR analysis of crude steam distillation form *B. papyrifera* in Ethiopia indicated that the main component (88%) of the resin is octylacetate, a GC-MS analysis's result, supported by NIST and Wiley database also confirmed it (Ermias *et al.*, 1997). The purifies PS from *B. papyrifera* has 4-8% protein while recently reported protein content of crude PS of *B. papyrifera* is 3.9%. (Mulugeta and Demel, 2003; Anderson, 2005).

Three types of frankincense products are recognized in Ethiopia, namely the Tigray, Ogaden and Borena types. The Tigray type is the gum resin obtained from *B. papyrifera* and the most widely traded frankincense (with over 90% of the natural gum export). This is the type of frankincense produced in the west, north and northwestern parts of Ethiopia. The Ogaden and Borena types represent frankincense produced in the eastern as well as southeastern and southern parts of the country, respectively (Girmay, 2000).

In the Tigray type the next process, after tapping, is grading. The grading system involves a lot of labor and is time taking. The price variation between grades is significant. Because of this foreign trade has been dominated for the lower grade which has attractive price. Other grades awaited few buyers because of their price. Hence, a study was initiated with the objective to see if the traditional grading system is chemically meaningful or not by studying the physico-chemical properties of frankincense of different types.

2. Materials and Methods

The study samples are from the Tigray, Ogaden and Borena types of frankincense. The samples were collected from Nazareth where the grading system is processed. The Tigray type frankincense sample is separated into 7 (seven) grades. Grading is in terms of size and color; namely, Tigray 1A, Tigray 1B, Tigray 2, Tigray 3, Tigray 4 normal, Tigray 4 special and Tigray 5 as shown in Table 1.

Table 1. Tigray types frankincense and their color

Type	Color
Tigray 1A	White
Tigray 1B	Brown
Tigray 2	White
Tigray 3	White
Tigray 4 normal (4N)	Brown
Tigray 4 special (4S)	Black
Tigray 5	Bark

Tigray 1A and 1B are different in color but the same in size. Tigray 1A, 2, and 3 are same in color but different in size. 1A is the biggest and 3 is the smallest. Tigray 4N is bigger in size and darker in color when compared to the 4S. The Tigray 5 is different from other Tigray samples and it is mainly composed of barks. Prior to the process of grading, Tigray 5 is picked out of the collected raw material and set aside for domestic sale. The next step is to separate by color grade 4 (dark-normal and brown-special) from the bulk containing grade 1, 2, and 3. Further, grade 1 is screened as 1A (white) and 1B which is not as white as 1A. The mixture of grades 1, 2, and 3, then, are subjected to separation by using sieves of different mesh size. Those granules that could not go through 6 mm mesh pore are classified as grade 1. The filtrate is again treated with a sieve of 4 mm mesh size; the residue is grade 2 and the powder, which passed through the 4 mm mesh is grade 3. The Borena type is black and it has a sticky property. The size of Borena type frankincense is not uniform. The Ogaden type frankincense has impurities. It has been mixed with stone and dust. It has a brown color. Like the Borena type, the Ogaden type has not been graded and it does not have a uniform size.

Three experiments were designed to find out if the 7 (seven) grades of Tigray types were chemically different and also with the Ogaden and Borena types. The three experiments were TLC, GC-MS, and evaporation durations determinations. A 20 g sample from each type (a total of 10 samples) was ground and soaked with hexane for 24 hours. The extraction was undertaken in an Erlenmeyer flask. From the extract a small amount was taken in a capillary tube and spotted on the TLC plate. The TLC was run with hexane as eluent. The spots were marked using UV with a wavelength of 315 nm (Aman, 2002; Asmare, 2007). The dry sample is directly taken for the GC-MS analysis.

3. Result

Evaporation durations

Evaporation durations were noted using coke (charcoal). The result of the 10 samples is as shown in Table 2.

Table 2. Evaporation duration of different types of frankincense

Type	Evaporation Duration (seconds)
Tigray 1 A	2.00
Tigray 1 B	3.00
Tigray 2	2.00
Tigray 3	2.00
Tigray 4 N	3.00
Tigray 4 S	3.00
Tigray 5	?
Ogaden	1.00
Borena	3.00

TLC

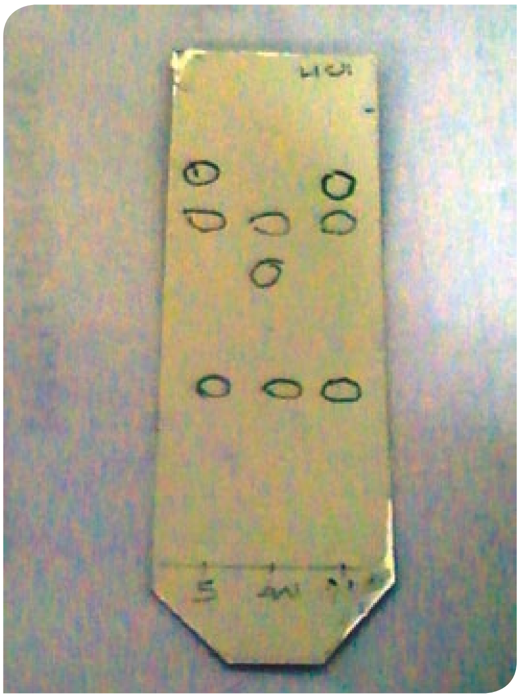
Tigray 1A, 2 and 3 samples showed spots when run with hexane and dichloromethane with a ratio of 1:1 and 1:3.

Tigray 4N, 4S and 1B samples showed three spots with 1:4 dichloromethane and hexane respectively. But 4N and 4S have different spots which run further upfront than Tigray1A, 2 and 3 samples.

From left to right Tigray 4N, 4S and 1B (1:4 dichloromethane and hexane) and the next one Tigray 1A, 4N and 1B (100% hexane)

Tigray 5 sample showed a similar feature as Tigray1A, 2 and 3 samples with hexane.

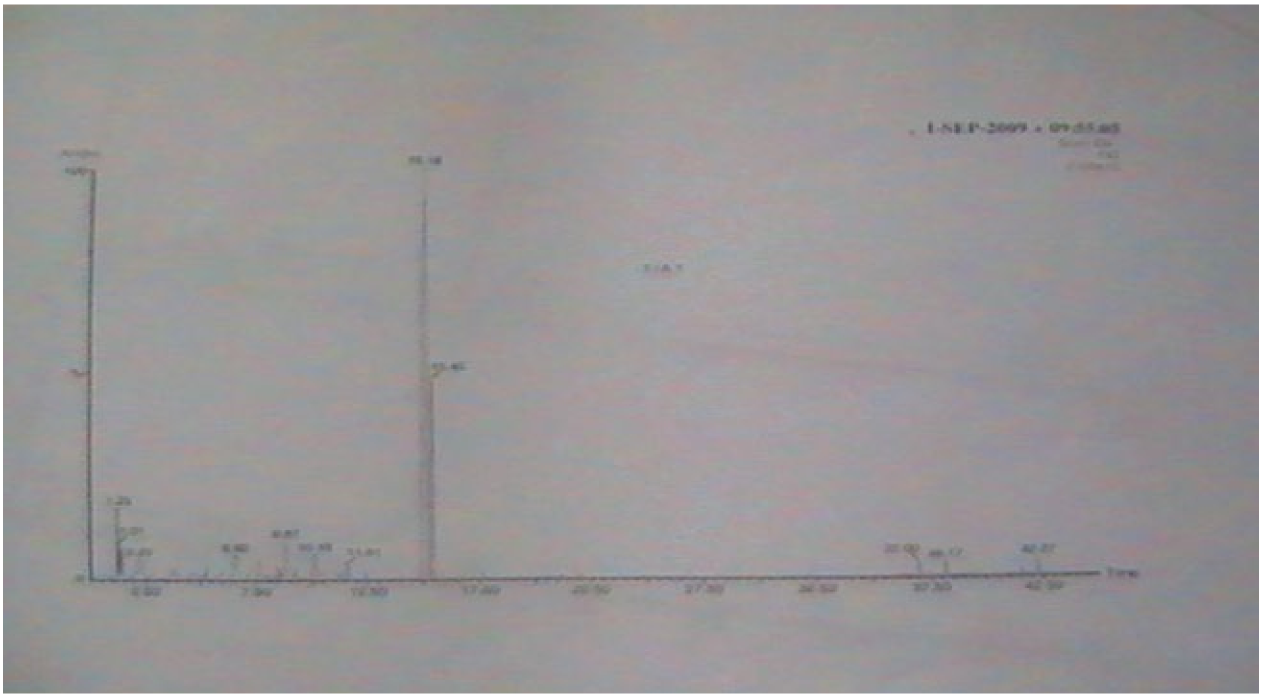


From left to right Tigray 5, 4N and 1A (hexane)

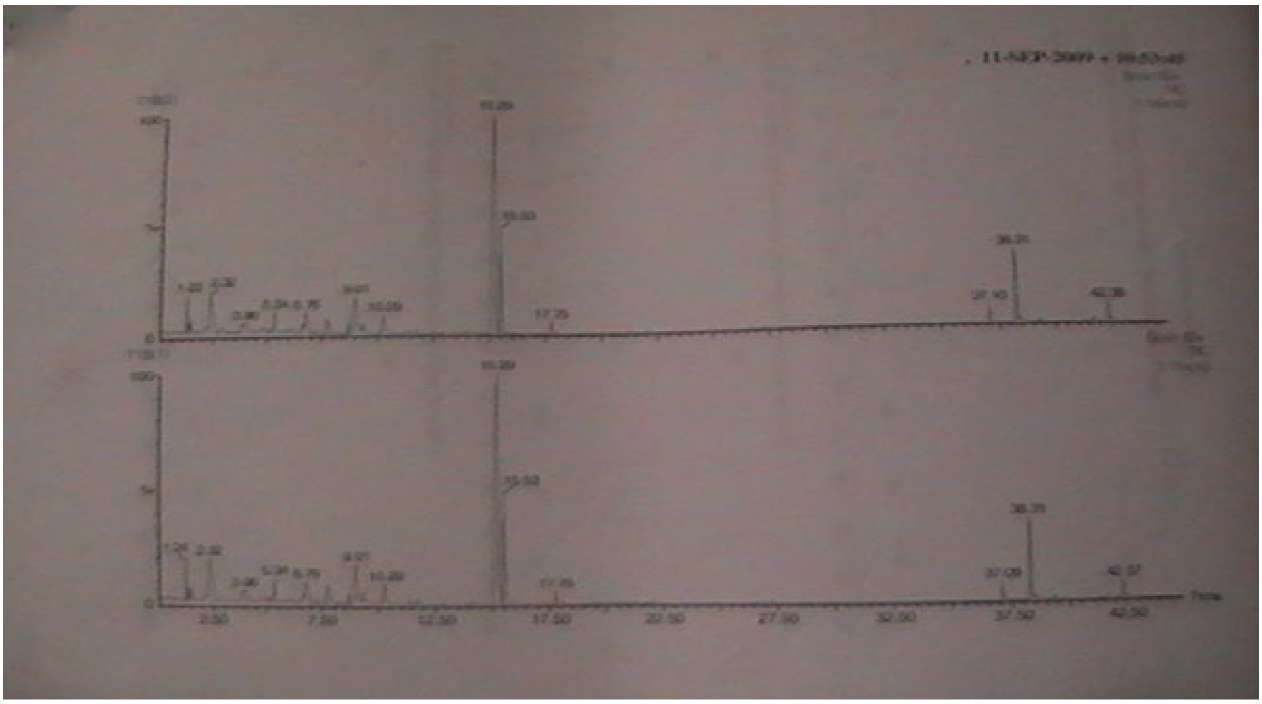
GC-MS

The GC-MS results of all 10 samples are as shown below.

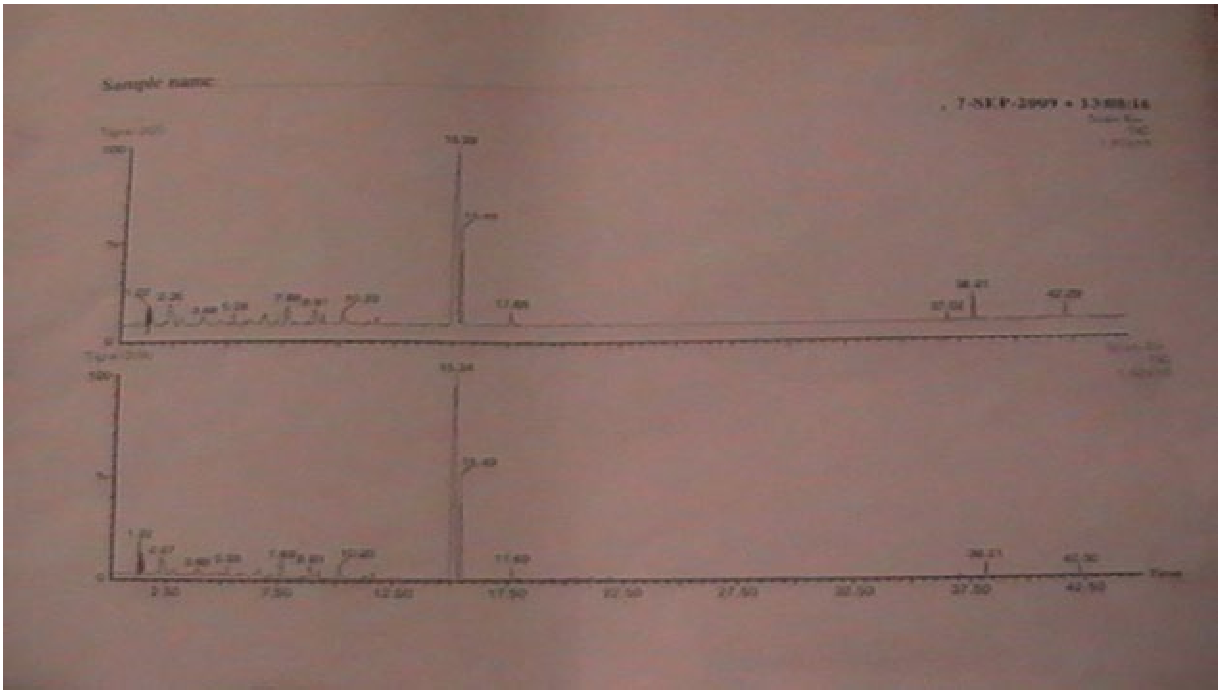
Tigray 1A



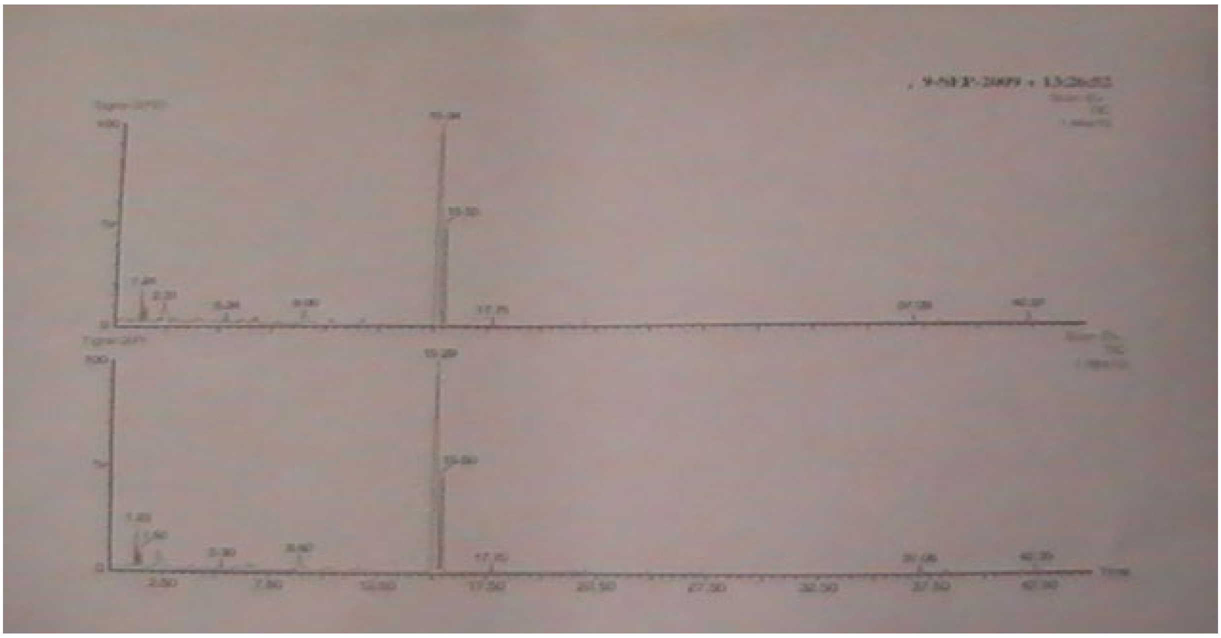
Tigray 1B



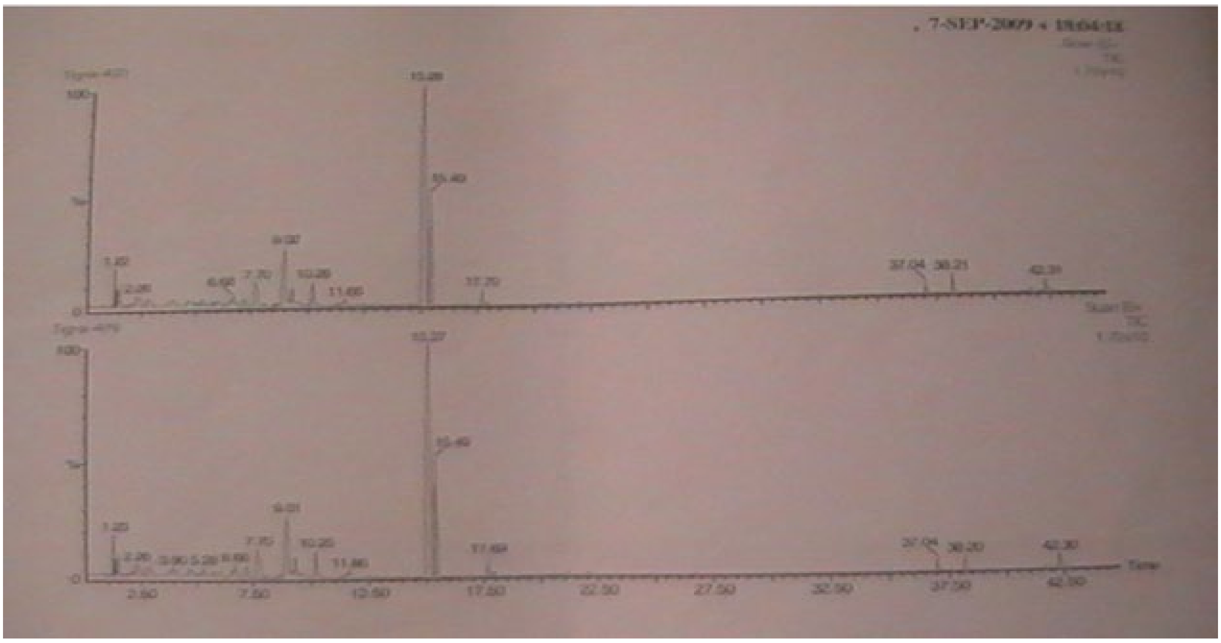
Tigray 2



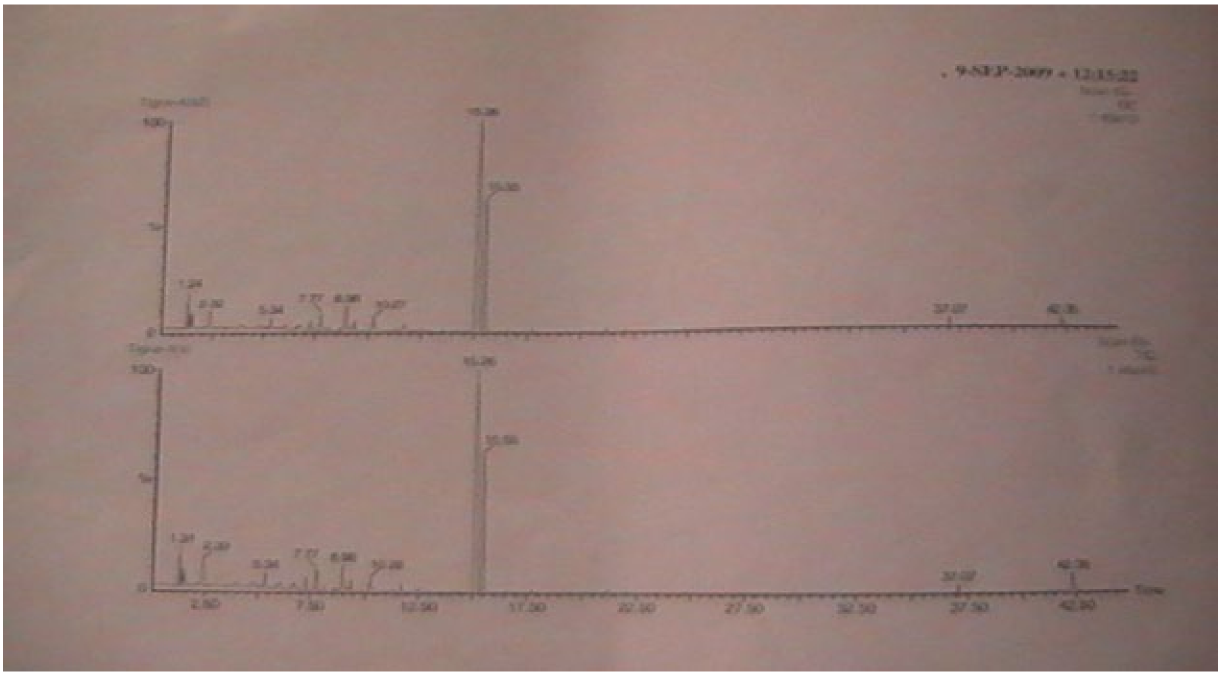
Tigray 3



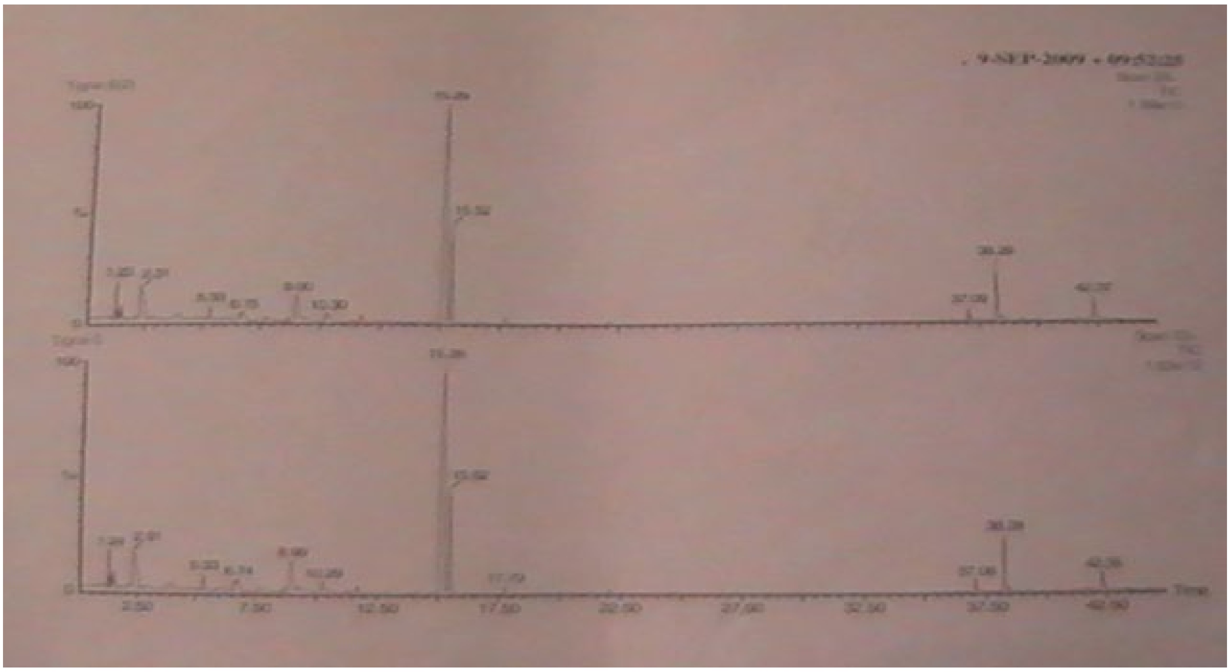
Tigray 4N



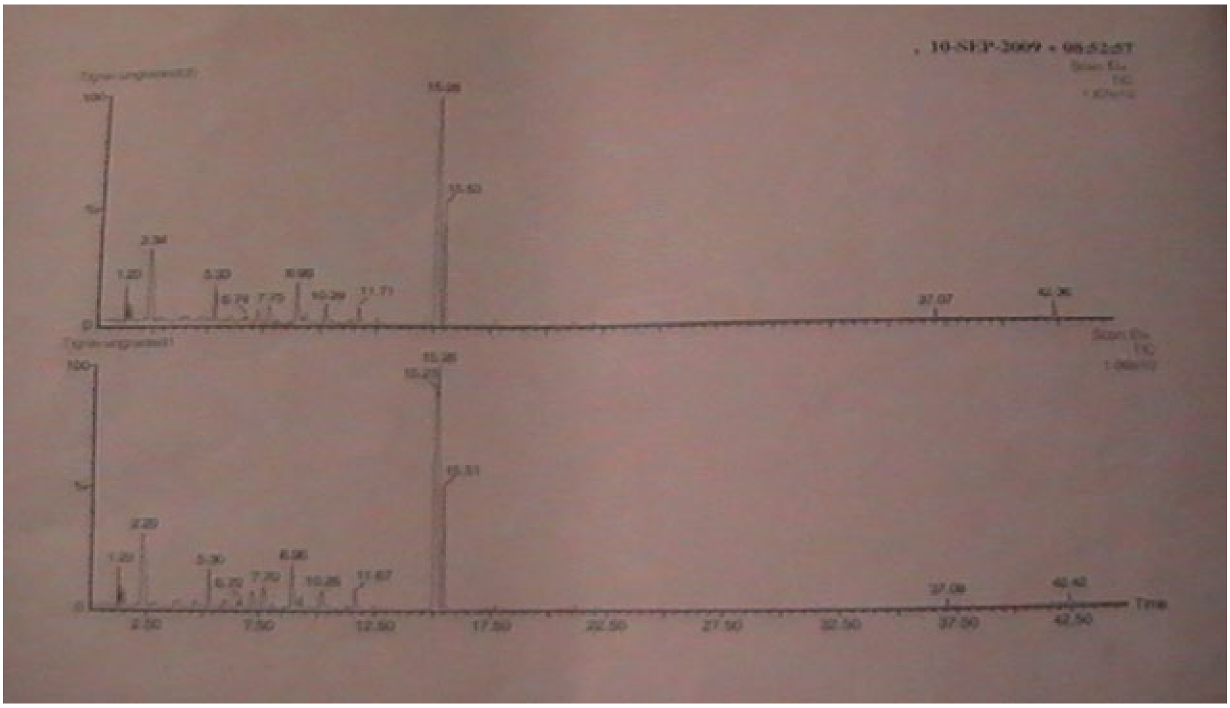
Tigray 4S



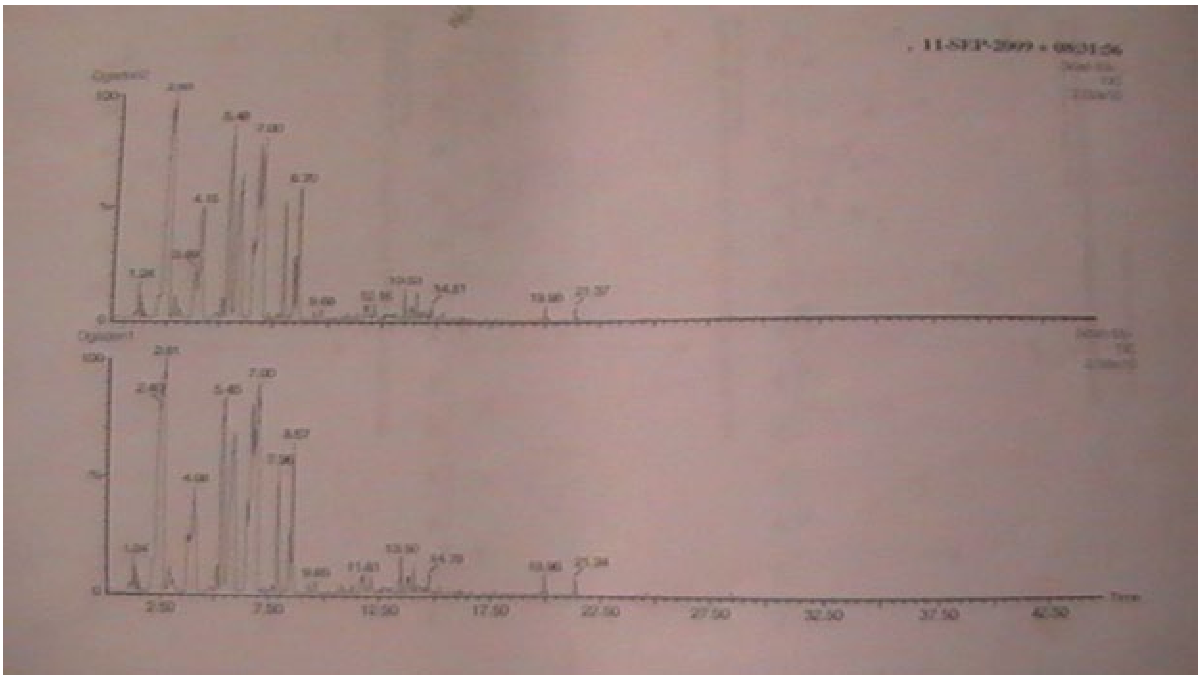
Tigray 5



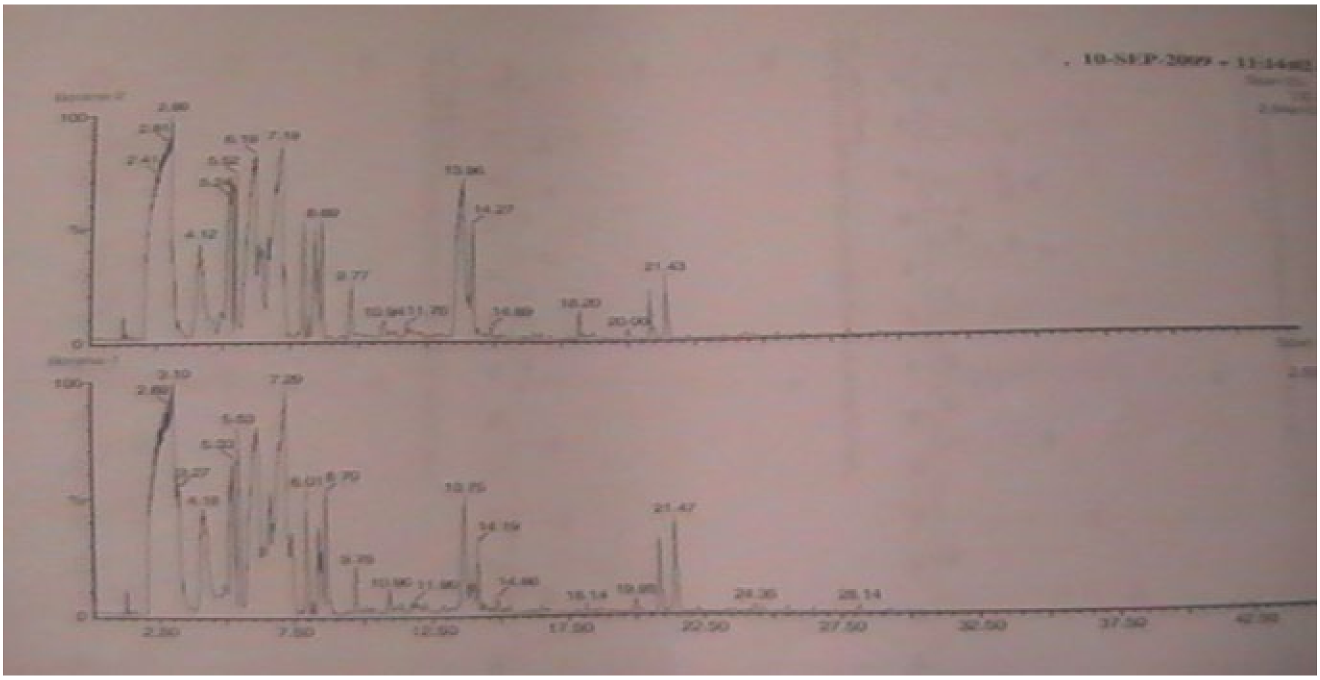
Tigray Ungraded



Borena



Ogaden



4. Discussion

TLC

As the spots on the TLC plates indicated there are similarities and also some differences among Tigray type grades. The first samples, Tigray 1A, 2 and 3, were found to be of the same kind. The 4N and 4S showed many similarities with samples, 1A, 2 and 3 with some differences in RF values. These 4N and 4S samples contain more polar compounds than the other group of samples (1A, 2 and 3). Tigray 1B also is composed of some polar compounds unlike the first three samples although not as significant as the two Tigray 4 types. The Tigray 5 (the bark) has similar spots as Tigray 1A, 2 and 3 samples. The TLC experiment more or less proved, in terms of physico-chemical preliminary work, that Tigray 5 has got very similar compounds as those of the first three, taken so far by many as quality export items.

GC-MS

The GC-MS data gave information that the compound with the highest percentage from Tigray type is octylacetate. This substance was found in similar proportion in all grades. There are also other compounds displayed on the spectra with percentages less than octylacetate but in similar significance in all the samples. The major probable molecules are the following.

The first compound which was observed with an average RT value of 1.23 min for all samples is alpha Pinene. Alpha-Pinene is a monoterpene, which may be the significant factor in affecting bacterial activities in nature and gives off a piney smelling odor. Terpenes are widely used as flavorings, deodorants, and medicines (as in the treatment of acne). The second compound with an average RT value of 6.7 is eucalyptol, which is a six member ring and is ether. Eucalyptol is a flavoring substance which can be used provisionally in foodstuffs. The third one has an average RT value of 7.73 which is called beta-cis-ocimen. It is a straight chain compound with a double bond. The fourth, with an average RT value of 9.00, is 1-octanol. The primary use of octanol is in the manufacture of various esters (both synthetic and naturally occurring). The fifth compound is beta-linalol. This compound has average RT value of 10.29. Beta -linalol is a straight chain and is an alcohol derivative. The sixth compound is the highest in percentage of *B.papyrifera* species. It has an average RT value of 15.29. It is called n-octylacetate and is a straight chain ester. This compound is also observed with an RT value of 15.53. Octylacetate is used in perfumery and flavors industry. The seventh compound is 1-bornyl acetate, which has an average RT value of 17.75. It is an ester and also has six member rings. The eighth one has an average RT value of 37.05. This compound is called verticol and also shows a pick with an average RT value of 38.31. The last compound observed is 4, 8, 13-duvatriene-1, 3-diol with an average RT value of 42.35.

The GC-MS results to Ogaden and Borena are different from Tigray samples. There were more broad picks shown in the Ogaden and Borena spectra. The other distinctive point about these samples is the compound with the highest composition is non-polar unlike the Tigray samples that has a polar compound available in high proportion.

The TLC data on the first three samples, Tigray 1A, 2 and 3, which have the same color but are different in size, gave same spots. The GC-MS data also proved again that these three samples do not have so much different picks' profile. One could confidently say that they all have similar compounds with slightly varying compositions. Chemically speaking, significance differences do not correspond to differences in identity. Tigray 1B with a different color from 1A, 2, and 3 showed almost similar spots on TLC plates. The GC-MS spectra of it indicated that it has similar compounds as the three samples but with better compositions' feature. Predominantly the difference in composition shown is in containing octanol which is industrially used to manufacture esters that have applications in perfume and other industries. The other two samples Tigray 4 normal and 4 special have one different spot when compared to the other four samples. This spot goes a distance on the chromatogram when it was eluted in a fairly polar solvent. Hence, this substance, which appeared at different spot is probably a polar compound. The GC-MS spectra helped to show that these two samples (4N and

4S) are more or less the same with the other four samples which are traditionally believed to have been quality samples and therefore quoted for higher prices. The Tigray 4 samples not only are the same with others but also have better compositions profile. The Tigray 5 type is the one which was not exported for industrial or medicinal applications. But as seen with the TLC and GC-MS spectra it also has similar compound compositions with the first three top graded samples with pseudo high values.

5. Conclusion

This preliminary physico-chemical study indicated profoundly that the Tigray type, the Ogaden type and the Borena type are distinctly different from each other. And this may mean as far as such that the plants growing at these three varying regions could also be biochemically different and genetically variant. The experimental data suggest that grading of frankincense of the Tigray type, if at all should be done in the future, and can be done in such a way that the raw material collected from the production area shall be separated in to only two grades. Grade A color samples, which contain polar substances in them and Grade B non-color with bark samples which are significantly composed of non-polar compounds.

6. Recommendation

Results of this preliminary physico-chemical experiment recommend that the age old practice observed at Nazareth frankincense processing and grading big store- banks needs to be revisited. The issue of frankincense export samples harvested from same area, for example the Tigray type, enabling us to separate them by color is found to be very interesting to analytical chemists. Separating them by color is leading to chemical distinction as well, in the sense that those products with dark or brown color contained much more polar compounds when compared to other products, which are white or with yellow barks that are markedly composed of non-polar substances. This observation motivates one to take up the study further until knowledge regarding, what could cause variation in color and thereby bringing forth chemical composition distinctions is clearly identified. This shall bring up to surface multidimensional benefits and beneficiaries (producer, exporter, importer, scientific community, and other stakeholders).

Acknowledgements

This work is the brain child of Dr. Habtemariam Kassa of the Center for International Forestry Research, CIFOR. The study was recommended by the National Working and Advisory Group that advises Dry Forest Project research activities in Ethiopia in December 2008. Both Habtemariam and the Group remain credited wherever and whenever the results obtained through this work found their due applications. Dr. Mesfin Redi of the Chemistry Department, Science Faculty of Addis Ababa University and Dr. Aman Dekebo of Ambo University are highly recognized in this work for their scientific and authoritative input they willingly contributed. They were very kind in facilitating the laboratory works at Addis Ababa and Ambo. Our future works on frankincense, if any, would run into serious drawbacks if these scientists are not taking part actively.

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WHAT THE FUTURE HOLDS FOR FORESTRY DEVELOPMENT IN ETHIOPIA? FORESIGHT THROUGH SCENARIOS CONSTRUCTION

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Abstract

Complex changes in socio-political, demographic, economic and environmental factors are affecting the way forests are used and managed in Ethiopia. The fast changing political economy makes the future of the forestry sector uncertain. This paper outlines possible development pathways of the forestry sector over the coming 30 years through scenarios construction. A questionnaire survey followed by a stakeholder workshop was employed to construct the scenarios. Over sixty different factors affecting forestry development were enumerated, among which economic development policy and political governance were selected as the two most influential and uncertain forces to shape the future of the forestry sector development. Based on how these two factors will likely evolve in the future four alternative scenarios emerged. These are (i) Miserable Forestry: a scenario that foresees the continuation of the present natural forest degradation and low regeneration with the consequent result in further marginalization of the sector that occurs under the condition of agriculture dominated economy and centrally controlled decision making; (ii) Forestry in Transition: a scenario that will evolve under increasing market deregulation that encourages increasing but restrict involvement of private sector in forest resources and industries development even though the natural forests will suffer continued degradation due to states' controlled central management and ownership; (iii) Economic Forestry: describes a situation where both private sector involvement in forest resources and industries develop due to market deregulation side by side with increasing sustainable and devolved management of natural forests through community participation and transfer of forest ownership as the result of political governance; and (iv) Farm/Social Forestry: scenario describes a forestry development likely to emerge under the combined pressure from population growth and agriculture dominated political economy, but with improving land and tree tenure security. Local community will continue farming their small plots of land sharing between crop, grazing land and woodlots. Natural forest will continue degrading due to conversion to cropland while the role of community and private family woodlots and other forms of tree farming predominate in forest products supply. We believe that the scenarios may help decision makers to imagine and consider how the different political and development pathway taken will affect the forestry sector and thereby its ecological and economic roles.

Key words: *Agriculture, economic development, deforestation, forest development, land policy, population growth, urbanization*

1. Introduction

Ethiopia owns a total of 59.7 million ha of vegetation resources among which 6.8% is forest, 49% woodlands and 44.2% shrublands (WBISPP, 2004). Ethiopia's remaining vegetation resources thus largely consist of woodlands and shrubslands, while most of the high forests have shrunk in size as well as in quality (Teketay *et al.,* 2010). Being a nation dominated by a rural population, the traditional uses of and dependence on vegetation resources for a large variety of products and services is high in Ethiopia. Energy in the form of fuelwood is one of the most significant contributions of the vegetation resources supplying 75% of the total national energy consumption (Lemenih, 2008). More importantly, the vegetation ecosystems have been servicing as rangelands and were used to provide productive croplands for the broad agrarian community. They are also sources of diverse non-wood forest products (NWFPs) used to provide subsistence or additional source of household cash income (Lemenih, 2008; Teketay *et al.*, 2010). Some of the NWFPs are largely exported to generate foreign currency and support the national economy.

The forestry sector in Ethiopia has been in the process of significant transformation. Although deforestation in the country is an on-going process for millennia (Brietenbah, 1963; Bekele, 1992, 2003; Pankhurst 1995; Wøien, 1995; Ritler, 1997; McCann, 1995, 1999; Darbyshire et al. 2003; Nyssen *et al*., 2004, 2009), recent decades have seen a significant intensification (e.g. WBISPP, 2004; FAO, 2007; Lemenih *et al*., 2008; Teketay *et al.,* 2010). Continuous forest landscapes are disappearing and being replaced by mosaics of fragmented landscapes predominated by croplands and eucalyptus woodlots. Vegetation degradation has long been recognized as the root cause for most of the environmental problems besetting the Ethiopian landscape such as high soil erosion, water resources degradation, and loss of land productivity (EFAP, 1994; Anonymous 1997; Lemenih, 2004; Lemenih *et al.,* 2008; Rahmato, 2008). However, development policies and practices in the country for a long time have overlooked the direct interdependence between forestry, environment, agriculture, economic development and societal wellbeing.

Drivers of forestry landscape change in Ethiopia are multiple and intertwined involving both short-term and long term factors and processes. Population growth, economic development (poverty), agricultural expansions, environmental problems (such as climate change and land degradation), and government programs like resettlement are some of the prominent underlying factors. Coupled with government policies, strategies, programs and institutional arrangements that largely neglect the forestry sector, these factors are resulting in significant vegetation landscape transformation. In short, what is happening to the forestry sector in Ethiopia is determined by developments made in other sectors and in the dynamics of the political economy of the country rather than in the shortfalls in the forestry policies. Moreover, Ethiopia is a country of instable social, economic and political systems (Assefa, 2008). This makes the various factors driving the forestry sector changes to vary dynamically in space and time (Bekele, 2008). The future development path of the sector thus is highly uncertain and a simple projection of the present and the past hardly will reflect the reality in the future. However, the identification and analyses of the development of the drivers of forestry landscape change into the future is of considerable interest in policy making processes as well as in designing appropriate forestry development interventions. One of the best ways to capture and analyze the future developments of the change drivers and their likely or possible impacts on the forestry sector development is by way of scenarios construction.

Scenarios are defined as plausible (believable), consistent and relevant sets of stories about how the future unfolds (Wack, 1985; van der Heijden, 1996; Ogilvy and Schwartz, 1998). They integrate various issues and dimensions to provide integrated outlook of the future and usually portray alternative evolutions of the futures describing sequence of events on probable events (what will happen?) or possible events (what can happen?) or what is preferable to happen. Indeed, they address real world questions of systems dynamics: policy choices, technology evolution, consumption and production patterns, market forces, environmental developments, demographic forces and the like. Their purposes are to widen the perceptions of future options in society and are often employed as a tool for development and assessment of strategies and optimize policy frameworks for best outcome or decision support (Ogilvy and Schwartz, 1998; Westhoek *et al., 2006*). The objective of this paper is, therefore, to assess and foresee forestry development in Ethiopia during the coming 30 years (up to 2040) through construction of future scenarios.

2. Overview of the Forestry Sector in Ethiopia: Past & Present

2.1 Forest management and development

Forests in Ethiopia are generally mined rather than managed for sustainable use. Except for some fragmentary management and development initiatives, most of which are donor supported, there existed no coherent national forest management plan and successful development practices in the history of Ethiopia. The decentralization of political administration during the last two decades also contributed to the lack of national level forestry development programs. As a result different regions are adopting different strategies and actions which result in large inter-regional differences in forest conservation and development out-comes. While good developments are ongoing in Tigray, partly in Amhara and Oromia with respect to forest development, other regional states are showing little forestry development activities so far. Each year millions of seedlings are reported to have been planted, while little landscape change is observed in term of forest cover. Even then, with these new forests coming back (e.g., in area exclosures in Tigray), old growth natural forests continue to shrink at faster rate and greater magnitude showing that the efforts claimed are far short to compensate the destruction (Bekele, 2003; Teketay *et al*., 2010). This also shows that if there is an intension to improve the forestry sector of the country and forest resources of the country it won't be with the 'business as usual'- but by critically learning from past experiences, questioning our so far efforts and its successes and constructing strategies, programs and policies as well as institutional environments that allow long term and progressive successes.

Among the few but important attempts made to improve forest management in the country is the introduction of Participatory Forest Management (PFM) by several Non-Governmental Organizations (NGOs). In Ethiopia forest resources, like all land, belongs to the State. The introduction of PFM assumed that the state ownership of forests have degraded the sense of ownership among the local people resulting in *de facto* open access. The main goal of all PFM programs was, therefore, to develop the sense of ownership of forests among locals through legal transfer of use right and introducing management obligation. Despite the apparent successes with PFM at experimental level (Gobeze *et al.,* 2009), the government still failed to mainstream the approach in the broader forest management system of the country. Thus, the approach is suffering lack of support for up-scaling, and appears almost to begin fading away by now.

Interesting changes in the forestry development of the country comes from the contribution made by smallholder farmers through small scale tree planting and their traditional agroforestry systems (Mekonnen et al., 2007; Tolera *et al.,* 2008; Jenbere, 2009; Asfaw and Lemenih, 2010). Smallholder farmers in Ethiopia now own many more farm forests than in the past and this is proliferating in many parts of the country. WBISPP (1995) estimate that there are 51 million on-farm trees in Ethiopia, while Teketay *et al.* (2010) estimated the same to be about 142 million. This can equate to 51,000-57,000 ha of production plantation forest estate. These planted trees are playing paramount role in wood products supply in Ethiopia as well as in reducing pressure on the remnant natural forest covers (Mekonnen *et al.,* 2007). The traditional agroforestry practices of the country are also contributing somehow to the conservation of but limited floral biodiversity (Tolera *et al.,* 2008; Asfaw and Lemenih, 2010).

Wood demands and supplies are increasing in Ethiopia driven by increasing population size as well as growing economy. This is not only fueling large illegal harvest but forces the country to import a large wood product. Data obtained from Ethiopian custom authority shows that forest product related import in recent years has reached over 400 Million Birr (≈ 45 Million USD) per annum (Ewnetu and Kelemework, unpublished).

2.2 Forestry sector institutional arrangements

The forestry sector in Ethiopia has shown improvement with respect to policies and legislations over the years. For long policies related to forest resources management in Ethiopia were vague, and can only be inferred from various related legal instruments such as institutional mandates or other bodies of legislation. Since 1994 a new forest law was installed with the Proclamation No. 94/1994, and a further forest policy was issued in 2007 with the accompanying proclamation number 542/2007, which is the first, ever, refined forestry policy in Ethiopia. In fact, there are a number of other policy instruments that apparently support forest development and conservation in Ethiopia. Among these policy instruments the Conservation Strategy of Ethiopia (CSE, 1997), the Environmental Policy of Ethiopia (1997), and the Rural Land Administration and Land Use Plan, Policy & Strategy (2004) can be identified. All of these policies and strategies support not only the conservation and management of the existing forests but also restoration of degraded forests and development of new forests through active participation of communities and private sector. Unfortunately, most of these policies and strategies remained statements of intents, suffering lack of implementation (Bekele, 2008). There is no clarity on who is responsible vis-à-vis organizationally for operationalization of most of these policies.

Organizationally, the forestry sector in Ethiopia remains the most unstable with low to very low budgetary and logistic support (Bekele, 2008; Mengesha, 2008; Yemishaw *et al.,* 2008). All policies related to forestry and environment lack strong and capacitated implementing bodies or organizations. Those organizations supposed to do so (such as the Ministry of Agriculture -MoA) are also unstable on the one hand and burdened by a number of competing institutional mandates on the other. Within the MoA, the forestry section is always the most understaffed with marginal budget and logistic allocations (Yemishaw, 2002; Mengesah, 2008).

The decentralization of forestry administration and management has further complicated the institutional setup in the sector with different regions pursuing different strategies. Additionally, human capacity varies between regions, and both resulted in significant regional differentiation in on-the-ground actions and achievements. Particularly, in most regional states with large remnant forest areas, forests and woodlands are subject to continuous degradation as a result of weak or absence of forestry supporting institutions.

The weakness in institutional arrangement is clearly reflected in the continued loss of forests/ vegetation ecosystems to croplands and other land uses as evidenced by several local-scale studies. For instance, Tadesse (2007) investigated forest cover change in selected four districts in the southwestern rainforest area for the period between 1973 and 2005, and found 67% (≈2.1% per year) forest cover decline during the 32 years period. Dessie and Kleman (2007) revealed 80% (≈4.4% per year) forest cover decline between 1972 and 2000 in the Awassa watershed, which is comparable to the 4.3% per year decline reported by Seifu (1998) for the Munessa-Shashamane forest. Getaneh (2008) reported a forest decline rate of 1.3% annually for Yayu forest in the southwest. In southern Wollo, Kebrom and Hedlund (2000) reported 3% and 14% forest and shrubland cover decline between 1958 and 1986. Near Ambo, bush and woodlands decreased from 42% to 33% between 1957 and 1994 (van Muysen *et al.,* 1998), while Zeleke and Hurni (2001) reported a 27% natural forest cover disappearance in parts of Gojam between 1957 and 2000. The report by Reusing

(1998) shows annual rates of agricultural clearings for three Regional States to be 1.16% per year in Oromiya, 2.35% in SNNPRS and 1.28% in Gambella. WBISPP (2004) also analyzed deforestation rates in districts where there are high natural forests, and predicted the loss of 1.33 million hectares of natural forests in Ethiopia between 1990 and 2020. This loss accounts for about 1% annual declines of the forest resources in the country. Similarly, Reusing (1998) indicated a deforestation rate of 163,600 ha per year between 1986 and 1990 (1% per year), and the report of FAO (2005) also indicates the deforestation rate of 0.93 – 1.04% per year between 1990- 2005. By combining these different studies it can be shown that Ethiopia is losing an average of 1.0 – 1.5% of its forests annual to deforestation.

3. Research Methodology

Scenarios can be told in words (qualitative scenarios) or numbers (quantitative scenarios) or both. In fact, traditional scenario analysis is largely based on quantitative variables like population growth rates, income changes and the like. In the context of rapidly evolving societies, especially those undergoing major political and institutional changes, scenario analyses based on a limited number of quantitative variables have significant limitations in indicating the likely changes in the future (Anonymous, 2003). Under such relatively fast changing conditions, scenarios can purely be defined qualitatively (Gallopin *et al.,* 1997; Anonymous, 2003).

This study selected qualitative scenario construction method. Qualitative scenario construction involves the identification and analysis of key factors that drive changes in the subject or object in question, which in our case is the forestry sector in Ethiopia. After the drivers of forest related land use/land cover changes and the development of the entire forestry sector are identified, they are further analyzed and categorized into a 2 x 2 table with strong and weak in the column and predictable & unpredictable factors in the row. Of those drivers listed as strong and uncertain (unpredictable) selection will be made of the two most influential again. These are then drawn on scenario axis (x-y axes) giving each factor a value load of contrasting uncertainty at the end of the axis (e.g., low and high, small and big, optimistic and pessimistic), which then defines possibly four different scenarios, one scenario for each quadrant of the x-y axes (van der Heijden, 1996; Ogilvy and Schwartz, 1998).

In this study data were collected in a two step process. First a questionnaire survey was held, and thereafter a stakeholder workshop for interactive and participatory scenario development was developed. The questionnaire based survey was conducted on 40 experts selected form various organizations (Governmental Organizations -GO and non governmental organization NGO). This process seeks the personal and professional opinions of those experts, on individual basis, regarding major aspects of the forestry sector: the past, the present and the future. For this a structured questionnaire was prepared, pre–tested and then sent to an identified variety of stakeholders via e-mail. The questionnaire was filled and returned to the researchers. After the questionnaire survey was completed and preliminarily analyzed, a stakeholder workshop was held. All selected experts, plus a number of others, were invited to participate in the workshop. Participants covered a wide range of stakeholders. Before the workshop, the questionnaire survey results were partially summarized, and lists of all drivers of forestry landscape change that were mentioned by respondents were constructed. These lists of drivers were presented during the workshop, along with selected topics of forestry landscape change. The workshop also involved a half day training on scenario science to stimulate the participants for the work ahead and also assist them with some introductory knowledge of the entire process.

Following the presentation of the lists of drivers and scenario introductory training, the participants were grouped into three task-forces. Each group was given the same group work task – constructing scenarios for the future of the forestry sector in Ethiopia. The purpose of dividing the participants into three groups but with the same kind of group work assignment was (i) to create more interactive discussion by forming smaller groups rather than dealing with one big group, and (ii) to also catch and obtain a wider range of variations in opinion and scenarios constructed. The three groups had mentors and secretaries. They also worked on the scenario development process in a stepwise approach using three separate sections. During the first round of group work the list of drivers was refined and clustered into related groups. In a second round group work the two most uncertain factors but with strong influence on future forestry sector development were identified, and alternative future scenarios were constructed. Finally, during the third round group work storylines for each of the scenarios were written.

After the driving forces of the forestry sector were refined and agreed upon on the workshop, the research team made a thorough treatment of the driving forces by assessing a variety of scientific and statistical literature. The literature reviews provided a strong background on the action-reaction chains between the driving forces and the forestry sector in the past, present and including their probable or possible effect in the future.

4. Results

4.1 Factors affecting the forestry sector

The results of the questionnaire survey and stakeholder workshop revealed that the current forestry situation in the country is dire, and the sector in general is characterized by negative trends. At aggregate national level Ethiopia is losing large forest cover, and the country is doing little to reverse it. Forest conservation and development efforts are generally insufficient in most part of the country, particularly in forested regions. Most of the available efforts, although still limited, are concentrating in regions with the least forest cover like Tigray and Amhara. The survey and the workshop also showed that a number of apparently conducive platforms are emerging in Ethiopia, which if properly utilized can contribute to positive development of the sector. These developments include the decentralization of political and natural resources administration, the issuance of forestry and related environmental policies and the economic policy that encourages the private sector.

In general, the questionnaire survey yielded over sixty forestry sector change drivers (i.e., factors that negatively or positively affect the sector), which were refined, amended and completed during the workshop. At the workshop the change drivers were clustered under four sub-categories namely: (i) political (policy) and institutional issues; (ii) population related factors, (iii) factors related to the economy and (iv) environmental factors (Table 1).

Table 1. Factors identified as affecting the forestry sector development in Ethiopia past, present and also in the future.

A. Policy and institutional issues	
1	Political changes and the subsequent reforms in the country
2	Government economic development policy and priorities (Macro-economic policy)
3	Land and tree tenure (land policy)
4	Land use planning and implementation policies and actions
5	Growing role of civil society
6	Civil wars and conflicts
7	Organizational setup including law enforcement
8	Forest policy
9	Budget and logistic support
10	Role of traditional institutions
11	Changing cultural landscape due to political interferences
12	NGOs and civil society roles
13	Corruption

14	Institutional instability of forestry sector
15	Poor support to research and education, thus poor capacity
16	Awareness problem
B. Population issues	
1	Population growth
2	Migration (resettlement, urban –rural distribution)
3	Refugees and internally displaced people
4	Education
5	Employment and sources of income
6	Impact of HIV/AIDS
7	Resettlement and its effects on forests and forestry
8	Alternative livelihoods and employment
9	Fire
10	Culture and religion
C. Economic issues	
1	Income and poverty
2	Land dependence/agriculture as economic base, i.e., Ethiopia remains an agriculture based economy
3	Prospect for structural shift
4	The overall state of technology (productivity)
5	Global economic crises
6	Prices of food and energy
7	Private sector involvement
8	Infrastructure development and emergence of urban centers
9	Economic contribution of the sector
10	Increasing dependence on biomass energy
11	Increasing prices of inputs (seed and fertilizer)
12	Increasing energy prices
13	Energy price increase demands biofuel development
14	Market regulation
D. Environmental issues	
1	Climate change
2	Desertification
3	Impact of environmental concern on forestry
4	Drought
5	Conservation orientation
6	Soil/land degradation
7	Emerging global opportunities such as carbon trade
8	Bush encroachment
9	Fire and habitat fragmentation
10	Poor regeneration
11	Soil nutrient loss constraining sustainability of the agricultural practices
12	And in turn challenging future food production
13	Biofuel development, wood land conversion

4.2 Assessing the actual and potential impacts of the change drivers on the sector

After the drivers of forestry sector in Ethiopia were refined and clustered, literature was reviewed, and spatial and time series data were analyzed to strengthen understanding about key processes, interactions, and their impacts on the forest resources and the sector as a whole from past to present and assess their possible continued development into the future. Obviously the driving factors are multiple, interlinked and complex (as shown in Table 1). These factors span a wide range of disciplines and sectors and cover areas such as politics, economics, social and environmental issues as captured in the following sections.

4.2.1 Policies and institutional issues

Ethiopia is one of the countries characterized by decades of instable political environment. The country was perplexed by long years of civil war and unpopular political administrations. The last half a century has hosted three ideologically distinct political administrations, each with distinct natural resource management arrangements and overall socio-economic settings. These are the Feudal regime of the imperial time (before 1974), the Socialist Derg (1974-1991) and the Revolutionary Democracy of the current government (since 1991). Each new system works to negate the preceding one, making policies and laws, in some cases, in sharp contrast to the old ones (Bekele, 2008). Such instability in political administration, combined with the years of civil war never allowed successful and sustainable management of the natural resources in the country, because institutions were frequently destabilized jeopardizing continuity of programs and implementation of plans. Political, policy and institutional instability always have overwhelming direct and indirect impacts on the forestry sector and this account as well for management of other natural resources in Ethiopia.

At the heart of Ethiopia's political economy is, since long, agriculture. For instance, in 1950 the Imperial regime's economic program emphasized the expansion of agriculture for domestic consumption as well as export, and forests were generously allocated to individuals wanting to convert to croplands (Bekele, 2008). Agriculture is, therefore, the pre-occupation of the Ethiopian economic policy for over half a century. Particularly, since the early 1990s, the country's long term economic development strategy was coined as Agriculture Development Led Industrialization (ADLI). All other policies, strategies and programs of the country, whether federal or regional, are derivatives of the ADLI strategy. The central assumption of the ADLI policy or strategy is that the country's overall development is to be agriculture and rural centered, while the basis for the rural sector is to be agriculture led development (Rahmato, 2008). Overall, the strategy assumes that agriculture, particularly crop production, should be the starting point for initiating structural transformation of the economy including industrialization, and small holder farmers constitute the cornerstone (MOPED, 1993). Within agriculture, the strategy provides a heavy bias towards crop production and small holder farmers, and little attention has been given to other components (Rahmato, 2008) including forestry (Bekele, 2008).

As both agriculture and forestry are land based, the latter even land extensive, there has been severe competition between the two for millennia. The magnitude of this competition has grown to the highest in recent decades due to many factors, one of the most important being the economic development policy, which is purely agriculture biased. Given its popular participation and government priority in support, the way agriculture develops, extensive or intensive, determines whether it can give space for forestry. Unfortunately agriculture in Ethiopia grows through extensification (area growth) rather than intensification (Lemenih *et al.,* 2008; Eberhardt, 2008). Data collected from the Central Statistical Authority (CSA) for the period between 1980 to 2006 shows that croplands in Ethiopia increased at least by 80% from 4.38 million ha in 1980 to 8.08 million ha in 2006, while productivity per unit area on average has almost stagnated (Eberhardt, 2008). The data shows that agriculture in Ethiopia is still land extensive and spreading into vegetated ecosystems. Most of the workshop participants also agree that this trend will continue for decades to come (see section 4.2.3).

Given the dominance of agriculture in employment and subsistence, access to land is an important issue for the majority of Ethiopian. The way land is owned or accessed is believed to affect how the landscape is shaped in many ways, although the subject of land tenure arrangement and its relation to production efficiency is a controversial area (Kebret, 2000). Important effects of land tenure arrangement are on people's migration between urban and rural settings, willingness to invest in land management and on involvement of private sector in production of agriculture and forestry (Alemu, 1999; Rahmato, 1999; Alemu, 2000; Haile and Mansberger; 2003; Deininger *et al.*, 2003). Land tenure is, therefore, one of the central policy and political issues in Ethiopia (Alemu, 2000; Kebret, 2000). It has been argued over and over again that land is not only an economic but also a political tool in Ethiopia (Deininger *et al.*, 2003; Rahmato, 2008). One of the major political issues that led to the defeat of the imperial regime in the early 1970s was the question of land ownership. The Derg brought an end to private land holding in Ethiopia. This policy change was a significant reform that changed both land ownership and the administration of its distribution. For the last 40 years or so land has been public (state) property, while individual farmers have unguaranteed use right.

The public ownership of land is reportedly shown to deter agricultural intensification, restrict people's mobility (migration) and constrain advancement in agricultural productivity (e.g., Kebret, 2000; Devereux and Guenther, 2007; Rahmato, 2008). This has been remarked by several bodies including the United Nations Economic Commission for Africa (UNECA), which in 2002 stated that land tenure, along with the issue of governance, were "the most pressing areas requiring institutional reforms in Ethiopia". Kebret (2000) also indicated that food insecurity and low agricultural performance in Ethiopia is not attributed to shortage of arable land, but is most likely the result of the inappropriate agrarian policy (one of it being land tenure) and low rate of resource utilization. Devereux and Guenther (2007) argued that inflexibility around land tenure arrangements has constructed a 'poverty trap' rather than a 'safety net' for small farmers in Ethiopia. Pro-poor land redistribution can boost agricultural productivity and raise the income of households that received land (Eastwood *et al.*, 2004). However, empirical studies on 'asset thresholds' reveal that households with inadequate access to key productive assets, such as landholdings that are too small, often fall short of getting their way out of poverty. Even worse, where livelihoods are subject to recurrent shocks, such as the droughts in Ethiopia, 'asset poverty' will be perpetuated as households repeatedly sell non-land assets for food, becoming chronically dependent on emergency relief for their survival (Carter and Barrett, 2007).

There are many dimensions by which the effects of current land tenure in Ethiopia are expressed. One of the most important effect is through discouraging migration (long term migration) because the policy prohibits selling or leaving land unfarmed e.g., for three consecutive years or staying physically away from it. Doing any of the above will risk losing the land. These problems in the land policy in effect resulted in rural overcrowding, low urbanization, land fragmentation, and ultimately diminution of holdings per capita due to intra-family redistribution. Rural confinement means each generation of farmers have to inherit lands which is smaller than before due to intra-family land re-distribution (Admassie, 2000; Rahmato, 2008), or pressing hard into the natural ecosystems for more croplands (Lemenih *et al.*, 2008). Declining land size prohibits fallowing and encourages continuous cultivation which in turn results in land degradation (Rahmato, 2008). As the result of high soil loss, the land is getting poorer in productivity each year and the user households as well. Consequently, agricultural land expansion was and still is the leading deforester in Ethiopia (WBISPP, 2004; Lemenih *et al.*, 2008), and this is expected to continue for decades to come (WBISPP, 2004). For instance, the study by WBISPP (2004) predicted the loss of 1.33 million hectares of natural forests in Ethiopia between 1990 and 2020.

Another important policy and governance issue affecting natural resources management in general and the forestry sector in particular in Ethiopia is the ethnic based politics. The ethnic federalism adopted since 1991 makes it difficult for farmers to access land in other regions. Regions with high population growth and small productive land resources will therefore suffocate and experience large scale land and forest degradation.

Despite the continuous and bold agricultural development efforts, Ethiopia is still far from being food secure at national level. To address the widespread food insecurity in the country the government has taken a number of measures. The measures include the political, policy and economic reforms partly discussed above. Within the frameworks of these broad reforms, the government has also issued a specific food security strategy in 2002 that sharpened further the government's commitment to address the multi-dimensional problems of food insecurity in the country. The objective of the strategy is to ensure food security at the household level. Among the components of the food security strategy is the resettlement program. This program aims at increasing food availability by cultivating 'potential and unused arable land'. The plan is to resettle chronically food insecure households (poor farmers) from degraded areas into suitable and 'under-utilized areas' voluntarily and intra-regionally. The strategy outlines that the program would bring underutilized land to economic use resulting in the improvement of welfare of resettled people and contributes to economic growth (Anonymous, 2003). The program is envisaged also to contribute to solving problems resulting from high land degradation, population growth and diminishing farm sizes in the places of origin. Although this strategy has positive elements as outlined in its objectives and goals, it has also overlooked the environmental consequences of such program as resettlement. The lands identified as 'under-utilized' or 'unused' in the program are in fact vegetated ecosystems, and there is no land absolutely vegetation free and that can be used for the implementation of such programs. Almost all resettlement villages are established inside forests or woodlands (e.g., Kebede, 2006; Lemenih *et al.,* 2007), and resettlement is causing widespread deforestation (Kebede, 2006; Lemenih *et al.,* 2007). Official resettlement has over four decades of history beginning with the Imperial period. Millions of people have been relocated in the past inter-regionally and now intra-regionally since the early 1960s. According to the New Coalition for Food Security in Ethiopia (NCFSE) document, the resettlement program planned to settle 440,000 households or about 2.2 million people *(*Devereux and Guenther, 2007) between 2002-2006. Nearly 340,000 households have already been resettled in three regional states (Oromia, Amhara and Tigray) since 2000. At arrival these settlers are allotted 2 ha of farm land. However, studies in several of the resettlement areas show that the average land holding of households is far more that 2 ha, and in some cases as high as 7 to 8 ha, all of which are curbed out of vegetation ecosystems (Lemenih *et al.,* 2007; Dejene, 2008). Conversion followed by improper land management result in soil and water erosion, and thus depletion of top soils. Furthermore, increased human population in an area increases demand and consumption of wood and non-wood products. Consequently, resettlement intensifies deforestation. Besides the resettlement program, a large number of self-migrating households to 'vacant' areas in search of farm plots is also recognized in Ethiopia (Lemenih *et al.,* 2007). Together the two forms of migration are causing wide spread vegetation ecosystem transformations.

4.2.2 Population growth and demographic changes

One of the most important factors determining the future of the forestry sector is population growth. Past experiences show that as human numbers increase, environment degradation such as deforestation, forest degradation and soil erosion increases: a Malthusian view (National Population Policy; 1993; Kidanu, 2000; Lemenih *et al.,* 2008). Ethiopia's population is about 79 Million, the second largest in Africa only after Nigeria, and has been increasing considerably since the turn of the 20th century. The size increased from 11.8 million in 1900 to 23.6 million in 1960, to 43.7 million in 1988 and to 79 million in 2007 (Minas, 2008). It is projected to reach 129 million in 2030 (Kidanu, 2000). Four population related variables are essential in analyzing the interaction between population and forest or environmental resources: (i) growth rate; (ii) distribution between urban and rural; (iii) the predominant livelihood system; and (iv) age structure.

Ethiopia experiences high population growth due to high fertility. The population policy adopted a decade ago has partially managed to subside the fertility rate and create good awareness on family planning. Contraceptive uses are increasing and fertility rates are declining from 7.9 in 1993 to 4.7 in 2000. In big cities like Addis Ababa, the fertility rate has already lowered to a replacement rate. With declining fertility the mortality rates are also declining, even at much higher rate (Kidanu, 2000). As a result the population is still growing 14 years after the issuance of the population policy (Minas, 2008). Even the most optimistic scenarios for declining fertility in Ethiopia imply a substantial increase in population for the coming couple of decades. Kidanu (2000) predicts that Ethiopia's population will be 129 million by 2030, a growth of 2 million people every year for a long time to come.

The population structure of Ethiopia shows youth bulge, which is the result of high fertility. Such an age structure creates a high dependency burden (Minas, 2008) which may create a situation where most of the income is consumed rather than saved for investment. Furthermore, the rural population grows fastest: 84% of the total growth is in the countryside. This combination of rural confinement coupled with a young population means that every year a huge working force (14-65 years) demanding means of living will be added to the rural population. This is another factor that will seriously exert great burden on the country's natural resources such as forests. With agriculture continuing as the main source of livelihoods, the new millions added each year will increase the demand for land, which most likely will be claimed out of forest or woodlands. It also results in a continuous decline of land holding size due to intra-family land re-distribution. Minas (2008) found a decline in land holding size and per capita food output in Ethiopia. As population increased from 23.5 million in 1960 to 48.6 million in 1990, predominantly in the rural setting, the per capita food output declined from 240.2 kg to 141.7 kg (Minas, 2008), whereas land holding per capita has diminished from 0.28 ha to 0.10 ha (Degefa and Nega, 2000). This decline is despite the expanding croplands by clearing forests. The overall implication of the growing human population is, therefore, a continued and devastating deforestation and woodland degradation (Population policy, 1993; Minas, 2008). Increasing population not only increases the demand on land for crop but also the demand for services, energy, wood for construction and income, and space for living. Fuel and construction wood needs are increasing and will keep increasing resulting in the continued mining of the forest and tree resources.

4.2.3 Economic changes

Most agree that the economy of Ethiopia is showing signs of positive growth. The economic policy and associate structural and governance changes are praised for this. However, the economy in Ethiopia is still agriculture based: agriculture accounts for half of gross domestic product (GDP), 60% of exports, and 80% of total employment, while the contribution from all other sectors such as manufacturing, remains low. Due to this dominance in the GDP, any significant performance of the economy reflects the performance of the agricultural sector. Agriculture is also the country's most promising resource, and other economic activities in the country including marketing, processing and export depend on it. For instance, Ethiopia exports exclusively primary products such as coffee, oil seeds, skins and hides, which are agricultural products. These exports are the main sources of foreign currency (except the aid based sources that is also significant nowadays), and hence capacity to import (Kebret, 1999). Therefore, agriculture almost controls the performance of the Ethiopian economy.

A characteristic feature of the agricultural production in Ethiopia is the dominance of small holder farmers producing mainly through rain fed system of production. These farmers account for 90% of the agricultural output, which in total has increased in volume by 1.7 % per annum. This increase is mostly attributed to the increased land put under cultivation rather than to an increment in productivity per unit area (Rahmato, 2008; Eberhardt 2008). According to the study by Eberhardt

(2008) land under cultivation has increased at least by 80 % since the early 1980s. The productivity per unit area, notwithstanding variability between crops, is stagnating however, despite a general increase in fertilizer consumption. This is mainly due to the extreme land degradation experienced in the highlands, the main crop producing area of the country (World Bank, 2007). Wheat and maize are two crops that showed a good productivity increment. Land productivities, despite the attention given to the sector and increased input, thus remained low or even declined. This declining land productivity is considered as a major threat to the expectation of agriculture based economic growth in Ethiopia. A further constraint is the rapidly expanding rural population, and the land policy that continues fragmenting and parceling land into small plots unworthy of intensification.

Productivity losses on croplands are attributed to many factors of production such as: lack of timely delivery of inputs (especially improved seed), inappropriate technologies (suitable farm implements, methods of harvesting and storage, etc.) to small farmers, lack of aggressive land management practices other than the meager and N-based fertilizer application, and continued soil degradation. Soils are losing their productivity potentials due to soil erosion and nutrient mining, which can not be repaired by few and limited amount of chemical fertilizer addition. Soil erosion is high due to the lack of a widely adopted soil-water conservation system. The increasingly smaller land units hamper use of improved - sustainable and profitable - technologies. Empirical evidence shows that small-land farmers less easily adopt fertilizer and improved seeds (Mulat *et al.,* 1998; Croppenstedt *et al.,* 1999; Mulat, 1999; Wolday, 1999). Trade liberalization and market reforms have increased involvement of private sectors, though to a limited extent.

4.2.4 Environmental constraints affecting forestry

The most important environmental constraints in Ethiopia are climate change and land degradation. For a smallholder rain-fed agriculture based economy, land and climate are essential production factors. Ethiopia is experiencing sever climatic anomalies such as erratic rain fall, generally attributed to global climate change. The climate variability map of Africa constructed by Thornton *et al.* (2006) put Ethiopia as one of the countries most vulnerable to climate change with the least capacity to respond (low resilience), and Vincent (2004) represents Ethiopia as the 7th most vulnerable countries in Africa. Evidence of climate change on the ground abounds. In the last 50 years the annual average minimum and maximum temperatures over the country have increased with 0.25 and 0.1 0C respectively, every decade (INCE-2001), a change that is also perceived by the local people (e.g., Deressa *et al.,* 2008). Coupled with a number of non-climatic developmental challenges such as endemic poverty, complex governance or weak institutional dimensions, limited access to capital (including markets), poor infrastructure and technology, and continued ecosystem degradation, climate change is indeed becoming a significant challenge to Ethiopia. Ethiopia, like many other least developed nations, is most vulnerable to the adverse impacts of climate change, mainly due to its low adaptive capacity and high sensitivity of its socio-economic systems.

According to most official documents (e.g., INCE, 2001; TNA, 2007; NAPA, 2007), and scientific inquiries (e.g., Hailemariam, 1999; Deresse *et al.,* 2008) diverse sectors such as agriculture, human health, water, energy and biodiversity (flora and fauna) resources of the country are climate sensitive. Agriculture is identified as the most vulnerable sector. In terms of livelihoods, small-scale rain-fed subsistence farmers and pastoralists are the most vulnerable to the effects of climate change and climatic shortfall may be expressed through food insecurity. According to FAO (2008), the combined effects of below average rainfall, conflict, insecurity and higher than average food prices in the Horn of Africa have resulted in more than 17 Million people suffering serious food insecurity. This trend was confirmed by USAID (2009). In Ethiopia poor seasonal rainfall and poor crop production coupled with raising cereal prices is resulting in nearly 5 million beneficiaries requiring emergency assistance, over and above the 7.2 million Productive Safety Net Program beneficiaries (Cullis, 2009). As a coping mechanism most households revert to public resources such as forests harvesting for wood and non-wood to augment family income. As such harvest is often unsustainable. This then results in the vicious cycle of poverty – environmental resource extraction – degradation – poverty. In the extreme case persistent food insecurity could lead to desertification, an encroaching threat over vast drylands of Ethiopia (Hawando, 1997).

Another environmental curse in Ethiopia is land degradation (Rahmato, 2008). Land degradation can be defined as the reduction or loss of biological or economic productivity of the land. The loss of productivity is the resultant of the loss of physical, chemical and biological properties of land arising from irresponsible or inappropriate and unsustainable use of land resources such as soil, water and woodlands. Land degradation is particularly problematic for both environmental sustainability and poverty reduction in dryland areas, and it requires great effort and resources to ameliorate. Causes of land degradation are complex and include: deforestation, improper cropping system (poor soil and water conservation), soil erosion, loss of soil fertility particularly organic matter and improper livestock husbandry. Inappropriate land-use systems, lack of legally enforceable tenure security and/or accountability in land use and management are exacerbating land degradation.

4.2.5 Other developments affecting forestry

One of the development processes that is affecting and will affect the forestry sector in Ethiopia is biofuel development. Ethiopia imports its entire petroleum fuel requirement and the demand for it is rising rapidly due to a growing economy, population and expanding infrastructure. Petroleum product imports accounts for 40% of the total imports and absorbs 60% of the export earnings. It is thus one of the largest saddles deterring the rapid socio-economic advancement of the country. As part of the solution, Ethiopia swiftly embarked on large scale biofuel development. A recently instituted biofuel development strategy and guideline lists a number of advantage in developing biofuel among which import substitution, employment generation and increasing economic opportunities for local and national economy were included. The strategy also outlined that biofuel development will be advanced in a way that does not cause competition of land with crop production. However, the strategy does not indicate if this is also the case with forestry and other protected areas. The total available potential land for the production of feedstock for bio-diesel has been indicated to amount 23,305,890 ha (Fessehaie**,** 2009). Already 52 developers are cultivating 350,000 ha of land. These lands developed and potentially developing are predominantly vegetated ecosystems (Lakew and Shiferaw, 2008). Given the likely increasing petroleum prices in the future, the biofuel development initiative is likely to continue, with the consequent large landscape change from woodlands and shrublands to biofuel farms, particularly those in the lowlands.

4.3 The future scenarios

The first step in developing the scenarios was to identify the major environmental and social-economic uncertainties relevant to the forestry sector of Ethiopia. Of the many drivers of the forestry sector developments listed in Table 1 two were selected during the workshop. These two great uncertainties were economic development policy and political governance. These two drivers were drawn on the two scenario axes with two contrasting value loads at the end of each axis (Fig.1). The two value loads of the economic policy refer to the case were ADLI remain dominant economic development strategy for Ethiopia with the planning being predominated by the State on the one end and the case were the economic policy reforms from centrally planned and agriculture predominated agenda to a more market oriented economy i.e., broad market deregulation (liberal economy) on the other corner. The two value loads of the political governance on the other hand refer to the case where decision making power with regard to most development agendas continue to concentrate on central government (centralized governance) verses where decision making process devolves truly to the grass roots (decentralized governance). The two axes form four quadrants (corners) that defined four alternative future scenarios of forestry development. These four scenarios are labeled as (i) Miserable Forestry, (ii) Forest in transition, (iii) Economic Forestry, and iv) Farm/Social Forestry (Fig.1). The likely unfolding of each of the scenario over the 30 years ahead is described in the storylines associated to the respective scenario. The storyline presents major action-reaction chains leading to the major forestry development expected in each scenario.

Miserable Forestry: This is a scenario likely to take place under agriculture biased economic policy and development coupled with the dominantly centralized decision making system, which typically characterizes the situation today in the country. This combination is one of the likely conditions foreseen to continue operating in the coming 30 years. Since it is a continuation of current condition, this scenario can also be described as Business-As-Usual (BAU) scenario.

The state control of forestry continues, the conservation orientation remains and the state focus are largely dominated by agriculture. Economic progress is little, and is based on environmentally unfriendly developments such as forest clearance for expansion of oil crops for biofuel, or for coffee production. Energy prices keep increasing and food prices either remain high or increase. Climate change will restrict the advances to be made in agricultural growth. The human population continues to grow, traditional institutes continue to weaken, mobility becomes more and more restricted and sedentarization (agro-pastoralism) becomes the main option. River sides continue to be used as irrigation land. Conservationist oriented policies continue to prohibit the use of fast growing exotic species. The consequence of all this is a suffering forestry sector where by the existing remnant stands will continue to be over exploited and thus decline in quality as well as in size.

Forestry in transition: Under a deregulated market policy private sector investment in forestry will begin to emerge. The involvement of the private sector will be both in forest industry (small and medium forest industries) which in turn requires development of forests to supply raw material. The owners of the forest industries will join farmers in forest resources development in the form of out growers scheme. On the other hand natural forests will continue to be owned and managed centrally by the States (Regional states). The weakness in central forest management however, will result in the continuous decline by the natural forests of the country as the result of population growth and cropland demand. The expansion of planted forests, while the natural forests are declining on the one hand and the increasing role that private sector plays on the other makes the forestry sector to take a new form in Ethiopia thus called forestry in transition.

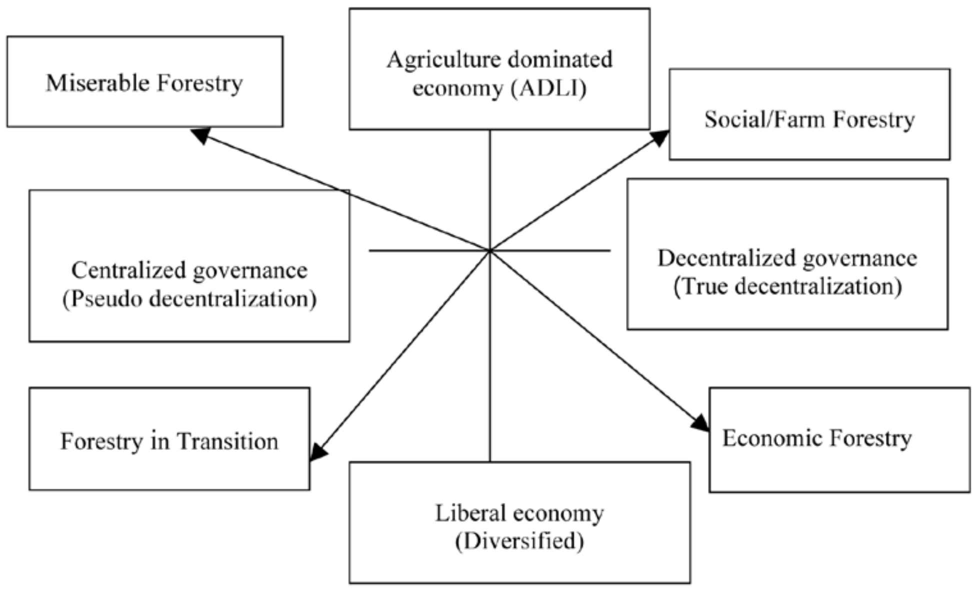

Fig. 1. Alternative forestry development scenarios in Ethiopia.

Economic Forestry: The process towards more decentralized decision making gradually provides regional and local authorities and people the power to decide on what to do with their land and other resources. In these processes land policy and tenure security issues evolve to provide strong confidence in ownership or use right including long term leasing and renting. Such empowerment of farmers to decide on what to do on their land will result in gradual land consolidation. At the same time, population policy gets stricter in implementation, and the economic and resource scarcities continue to press on family planning. In the mean time the forest product market continues to boom as urban centers continue to grow. The raise in forest product demand makes forestry profitable, and the overall position of tree/forest farming in livelihoods rises. State supports as well as donor supports due to global environmental issues also grow, and forestry will gain importance as a sector and thus will play and increasing role in sustainable development. Forestry entrepreneurs both at primary and secondary processing stage as well as in developing the resources begin to proliferate. With increasing economic activities in the country, many people, companies and organizations learn that forestry offers a lucrative business, and increasingly invest in it.

Farm/Social Forestry: The countries economic situation is still dominated by agriculture, but decentralization is progressing well as a result of policies and strategies that are enriched through people's participation. The land administration policy in improving security continues to mature and all legal and institutional systems begin to develop capacity in dispute resolution. Farmers continue to develop confidence in the state, and start leasing lands. However, population growth still is high and rural-to-urban migration is low due to slow economic growth and low levels of urbanization development. Climate change and soil degradation impose challenges to agricultural intensification and this is coupled with high prices and low availability of input for high-intensity agriculture. Agricultural modernization remains low due to the small land size of individual landowners. Forest product demand continues to rise, while supply from natural forests sources continues to decline. Despite increasing awareness regarding the value of the natural stands, population growth does not allow people to devote it for conservation only. Thus encroachment continues to expand. Furthermore, climate change and land degradation expands food insecurity in the highlands, with continued resettlement demand as a consequence. To maintain the economic growth, Governments continue to give some of the natural areas for investment to high value crops. Similarly, an increasing energy price will force bio-fuel expansion. These developments will force forestry to concentrate on small fragments of land, mostly farmers owned. The timber industry is small scaled and the forest patches may provide high value non-timber forest products.

5. Conclusions

Appraisal of the development of various factors affecting the forestry sector revealed that forestry will have a hard time in the future, although there is also a possibility for its increasing development and role in the country. First and foremost the scenarios reveal that forestry sector is significantly influenced by factors outside the sector primarily by political and macro-economic development direction. Secondly the issue of property right- the level of devolution of forest and land ownerships or use right has strong influence on forestry development by affecting private sector involvement. Thirdly, to offer good space for forestry significant achievement should be made in controlling human population growth and intensifying agricultural production. Simultaneously, the development policy of the government needs to be all-embracing and should not be pre-occupied by just one sector - crop production. Like agriculture, forestry is also rural centered, and it can offer rural communities a better alternative means of survival if properly practiced. Most importantly the two can be planned and developed in such a way that both support each other through appropriate land use planning and proper implementation of such plans. The scenarios are not arbitrary imagination but some already emerging, others on-going and some are very likely to emerge types according to the perception of the stakeholders that participated in the workshops. Consequently, the scenarios may help decision makers to visualize and consider how the different political and economic development pathways taken will affect the forestry sector and thereby its ecological and economic roles.

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LANDUSE/LANDCOVER CHANGE ANALYSIS IN SELECTED DRYLANDS OF ETHIOPIA: IMPLICATION FOR SUSTAINABLE DEVELOPMENT

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prepared by Ministry of Rural Development (2003), there is a plan to resettle 440,000 households or 2.2 million people. The programme will be implemented in Tigray, Amhara, Oromia and Southern Peoples Nation and Nationalities regions at an estimated total cost of over 1.4 billion Birr. The settlements encompass 200,000; 100,000; 100,000; and 40,000 households in Amhara, Oromiya, SNNP and Tigray, respectively (MoRAD 2003). This resettlements and agricultural investment for commercial crop farms are exerting pressure on the woodlands. Losses of woodlands are reported by different scholars with its dominant effect and causative factors. With this background, this paper attempts to summarize the major land use/land cover shift and identify the main driving forces and consequences in selected drylands of Ethiopia. The paper also briefly touches its implication for sustainable development.

2. Landuse/Landcover Changes in Selected Drylands

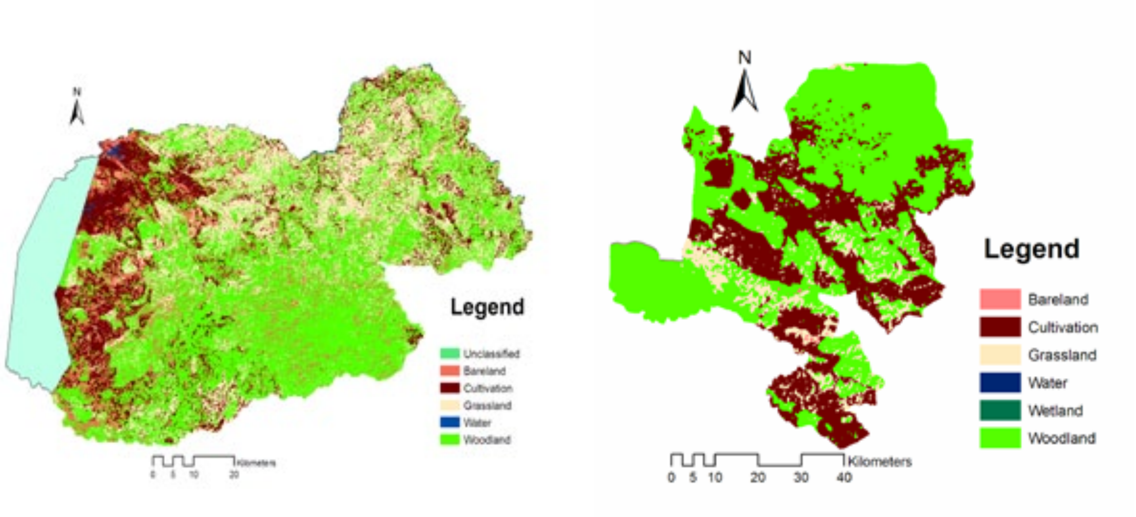
2.1 Landuse/landcover change of the North western drylands

The North western parts of the country are dominantly covered with woodland species of gum and resin production potentials. The inhabitants of the region were very few in size before 1960's. From the mid 1960's up to the present, resettlement has been undergoing with the assumption that there are sufficient agricultural resources to accommodate a large number of settlers (Haile, 2007).The identified areas for settlement in Tigray and Amhara regions dominantly found in the northwestern lowland parts. The resettlement in this area was meant to transfer peasants to a new surrounding; but has not involved changing their agricultural skills, habits and environmental protection knowledge. This means that the peasants accustom merely their unsound agricultural and environmental practices in their new settlement, and result in less productivity (Dessalegn, 2003).

The satellite image analysis of the 2001 has showed small areas were occupied with agriculture while there is huge expansion in 2006 (Fig. 1). The expansion of agriculture is on the expense of the woodlands. The driving forces behind the agricultural expansion are investment and resettlement. The resettlement program is narrowly focusing on shifting of people from the densely populated and degraded highlands to sparsely populated areas of the lowlands. The resettlement program has been implemented in virgin lands of the woodland. This has caused considerable damage to the natural vegetation which may end up in loss of biodiversity and local extinction of certain species. Large areas were cleared of their vegetation for crop production, to build houses and to acquire fuel wood. As a result the cultivated fields increased to 44.64% while the woodland shrunk by 43.71% in Metema. Similarly, in Humera the agriculture expanded by 20.77% while the woodland shrunk by 42.69 % (Table 1)

Table 1. Landuse/landcover of Humera and Metema

	Humera				Metema			
	2001		2006		2001		2006	
			Ha	%	ha	%	ha	%
Cultivation	94148.27	15.26	128138.27	+20.77	80024.5	23.65	151008.5	+44.64
			257196.6	-41.69	218907.9	64.69	147923.9	-43.71



(a) (b)

Fig. 1. Landuse/landcover of Humera (a) and Metema (b) in 2001

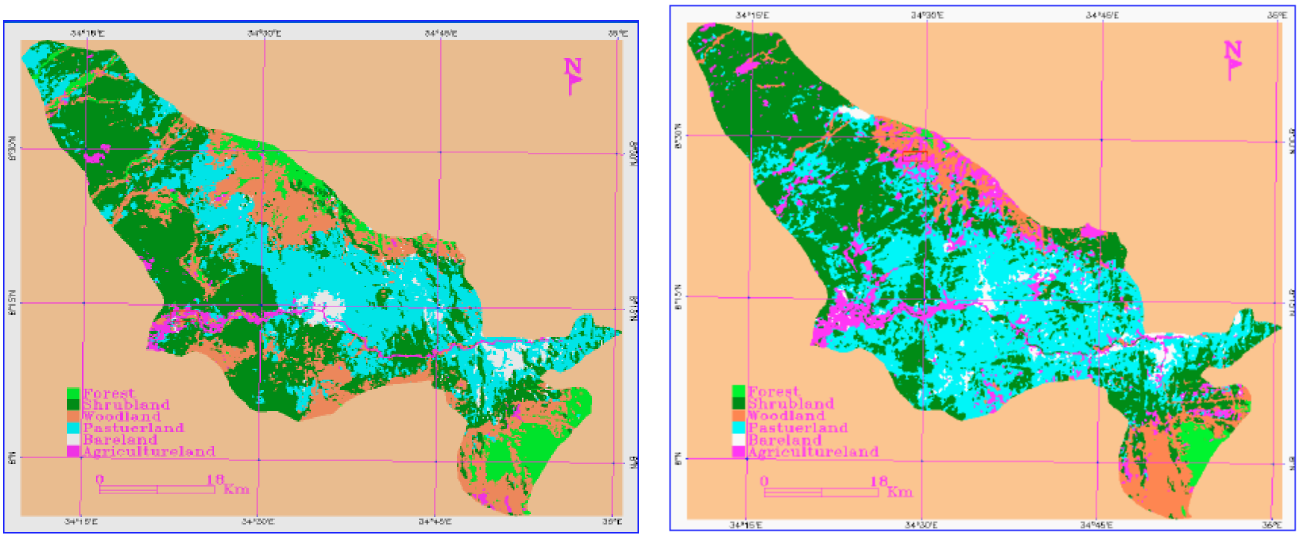
2.2 Landuse/ landcover change of the south western drylands

The south western drylands of the country is dominated by Combretum-Terminalia broad-leaved deciduous woodland vegetation type. Different pressures are exerted on these woodlands from different perspectives. A satellite image analysis of Gambella Woreda for the year between 1987 and 2000 has showed a decrease in the woodland by 57.82 % (Table 2; Fig. 2). With in the same year agriculture has showed an increase in 244%. The loss in vegetation can be linked to the resettlement program from the central highlands of the country. In addition the southern Sudan refuges occupied certain parts of the Woreda that exerted pressure on the woodlands.

Table 2. Landuse/landcover (LU/LC) change between 1987 and 2000

Land use	1987		2000		Change in LU/LC
	Ha	%	ha	%	%
Wood land	800276	27.98	337636	11.8	-57.82
Agriculture land	79906.8	2.79	276303.8	9.62	+ 244
Bare land	79817.6	2.78	76524.3	2.68	- 3.5

Source (Woldesemayat, 2007)



1987 2000

Fig. 2. Landuse/landcover map of Gambela Woreda (Source: Woldesemayat, 2007)

The other study by Birehanu (2007) undertaken at Didessa valley between the year 2001 and 2007 has showed a conversion of 145 km2 of the woodland into combinations of agriculture and settlement. This equates to the decline in the woodland by 42.4 percent. This area is located between the big rivers of Dabena and Dhidhessa. These two rivers are tributaries to the Blue Nile. The loss in vegetation of this area has an impact on the lower catchment which has been leading to sediment accumulation. The Chewaka resettlement site is among areas that hosted large number of settlers in Oromia Regional State. About 12,000 households (60,000 people) from Western Hararghe resettled in the area since 2003 (Birehanu, 2007). The area is intact before the resettlement. The main driving force for the loss of the vegetation is therefore, linked to this resettlement scheme. The resettlement at Haro Tatessa has also resulted in huge damage to the woodland of the area as well as to the killing and fleeing of wild animals which are not easily reversible, even leading to the extinction of some species (Ahimed, 2005). The indiscriminate cutting of trees by resettlers influenced the traditional way of conserving the natural forest.

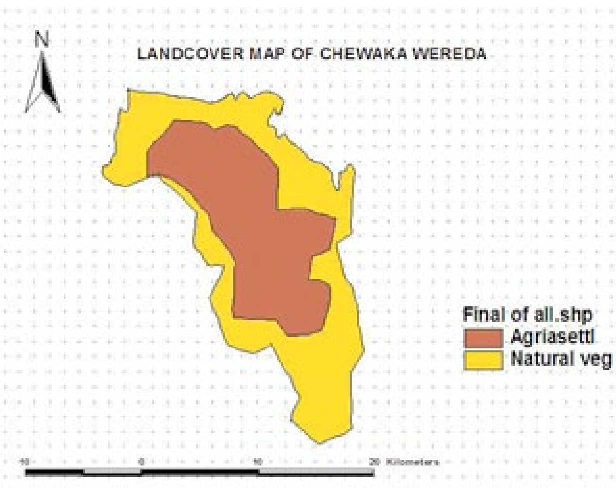


Fig. 3 . Map Chewaqa Woreda (source Birehanu, 2007)

2.3 Landuse/landcover of the central Ethiopian drylands

The central Rift Valley areas are previously dominated with acacia woodlands. However the expansion of agriculture and resettlement is exerting pressure and is a main cause for the dwindling of the woodland resources. Satellite image analysis of the years 1973 to 2000 has showed that agriculture alone was the driving force for 83.4% and 70.1% of the natural vegetation loss in Abjiat Shall National Park and in Zeway- Awassa Basin, respectively (Bedru, 2006). The loss in vegetation has a contribution for occurrence of sheet and gully erosion. During short and intense flash rains, the torrents carry sediments usually rich in nutrients that end up in the lakes, thereby resulting in sedimentation and eutrophication (Bedru, 2006). The loss in vegetation has decreased the amount of inflow to the lakes from the feeding rivers due to the removal of the fertile top soil which reduced infiltration potential of the soils and resulted in runoff.

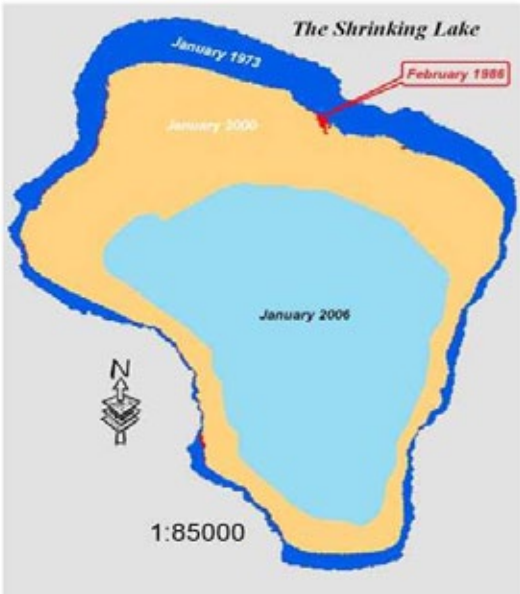


Fig. 4. The shrinking Abijjata lake (Source: Bedru, 2006)

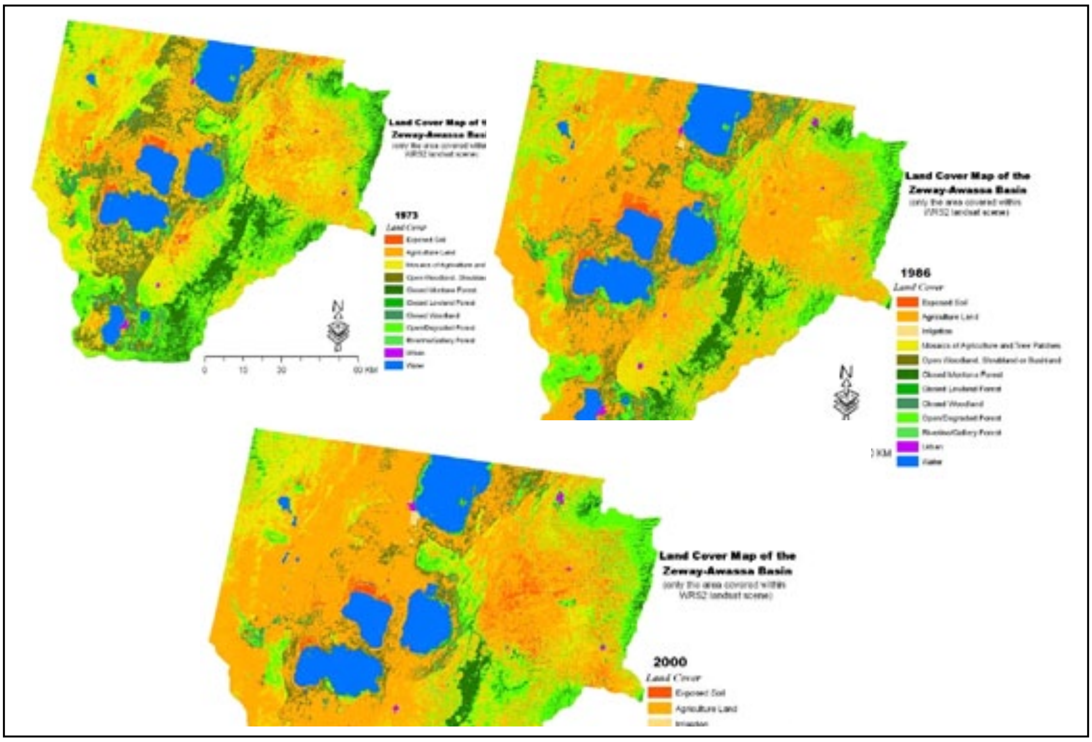


Fig. 5. Landuse/landcover of Rift valley area (source: Bedru, 2006)

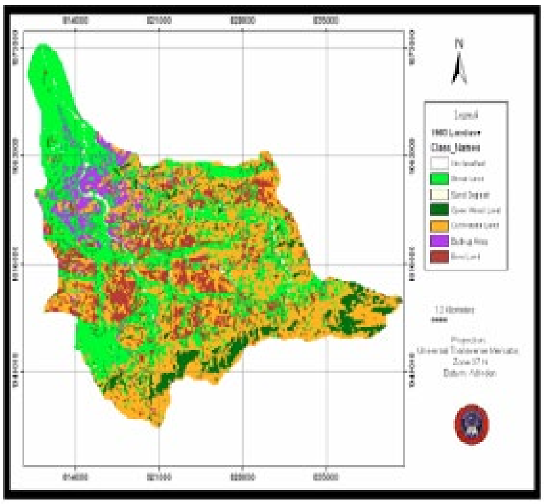
Table 3. Landuse/Landcover of Ziway Awasa basin

Land use type	1973		2000	
	ha	%	ha	%
Agriculture	275677.2	21.22	591542	45.53
Closed lowland forest	8641.93	0.67/4.19	2619.6	0.2
Closed Montane forest	97989.26	7.54	35233.6	2.71
Closed woodland	45691.61	3.52	25099.5	1.93
Mosaic of agriculture & tree patches	383515.38	29.52	208704.2	16.06
Open woodland/shrubland	108680.33	8.36	60778.9	4.68
Open/degraded forest	222147.81	17.1	210302.2	16.19
Riverine/gallery forest	5723.67	0.44	5974.2	0.46

Source: Bedru, 2006

2.4 Landuse/landcover change of eastern dry lands of Ethiopian

The eastern lowlands have also facing reduction in vegetation. Daniel (2007) conducted satellite image analysis in Dechatu catchment of the Dire Dawa Administrative Council which covers a total area of 128,802 ha in the eastern marginal catchment of Awash basin. The 1985 and 2006 image analysis has showed a dramatic increase of built up area by 93.8% and a sharp reduction in woodland vegetation of 39.6% (Fig. 6). The expansion of built up area is linked with increase in population size. This reduction in vegetation cover speed up surface runoff causing a sever flood in the city of Dire Dawa causing damage on roads, bridges, human and animal lives.



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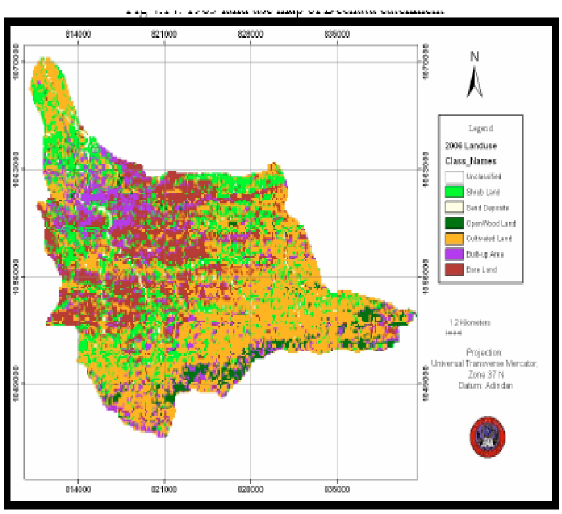

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Fig. 6. Land use map of Dechatu catchment (source: Daniel, 2007)

3. Consequence of Landuse Changes in Dryland Areas

The conversion of woodlands to other landuse types has several consequences on the sustainable productivity of drylands unless planned and changed to avoid degradation of the environment. Dryland vegetations play significant role acting as a buffer ecosystems between the highland and arid environments and have limited capacity to endure intense human interference (Birhanu, 2007). Most of the trees in the drylands are bearing gums and resins which has a huge potential for tapping foreign currency. The regeneration of certain species is very low and needs attention for their sustainable utilization. The expansion of agriculture and settlement has a double impact on the future existence of these species. Plantation development in drylands is uncommon and establishing trees is also a challenging activity. Poor regeneration, low attention to woodland conservation and unwise utilization of these resources will result in loss of biodiversity and local extinction of species.

The removal of dryland vegetation can causes expansion of desertification. Tree roots penetrate deep into the ground, holding together several soil layers which prevent the formation of dust and maintain the topsoil intact. The removal of trees will pave the way for heavy rainfall and high sunlight to cause damage to the topsoil and formation of dust. Heavy winds and storms transport significant amount of these fertile soil to distant areas. On the other hand the woodlands need much longer period for regeneration and sustain itself and the land will not be suitable for agricultural use for quite some time (Birhanu, 2007). Biodiversity will also be reduced due to the change in landuse. The change of woodlands to farmlands removes the forest species, and the shrinkage in woodlands fragments the existing habitat.

Desertification which is caused by severe degradation of arid and semi-arid lands exacerbates dust formation. Even if dust storms are a natural phenomenon, anthropogenic activities facilitates formation and transportation of dusts over long distances. It is estimated that 2-3 billion tones of fine soil particles leave Africa each year in dust storms, slowly draining the continent of its fertility and biological productivity. On the other hand, the formation of soil takes longer periods to replace it (URL3). In different parts of the world, there is an increase in dust storms due to deforestation and heavy grazing. The changed African climate, combined with widespread overgrazing by livestock and the spread of destructive, often export-oriented farming practices in the Sahel, were sending vast quantities of exposed soil into the sky.

Deforestation of the woodlands has an impact on carbon cycle of the drylands. Tree growth related to carbon accumulation is very low. Thus, the removal of these vegetation paves the way for loss of the carbon accumulated through time. The image analysis at different parts of the drylands has showed a significant shift of the woodlands to agricultural plots. The deforestation process has its own contribution in releasing carbon dioxide to the atmosphere which is the main source of greenhouse gas. The expansion of agriculture also disturbs the soil which resulted in release of soil carbon.

The deforestation is exacerbated due to resettlement and expansion of agriculture. The removal of the northwestern woodlands of the country has also favored the formation of dust storms which is an indication of southward expansion of Sudano-Sahelian desert. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite taken on May 11, 2009 has shown that dust continued to hover over central Sudan and to spread into neighboring countries to the east, Eritrea and Ethiopia (Fig. 7). The dust completely obscures Lake Tana, which is visible in the image acquired on April 23.

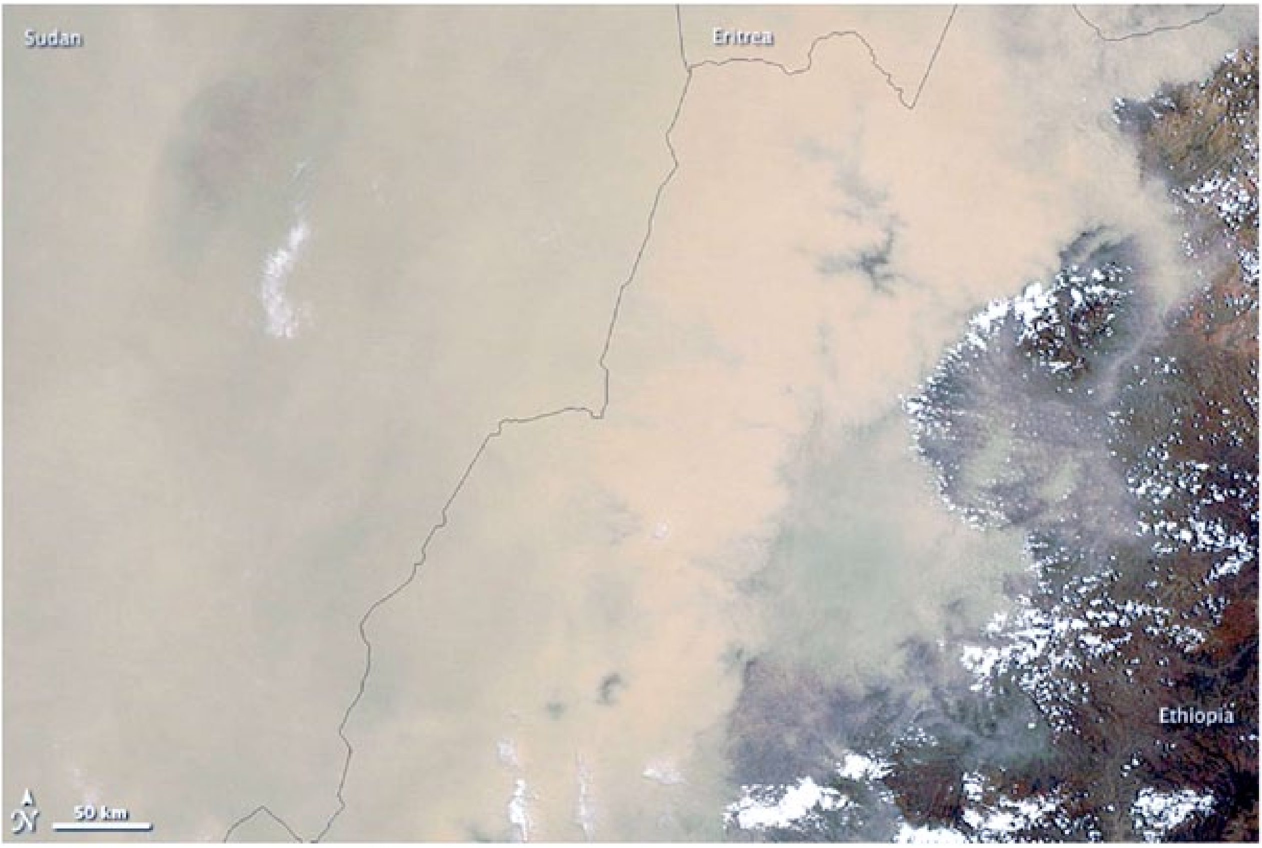

Fig. 7. Dust storms over Sudan and northwest Ethiopia (Source: NASA, 2009)

The removal of woodlands provides perfect conditions for high winds to whip loose soil into the air and carry it thousands of miles across the continent. In most cases, the occurrence of storms linked to drought but deforestation, overgrazing of pastures and climate change exacerbate the conditions. This soil transportation in turn has long term effect that leads to land degradation. The long term process of land degradation favors desertification. This has also a direct impact on sustainable agricultural production that may lead to reallocate the settlers and the farming activity to other woodland areas. Meteorologists predict that more major dust storms can be expected, carrying minute particles of beneficial soil and nutrients as well as potentially harmful bacteria, viruses and fungal spores (URL3).

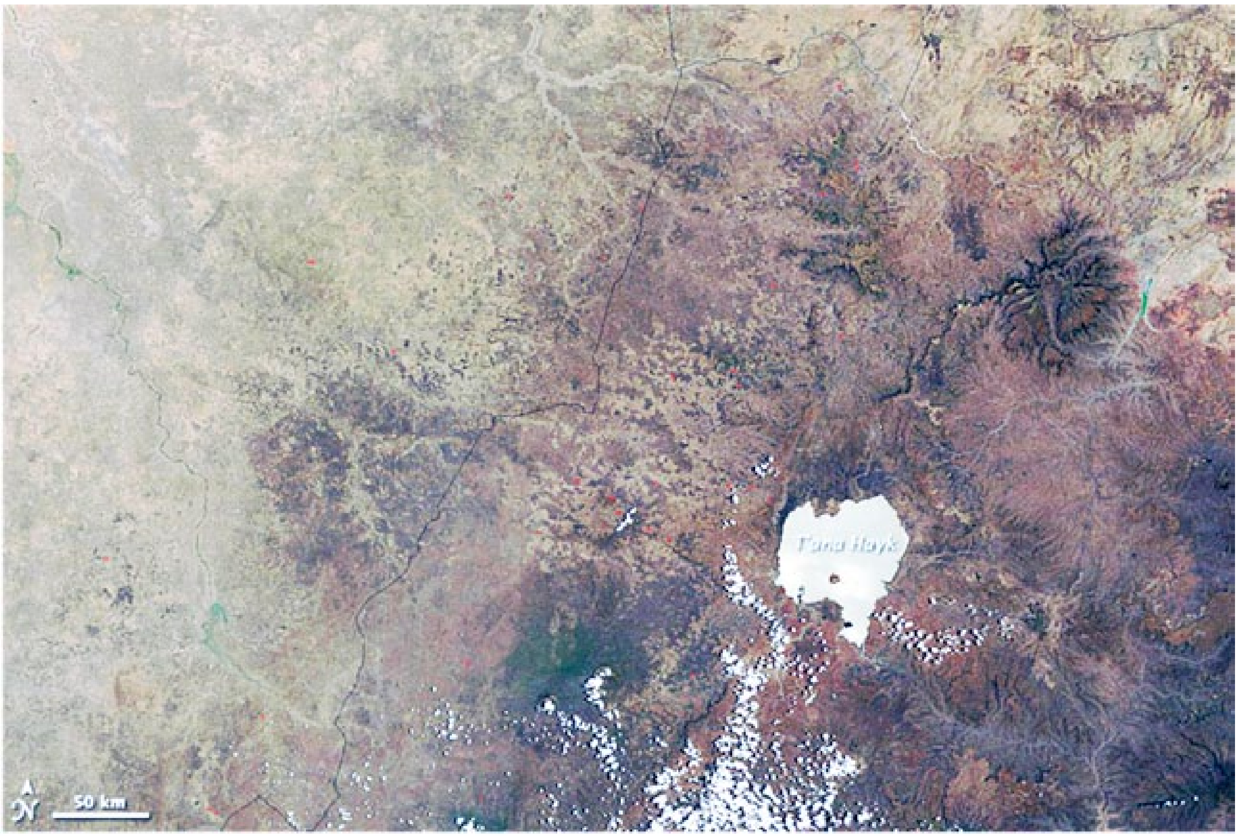

Fig. 8. Image of the same place free of dust storms (Source: NASA, 2009)

Researchers have barely begun looking into the health effects of African dust. They found the existence of pesticides banned for use in the United States mixed with dust particles that may be too small for human lungs to expel (URL 4). Dust storms have a number of impacts upon the environment including radioactive forcing, and biogeochemical cycling, transporting material over many thousands of kilometers having an impact on humans (Andrew, 2008). The dust storm which blows from Sudan to Ethiopia will have an implication on the agricultural production, health and productivity. Even if it needs further study on the amount and type of particles brought to Ethiopia, it is a precaution on the future activities of tree planting and conservation of the existing woodlands for sustainable production.

4. Implication for Sustainable Development

The existence of woodlands has multifaceted function to production and productivity of the dryland agricultural. Trees on farm can serve both as fodder for livestock and maintain the fertility of the soil. However, in many parts of the drylands, trees that are found scattered on agricultural plots are totally removed and exposed the soil for strong sunlight and heavy rainfall. It is also evident that high wind storms are prevalent in lowland areas due to their climatic condition. On the other hand several resettlements are found within these dryland areas in which the highlanders brought the customs and way of life of the highland areas. The target of resettlement should be reducing environmental degradation. But studies carried out in Humera settlement indicated the depletion of organic matter in all landuse types of the settlement areas (Haile, 2007). Deforestation in the study area also existed as a result of expansion of agricultural activities, wood consumption for fuel, construction and other uses. Land degradation linked to deforestation, poor agricultural practices and poor livestock management of the residents. Food security in these areas will not be fulfilled without strong commitment of management of natural resource base.

Drought is prevalent in most dryland areas of the country. Such areas are susceptible to failure of crops and shortage of feed for their livestock. Study of NASA has showed that due to an increase in temperature of the Indian Ocean, little precipitation has been reaching the East African land masses (Fig. 9). The image compares the growth of vegetation between July 21st and October 10, 2009 to the average growth over the same period from 2002-2008. Green areas show better than average growth and brown areas show poorer than average growth.

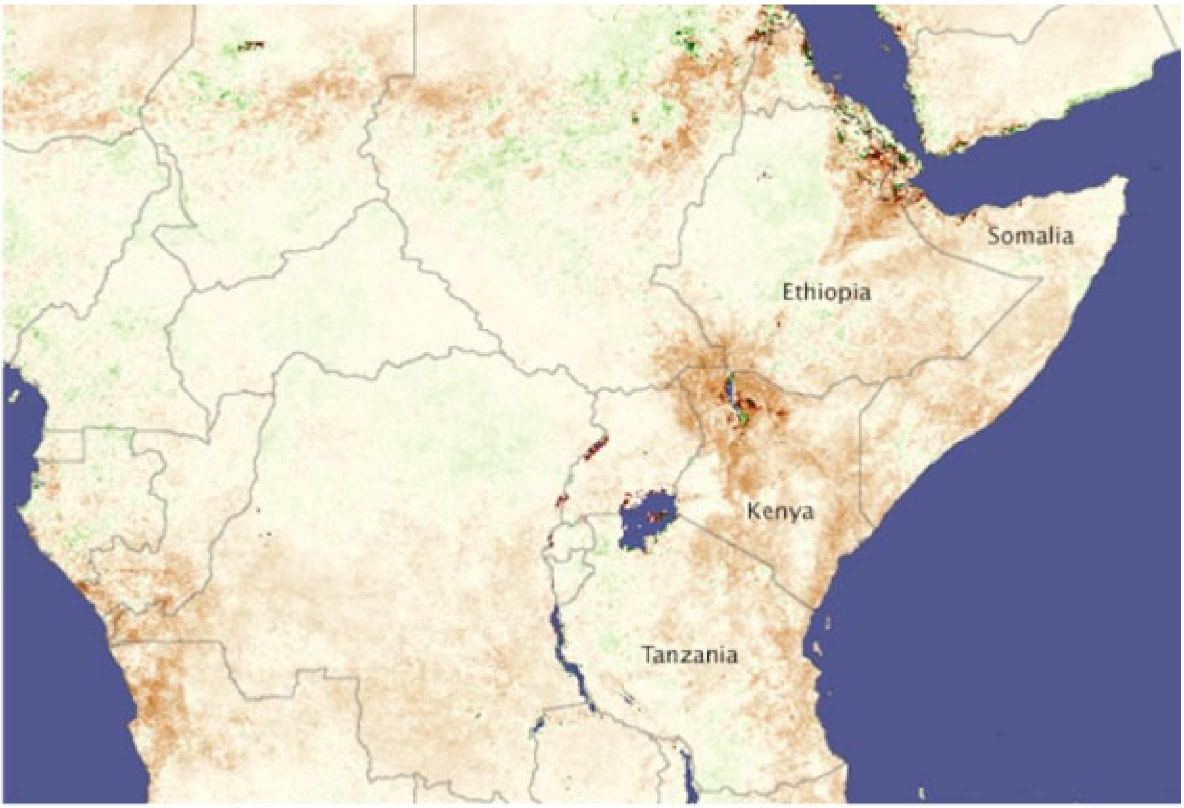

Fig. 9. Drought forecast on East Africa (Source: NASA,2009)

In most dryland areas, crop rotation and fallowing practices has been changed due to the cash oriented farming practices. In Humera farmers don't practice crop rotation, fallowing and application of manure (Haile, 2007). This also has its own part on the depletion of the nutrients of the soil and resulted in yield reduction year after year. The main reason was the escalated price of sesame both at local and international markets. In other dryland areas, there is also a similar trend of deforestation, degradation and reduced biodiversity which leads to lower agricultural productivity (Birehanu, 2007).

The removal of trees from farmlands has exposed the soil to prolonged heavy sunlight. The prolonged high temperature does not favor the organic matter accumulation and moisture conserving capacity of these soils (Haile, 2007). The soils of warmer climates normally contain less organic matter, but have a higher percentage of mineralization each year than the soils of cooler climates. Legesse and Tsegai (1998) indicated that the organic matter content for the different soil types of Kafta-Humera Woreda to be not more than 2%, which is low to medium. Soil organic matter is the main supplier of soil N, S and P in low input farming systems. A continuous decline in the soil organic matter content of soils is likely to affect the soil productivity and sustainability in the long term (Haile, 2007).

In addition to settlement there is expansion of mechanized farming in most lowland areas of the country. Mechanized farming needs wider and appropriate areas and the investors remove all trees from their farms to facilitate their farming activities and deplete vegetation covers. The removals of trees and less practice of crop rotation have its own impact on nutrient cycling and hence result in degradation of agricultural plots. The long term process of land degradation leads to desertification. The expansion of desertification southwards has been explained by the occurrence of dust storms over northwestern parts of the country. Desertification declines agricultural productivity, reduces biodiversity, and degrades the environment, which diminish ecosystem resilience. The lower agricultural productivity urges the farming community to encroach new woodland areas which has a similar fate to the previous land use types. It is crucial to enforce sustainable use of lands with a focus on conservation of the natural resources.

5. Conclusion

The satellite image analysis at different parts of the country has shown expansion in agriculture and settlement with the expense of woodlands. The nature of the soil in the dryland areas are fragile and with low organic mater content. The ecosystem is also vulnerable and exposed to the current effect of climate change. In order to maintain agricultural productivity, there is a need of sustainable management of the existing natural resources.

Man induced causes of land degradation in the drylands of Ethiopia are poor farming practices, population pressure, overgrazing, soil erosion, deforestation, salinity problems and the use of livestock manure and crop residue for fuel as energy source of the rural households (Cesen 1986; World Bank, 1984). Most of the lowland societies depend on rearing livestock for decades and the loss in vegetation and degradation of grazing fields has an impact on their livelihood. This situation together with the recurrent drought and current climate change has posed a burden on the sustainable agricultural production. It is crucial to consider proper and effective landuse plan for sustaining the productivity of agriculture and for the pastoral community.

The resettlement plans should incorporate strategies for protecting the natural resources base of the settlement areas for sustaining the environment for the benefit of both settler and local communities. If appropriate natural resource protection measures are not taken, resettlement will have done little more than transferring the problems of deforestation and degradation from the highlands to the lowlands. The habit of natural resource conservation in the drylands should be shared among the new settlers. The mechanized farming should also incorporate trees on their farms for both nutrient cycling and windbreak.

The dryland tree species have been useful as windbreaks and shelter belts against desert encroachment and hence desertification control, their canopies intercept rain drops while root systems are effective in reducing soil erosion, thereby stabilizing soils (Jaiyeoba, 1996). The expansion of desertification is prevalent in the country due to the removal of such important trees. If the current loss of woodlands continued in northwestern part of the country, Sudano-Sahelien deserts will expand towards south. There is an indication of desert expansion through the movement of sand storms from Sudan to the northwest part of the country. This long term process will result in abandoning the area from agricultural production.

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DISPUTATIVE SIGNALS: GLOBAL AND OUR PRESENT EXPERIENCE INFERENCE FOR BIOFUEL DEVELOPMENT IN ETHIOPIA

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Abstract

As a consequence of fossil reserve depletion and change of atmosphere chemistry, interest to searching alternate energy sources become a global issue. Biofuel has attracted attention of many scientists and strong efforts have been made to improve efficiency of different biofuel technologies. Some of these efforts include looking for alternate feedstocks, improving productivity of these feedstocks, and design different engines. At its initial stage it was assumed that use of biofuel can contribute to food security, reduce greenhouse gasses emission, and increase rural jobs opportunities. However, current approaches have affected food security; biodiversity conservation and land cover both globally and at local level. Situations of largest biofuel developer countries clearly reveal these challenges. Nowadays, in Ethiopia more than 64 biofuel developers have been registered and leased feedstock production land. Most of the rented lands are happening in agriculture, forest, woodland and wildlife conservation areas. These can affect present and future food security, land coverage of the country, wildlife conservation and overall agricultural productivity including biofuel feedstocks itself. Thus, amendment of the current approaches such as use of arable area, forest land and woodland areas for biofuel production can contribute to the success of biofuel development in the country.

***Key words**: Biofuel, biodiversity, energy source, food security*

1. Introduction

Historical records indicate that Rudolph Diesel, the inventor of diesel engine, used vegetable oil in his engine as early as 1900. Henery Ford one of the pioneers of automobile manufacture designed his equipment to run on ethanol. At the early stage of diesel engine, strong interest was shown to use biofuel, whereas this interest declined in the late 1950s when petroleum products became abundant (Goering *et al.,* 1982). Since discovery of petroleum fuels, serious oil crisis happened during the first and the Second World War and in the early 1970s. These crisis renewed interest to the use biofuel (Garba, 2008). Particularly, the oil crisis during 1970s was a major cause to biofuel development programs in many countries. This lead to commercial scale biodiesel production in many European countries such as Austria, where the first industrial scale biodiesel production plants went into operation in 1991. This was followed by similar initiatives in other European countries such as Germany, France and Italy. The 1970s oil crisis also drived North American countries (USA, Canada,) and Latin American countries (Brazil and Argentina) to develop national biofuel development programs, which resulted in development of big biofuel producing industries.

The recent environmental concern due to global climate change has been other driving force to substitute mineral fuel by renewable biofuel. The Kyoto Conference on global climate change and the latter consecutive international environment related conferences have created awareness about the greenhouse gases emission by fossil fuel and need of paradigm shift in the primary energy sector. Depletion of the fossil reserve, trade balance and global geopolitics also have contributed to rekindled use of biofuel. This paradigm shift has conveyed the use of biofuel as alternative to fossil fuel for the transportation sector.

The use of fossil fuel is accepted as unsustainable due to depleting resources and accumulation of greenhouse gases in the atmosphere that have already exceeded the dangerous high threshold of 450 ppm CO_2-e (Rial, 2004). To achieve environment and economic sustainability, the future fuel production process requires not only renewable energy it shall also need to be capable of sequestering atmospheric CO_2. Biofuel have been considered as alternate energy to fossils fuel and fulfill these criteria. It attracted global attention. The sustainability and feasibility of biofuel also being an issue of argument among scholars. Consequently, to improve its efficiency and sustainability different biofuel technology generation have been developed. Based on feedstocks technology development biofuel can be grouped into four different technology generation.

The first biofuel technology generation is biofuel that are produced from starch and oil of some plants. These plants include corn, wheat, sugarcane, sugar beet, soybean, rapeseed, Jatropha curcas, castor bean and oil palms. Sugars and digested starchy grains are being fermented to ethanol and butanol. Production of bioethanol is not a new technology, albeit slight continuos improvement in chemical engineering and in genetic engineering of the yeast used to increase overall efficiency. The enzyme use to digest starch has also been made more efficient and cheaper through genetic engineering.

Grains used to make bioethanol mainly corn have been subjected to decades of intensive breeding, resulting in increased yield. Change in starch composition to increase the easyness and rapidness of enzymatic conversion to sugar can also be performed more quickly by genetic engineering than by breeding. Recently, it was reported that vacuolar targeting of highly efficient sucrose isomerase which convert vacuolar sucrose to isomaltose (palatinose) by enzymatic rearrangement of the glycosidic linkage from α (1,2)- fructoside in sucrose to α (1,6)- fructoside allowed an accumulation of 0.5 M isomaltulose in sugarcane stems without reduction in sucrose concentration, resulting in doubling of total sugar concentration in juice for selected transgenic lines relative to their elite parent cultivars (Robert and Birch, 2007).

The use of food crops and agricultural land for biofuel production is affecting global food security. On the other hand, first generation biofuel requires more land than available to replace current global energy demand. Thus, the new feedstock (second technology generation is being developed from agricultural wastes). This technology generation converts cellulose, hemicelluloses, and lignin of plants to biofuel. Some of these feedstocks include straw, switchgrasses, miscanthus and forest logs. These feedstocks are pyrolized or first treated with acid, heated, and then digested with cellulase for production of bioethanol. The residue also can be used for production of energy by burring or pyrolysis. At present there is a large and expanding effort to increase the efficiency of the cellulotic enzymes. There has already been an increase in efficiency of production, with the price per unit activity decreasing 20- fold over the past decades (Robert and Birch, 2007). Straws and switchcanthus grasses contain large amount of hemicelluloses, which have a high content of five carbon sugars that are not well degraded by the present ready available technologies.

The third technology generation involves production of biofuel from algae and cyanobacteria. Algae in ponds can more efficient than higher plants in capturing solar energy, more so in bioreactors. From algae and cyanobacteria biomass different biofuels can be produced. From the oil (biodiesel), from starch and cellulose (bioethanol, methanol and biohydrogen) can be produced. According to Sheehan (1998), if algae production could be scaled up industrially, less than 6 million hectare would be necessary world wide to meet current fuel demands. The US Department of Energy funded a large international project on microalgae for biofuel production that ceased operations by 1996. The project achieved sporadic maximum yield more than 100 times greater than oil palm per unit area. When the project was terminated it was considered that the production of algae biofuel would be double the cost of petrol-diesel. Given the increase of the cost of fossil fuel at present before biotechnological optimization, the use of algae may already provide a margin of profitability. If the limitations of algal production systems (organism survival, growth and lipid content, CO_2 enrichment, light penetration, seasonality and harvest) can be overcomed, such a crop would be highly competitive with diesel derived from fossil fuel.

The fourth technology generation of biofuel is engaging production of biohydrogen and bioelectricity. Biophysicists have seen it as an intellectual and practical challenge to harvest solar energy for hydrogen and /or bioelectricity (Chisti, 2007) using nature photosynthetic mechanism directly or by embedding the part of photosynthetic apparatus I artificial membranes or using algal to produce sugar and yeast or bacteria enzyme to produce electrochemical energy. Biological hydrogen production processes are more environmental friendly and less energy intensive as compared to thermo chemical and electrochemical processes (Das and Vzeroglu, 2001).

2. Global Experience and Major Debates of Biofuel Development

Despite its initial objectives, i.e. to secure global energy demand and mitigation of greenhouse gas emission, the use of biofuels have raised several debates. These major disputative perspectives of biofuel production and use at global and national scale are the focus of this paper.

2.1 Conflict between biofuel feedstocks and human food production

Today about 6.8 billion people are living on our planet. According to Carleton and David (2009) about one-sixth of these population are malnourished. After four decades or by the year 2050, the world population has been estimated to reach 9.1 billion. In order to feed this growing population, food production should be increased by 70% (WFP, 2009), which is going to be most challenging than ever. Increasing productivity per unit area, increasing land under cultivation and diversifying food items are among possible options to achieve food security for the present and the future increasing population. The escalating world population not only raises demand for food but also demand for energy and other basic necessities. Nowadays, like food the global energy demand is increasing. As such the gap between demand and supply for energy is getting wider. There are five main reasons for such widening gap. These are: global population increase and associated need for energy; depletion of fossil fuel reserves; economic growth of some developing countries particularly China, India and Brazil that has raised energy demand; political insecurity of major petroleum production areas; and over utilization of fossil fuel resources by some developed countries.

Biofuel is one of the alternative energy source that currently attracts attention of many nations and companies to fill the gap in energy supply and demand. The largest volume of biofuel production comes from bioethanol which is mainly produced from food crops such as maize (in USA) and wheat (in Canada), sugarcane and sugar beet (in Brazil). A total of about 80% of the global ethanol used for biofuel comes from corn that supports 20% of global population food demand and sugar cane (WFP, 2009). The second largest volume of biofuel production comes from biodiesel. Currently, it is mainly produced from edible oil such as appeased oil in European countries, soybean in the United States, Argentina and Brazil, and oil palm in Malaysia and Indonesia. These biodiesel feedstocks are also major sources of oil for human consumption and other industrial purposes. The use of food crops for biofuel feedstocks affects food security in two main ways. First, it uses the same crops and increase demand and price of the crops. Secondly, it competes for resources such as agricultural land, inputs and national resource allocation and has an effect on present and future food security. There are current confirmations indicating the development of biofuel production from food crops to cause rapid augmentation in global food price. Bureau for Democracy, Conflict and Humanitarian Assistance Office of the USA Foreign Disaster Assistance also reported escalating on major food prices as the consequence of the first generation biofuel development. According to this report between March 2007 and March 2008, global food price increased on average by 43%. During this time period, the change of price was wheat 146%, Corn 41%, soybean 71%, rice 29%, and oil 68%. Another report that covers from January 2005 until February 2008, indicated a rise in price of major food items (FAO, 2008a). According to this report, rice price increased by 62%, maize by 131% and wheat by 177%. During these times biofuel production showed swift increase particularly during 2007/8 as the result of increase in the price of petroleum fuel. One should bear in mind that biofuel production from food grains and edible oil is not the only possible cause of current rapid increases of food prices, but it is among the main contributing factors.

Different estimates were made on the contribution of biofuel to the current food price augmentation. Council of Economic Advisors suggested that retail food prices have increased by 3% in the year 2007/8 as result of biofuel. In contrast, World Bank estimated that as much as three-quarter of the rise in food price were attributable to biofuel (Mitchell, 2008). None of these estimates did consider however, the contribution of biofuel to fill energy imbalance that occurred at the same time period. In this respect biofuel neutralize the effect of energy shortage on food price increase. In general it is possible to say that the current increase in world food prices have not been caused primarily by biofuels, rather the drivers have been weather related such as short rain fails, and others like reduced global stocks, increased demand for food and feed from growing economies of some Asian countries and raise in petroleum price. However, competition between biofuels and food, as an end use of the some crops such as maize, wheat, rapeseed, and soybean or as an alternative land use like switch grass, castor bean, oil palm versus food crops, exert sever pressure over world food price over the coming few years. Thus, biofuel development should be carefully planed as with every one percent increase in the cost of food today leads to 16 million people be made food insecure (FAO, 2008a).

2.2 Resource competition of biofuel feedstock production

As biofuel industries grow, so does the argument over the merits and demerits of biofuels technology. Resource competitions for land to food production and other uses, water, agricultural inputs, are among the major concern of argument of biofuel development. Food security has multiple dimensions that including availability, access, stability and utilization and a key determinant of all is how access to land is distributed and controlled within society (FAO, 2007). Biofuel production from edible grains and vegetable oil bring about: a shift of large agriculture land to biofuel feedstock production; cultivation of reserve arable land to biofuel feedstock production that assumed to be used to feed rapidly growing word population; rapid encroachment of natural forest and biodiversity conservation areas; and competing water resources to human and livestock consumption and food crop production.

In 2006 an estimated 14 million ha of land was used for the production of biofuels and byproducts, which is approximately 1% of globally available arable land (IEA, 2006). Several analysis indicated projection of future land need for biofuel production. According to Searchinger et al. (2008) the demand for maize based ethanol from US alone will put 12.8 million ha under maize by 2016, thereby bringing 10.8 million ha new agricultural land into production. The growth of soybean cultivation in Brazil has been expanded from 3 million ha in 1970 to 18.5 million ha in 2003, with demand expected to increase further due to its use as biofuel feedstock (Bickel and Dross, 2003). During this expansion, in some areas inhabitants were displaced and this often lead to depopulation, with displaced farmers moving to peri-urban slums or to forest areas to clear new farm land. These (1) aggravate the problem of food insecurity due to agricultural land change to biofuel feedstocks production; (2) shrink reserve arable land and will harm the future growing population; and (3) cause large scale land use change. Finally, biofuel fail to achieve the anticipated objectives that are securing energy, reducing greenhouse gases emission and enhancing economic development of developing countries.

2.3 Conflict between biofuel development and biodiversity conservation

As defined in the proposed US Congressional Biodiversity "biological diversity means the full range of variety and variability within and among living organisms and the ecological complexes in which they occur, and encompasses ecosystem or community diversity, species diversity, and genetic diversity." Greater diversity at the levels of biological entity lead to greater plant productivity, more nutrient retention, and more stable ecosystem (Tilman, 2000). Several studies indicated that lower plant diversity lead to greater loss of nutrients from the soil through leaching and subjects ecosystem to loss of productivity through drought, disease and insect infestation (Tilman *et al.,* 2005). The major factors that contribute to lose of biodiversity are agricultural expansion, land degradation due to some natural and anthropologic events, deforestation, environmental pollution of water and land, invasive species, and climate change. The global dependence on fossil fuels has indirectly driven much of the loss of biodiversity (Tilman *et al., 2*005). These factors are interlinked and the exhibition of one factor can aggravate contribution of other factors in biodiversity loss. The expansion of agriculture accompanied with use of pollutants, clearing of forest areas, and cause environmental pollution, land degradation and emission of more greenhouse gasses.

The change of atmosphere chemistry which has caused global warming is one of the current driving force to the loss of biodiversity. Particularly the greenhouse gas emission by fossil fuel used for transportation sector is considered as a main source such gases. Hence, due emphasis has been given to substitute this energy by renewable energy that emit less greenhouse gasses. This concern brings about development of biofuels. From environment perspective, development in biofuel production presents great opportunities and challenges. The diversity of potential biofuel feedstocks create the opportunities whereas the present trend focus on few feedstocks particularly on first generation feedstocks is a challenge. Feedstocks particularly, on food and oil crops require more fertile lands and thus, drive encroachment of forest and woodland areas that maintain much of the world biodiversity.

Currently, the United States, Brazil, China, India and France are the top five ethanol producing countries (FAO, 2008b). By 2008 the USA and Brazil alone produced 15.6 billion gallon of ethanol out of 17.15 billion gallon of global production (Tilman et al., 2005). The European Union (EU) currently dominates world biodiesel production, led by Germany, France and Italy. Around 80% of EU biodiesel is produced from rapeseed (canola or mustard oil) (Bendz, 2006). The United State producing biodiesel primarily from soybeans is the world's second largest biodiesel producer (Bendz, 2006). According to Global Market Survey (2007) report the highest rate of biodiesel expansion is occurring in palm oil production in Malaysia and Indonesia, and these two countries produce 85% of the world palm oil. According USDA data of Foreign Agriculture (2007) about one quarter of the world's palm oil goes to industrial use, largely biodiesel. Now let us see the impacts of biofuel production on biodiversity in these global leading biofuel producing nations.

The United State "corn belt" where biofuel production is currently concentrated has a number of bioregions. Some of these bioregions are among the world most endangered ecosystem. The Upper Forest Savanna Transition, the Northern Tall Grasslands region and the Central Tall Grasslands are among the most productive eco-region on the earth. The central Forest Grassland Transition was one of the richer eco-regions in North America with large number of species. But most of the area of these eco-region are now cultivated for corn and soybean. As a consequence most of the native habitat is considered to be fragmented with high degree fragmentation (Tilman et al., 2005). However, many of these areas were significantly changed before biofuel production began. Some of this alteration is due to the production of the same crops that are now used for biofuel (maize and soybean). Report of International Crop Research Institute for the Semi-Arid Tropics (2007) indicated that by 2007 the United States had 135 active ethanol plants capable of producing more than seven billion gallons of corn based ethanol and plan to grow the annual production to 36 billion gallon generable fuel by 2022. This requires more land for production that exerts strong pressure on biodiversity conservation. One of the best indications is the situation at Nebraska where decline in conservation reserved land by about 6.5% in the year 2006/7 was observed (International Crop Research Institute for the Semi-Arid Tropics (2007)).

Mata Alantica, Cerrado, Amazonia, Pantanal, Caatinga and Pampar are the six unique ecoregions of Brazil. According to Valdes (2007) 381 species higher plants, 815 species of mammals, 114 species of birds, 22 species of reptiles and 6 species of amphibians are threatened. In 2006, Brazil had about 300 sugar cane ethanol mills with about 90 new mills planned by 2014 (Valdes, 2007). During this period the country had five biodiesel plants in operation and another five plants under development. Currently, Brazil use sugar cane in its bioethanol production and soybean with some palm oil and caster bean oil in its biodiesel production. Such supply of feedstocks requires expansion of arable land and involves the use of fertilizers and insecticides. Therefore, directly or indirectly exert pressure on biodiversity conservation.

As in the USA, land use change and its impact on biodiversity had been one of primary results of biodiesel boom in Brazil. Once the country's Mata Atlantica /Atlantic Rain Forest/ covered more than half a million square miles, but only about 7% remain (Mongabay, 2007) and much of that is severely fragmented. Report of Conservation International (2004) indicated that this area is known to be home to more than 60% of the country sugarcane and 85% of its ethanol production. According to this report nearly about 60% of the Cerrador's original vegetation has now been completely destroyed and Conservation International predicts that Cerrado could disappear by the year 2030. The situation at Amazon is also similar.

Like Brazilian forests, the tropical forest of Indonesia and Malaysia are among the most diverse ecoregions of the planet (Mongabay, 2007). The introduction of palm oil from its origin central Africa in the 19th century to these areas did not adversely affect the ecoregions until they have been cultivated as vast monoculture. Since the 1960s, palm oil plantations have been grown 30 fold in Indonesia and covered about 12,000 square miles by 2003 (Wakker, 2005). In Malaysia palm oil plantation increased by around 660% between 1985 and 2006. Since these expansion require more land, the biodiversity rich forest of both country were traded by clearing of land for palm oil and other commercial crop such rubber and pulp production. According to Wakker (2005) in Malaysia, 87% of the forest distraction between 1985 and 2000 was connected to the increase in palm tree plantation. This implies that biodiesel expansion at these areas bring about biodiversity reduction.

3. Threat and Risk Management of Biofuel Development in Ethiopia

3.1 Driving forces of biofuel development in Ethiopia

Ethiopia is an agrarian developing country with about 80 million populations. The annual population growth rate of the country is estimated to be about 2.7%. According to the National Bank of Ethiopia (NBE, 2006) after 2000 average agricultural productivity is increasing by 2.7% per year. Currently, the country is carrying out many construction activities such as real estate, roads, industries and hydropower dams. All these construction activities require energy and the national demand for fuel consumption is escalating. The country depends totally on imported fossil fuel for transportation sector. By 2008, the country imported more than one billion liters of petroleum, which costed about one fifth of the budgeted capital by the federal government of the country. Current increases of petroleum price and limitation of foreign currency has increased the country's expense for fossil fuel. This becomes a challenge to secure energy supply and to sustain the rapid economic growth of the country. Because of this, use of an alternate energy particularly for transportation sector which consumes about 70% of imported fossil oil become mandatory which this has led to biofuel development (Source…;).

The economic policy of the country is agricultural based industry which assumed to convey rapid economic growth and lead to the country to have middle income in the coming two decades. The ample human and land resources with limited capital are assumed to be the cornerstone of this economy policy. In its nature agricultural based industries endowed several manpowers during raw material production and the anticipated products. Biofuel industry is one of agri-industry that absorbs enormous manpower. Thus, creating job opportunities for rural community is the second driving force for biofuel development in Ethiopia. Beside these two main deriving forces, trade balance, interest of investors to involve in this sector, global greenhouse gas emission and global politics are some other driving forces with less significance than the first two.

3.2 Current status of biofuel development in Ethiopia

Biofuel development and utilization strategy had been formulated by Ministry of Mines and Energy in September 2007. The goal of the strategy is to produce adequate biofuel energy from domestic resources for substituting imported petroleum products and to export excess products. Ethanol is the first biofuel produced in Ethiopia. By 2006/7 the Ethiopia Sugar Development Agency produced about 8,000 m3 ethanol at Fincha Sugar Factory. The agency planed to produce about 128,165 m3 ethanol by 2012/13 fiscal year (Anonymous, 2007) from four state owned sugar factories. Sun biofuel (National biodiesel cooperation) first initiated the private sector biofuel development in the country by 2006. The company allocated the first land for biodiesel production from *Jatropha curcas* in Benshangul Gumuz regional state during this time period. Since then, according to data from Ministry of Mines and Energy a total of 64 local and international biofuel developers have been registered and have leased land for feedstock production in the country. Since September 2008 a total of 327,094 ha of land has been acquired by companies and about 42,500 ha of land has been acquired by out growers of 14 companies (MELCA Mahiber, 2008).

3.3 Current biofuel development in Ethiopia versus its strategy

As indicated in the strategy document (Art. 4.2) one of the general objectives of the biofuel development is to increase rural community income (objective No. 2) by creating job in feedstock production and other activities of biofuel production. In section five of the document (Principles for implementation of the strategy), to implement biofuel development it ought to ensure and/or support food security. In this section the strategy stated implementation of the strategy must ensure environmental sustainability such as biodiversity conservation. In contrast to these objective and implementation guideline, about 80% of land allocated is arable land, forest and woodland (MELCA Mehber, 2008) where high biodiversities and food crop production are occurring. This implies current biofuel development is not protecting biodiversity of the country. In the general objective (objective No. 3) and implementation principle (Art. 5), biofuel development of the country shall attempt to reduce greenhouse gas emission. This will not be achieved when feedstock production is taking place by clearing forest and wood. Regarding to this issue a typical study was done by Romijn (2009). Romijn (2009) carried out his study on Miombo woodland which is a tropical dryland ecosystem spanning 2.8 million Km2 of South Central Africa. The area is open woodland with 20-60% canopy cover. He studied the greenhouse gas emission if the woodland converted to *Jatropha* plantation. His result indicated that conversion of virgin Miombo woodland into *Jatropha* Plantation will definitely lead to increase greenhouse gas emissions compared to fossil fuel. Consequently, the scenario in which *Jatropha curas* is established on waste land is to result in considerable greenhouse gas emission saving whereas the substitution of natural forest and woodlands exacerbate the problem.

3.4 Major threats of biofuel development in Ethiopia

Although biofuel development is at an infant stage in Ethiopia, the rapid growth of its demand and investments has raised some concerns. Some of the perturbing signals that have been seen at this early stage will cause significant ecological, economic and social crisis unless cautiously amended. These worrying signals or threats of biofuel development in Ethiopia are not different from other part of the world. The most common threats have been discussed in the following sections.

3.4.1 Biofuel boom and food insecurity in Ethiopia

Ethiopia has a total area of about 1.1 million square kilometers which is equivalent to 110 million ha. The UN Population Division (2006) predicted that the current 80 million population of Ethiopia will reach 100 million by 2015, and will double by 2040. Among these current population 31.3% are living below the poverty line of US$ 1 a day, 42% are undernourished, and 35% of the children upto the age 5 are under weight. This implies many Ethiopians live in conditions of chronic hunger.

The agricultural production of Ethiopia is characterized as climate or nature dependent and its productivity is subsistence. Consequently small deviation of rainfall distribution causes significant starvation. The current 2.7% growth rate of agricultural productivity, which is equal to the annual population growth rate of the country will not solve the problem of food security. The severity of food insecurity becomes more challenging due to global climate change. The increase agricultural productivity and production requires the use of arable land in a sustainable way for food crop production and/or for other better options. The current biofuel development trend in Ethiopia is competing for lands that are used for food crop production. According to biofuel development strategy developed by Ministry of Mines and Energy (Anonymous, 2007) about 23.3 million ha of land has been identified as potential area for biofuel investment. This makes about one-fifth of the total area of the country. Using this much land for biofuel production in food unsecured country can be worrying.

Today, about 14 registered biofuel developers have participated as out growers that have acquired about 42,500 ha of land. Biofuel production of these companies is competing land for food production in two major ways. In the first case, the companies have leased potential arable land where future food crops production expansion is possible (MELCA Mahber, 2008). In the second case, the companies negotiated the local farmers to grow castor been **(***Ricinus communis* L.) on their farm lands to be bought with attractive price. However, the price that the companies provided to a 100 kg of castor bean was about 200 Ethiopia Birr. In the Biofuel Development and Utilization Strategy of the country the yield of this plant indicated to be about 750 kg to 1250 kg per ha. Taking the average yield which is about 1000 kg per ha per year and make simple analysis to compare with local dominant crops' total sale price (Table 1). This comparison indicated that production of castor bean on farmers land is not profitable.

Table 1. Total sale price comparison of castor bean and common food crops in Ethiopia

Crop Type	Average Yield ha^{-1} (quintal)	Current Market Price Per Quintal	Total Sale Price	Input cost (fertilize + seed)	Net loss ha^{-1} = total sale – (2000 + input cost)
Castor bean	10, 20**	200*	2,000, 4,000**	0	-
Maize	60		24,000	5000	17,000
Sorghum	20	600	12,000	300	9,700
Teff	12	100		3000	7,000
Wheat	24	650	15,600	5000	8,600
crops	10	450	4,500	450	2,000
Average	22.66	620	11,683.33	2291.667	8,860

N.B. Average yield of the competitive crops obtained from national mean productivity of the respective crops indicated by Central Statistics Agency, 2006; * Information from the company and ** mean yield of improved varieties in largest castor bean producer countries

3.4.2 Biofuel boom versus biodiversity conservation

According to biofuel developers list obtained from Ministry of Mines and Energy, more than 80% of the developers showed interest in biodiesel production form *Jatropha curcas* feedstock. Although *Jatropha curcas* has some advantage over other feedstocks such as castor bean, soybean, rapeseed and canola, it's utility for biofuel production has raised some anxiety. Some of these concerns are the result of miss implementation of biofuel development from the species, whereas some other concerns are due to inaccessibility to efficient technology. *Jatropha* is an arid and semi-arid plant and well adapted to lowland dry area. Large scale investment of *Jatropha* plantation for biofuel development may affect the dryland ecosystem and biodiversity.

3.4.2.1 Unique features and potential uses of dryland biodiversity

In this particular paper dryland refers to terrestrial regions where water shortage is a dominant factor limiting production of food crop, forage, wood and other ecosystem services. This includes dry sub humid, semi-arid, arid and hyper arid areas. These areas have global significance which include (i) support more than one third of word population; (ii) 70% of Africans depend directly on them for their daily livelihood; (iii) possess vital oil resources; and (iv) are habitat for enormous biodiversity which have high economic or potential economic value (FAO, 2001).

The origin of many of the earth's most important food crops are found in drylands. For example, corn, bean, tomato and potatoes originated from the drylands of Mexico, Peru, Bolivia and Chile, millets, sorghum, wheat and rice came from African drylands. To day these areas comprise large numbers of plant and animal species. For example, the drier part of Mediterranean biome of south west Australia has globally significant levels of plant species diversity including 2400 plant species which represent 1/6 of all Australians vascular plants (Judd *et al.,* 2008).

Ethiopia has large dryland area. Although, it is less studied and documented, the lowland of the country is habitat of many wild plants and animals and thus, high economic potential via sustainable harvesting of some products from the plants. For example, the dryland of the country is a habitat for diverse Oleo-gum bearing plant species which has potential of producing about 300,000 metric tones of natural gum (Tadese *et al.,* 2007). Dryland part of the country also consist many spice and medicinal plants, national parks, sanctuaries and many natural scenic beauties and thus important source of income through conservation campaigns, game hunting and ecotourism. Furthermore, the lowland part of the country is supporting large number of population and livestock. It is also an area where future food crop production will be expanded to feed the rapid growing population as the highland parts of the country is overpopulated and degraded.

3.4.2.2 Significance of dryland biodiversity to adapt global warming

The severe selection pressure of the drylands has selected plants for a large diversity of adaptive traits. These selection pressures include good traits for moisture stress, nutrient deficit, high temperature, and disease and pest incidence. To survive under this selection pressure dryland species developed their own coping mechanisms. Mongabay (2007) indicated that wild plants found in the arid zone are equipped with specialized mechanisms for either avoiding or tolerating drought and successfully adapt to harsh conditions. Recent, molecular studies on the wild plants has shown new light on unique features of their resistance mechanism, which are different from those found in model and/ or domesticated crop plants. Molecular studies of *Craterstigma plantagineum* enabled to isolate regulatory factors involved in the desiccation tolerance of this plant. The CDT1/2 gene family of this plant was identified to play an important role in the signal transduction for desiccation tolerance. Genes that codes such important traits are very important to develop tolerant resistance varieties to drought, salt and pests which will be a global strategy to adapt impact of global warming. Despite such potentials of dryland areas, current trend of land use change due to biofuel production is threatening the resources. Effects of some biofuel developers on biodiversity were indicated by prior workshops.

3.5 Impact of energy insecurity on food security and Ethiopia economy

Fossil fuel energy has been the cheapest and most convenient energy sources ever discovered by man. Mongabay (2007) indicated that within the next few years global production of oil will peak. He stated in his book "The Pary's over: Oil, War and the Fate of Industrial Society" the only significant choice human have will be how to reduce energy usage and make the transition to renewable alternatives. On the other hand, the demand for fossil fuel form some Asian and Latin America Countries is increasing from time to time resulting in growing prices (Andrew and Practical, 2009) and consequently: (1) in increase transportation cost of agricultural inputs such as fertilizer, pesticides and herbicides and increase cost of production which results in increasing food price; (2) in increase transporting (distribution) costs of agricultural product and make difficult food security and rise in food price; (3) in increase costs of pumping ground water that affect irrigation agriculture; (4) in increase cost of mechanized agriculture and consequently increase food price; and (5) in affecting resource allocation for agricultural research and development. Finally, these and other impacts of energy insecurity can convey or bring about inflation that retard economic development, and less job opportunities. Hence, paradigm shift in energy source is a must, but it should be in line with achieving food security of the present and future population, sustainable land use and land resource utilization such as the wildlife, forest and woodland resources, and water with very little negative impact on the environmental.

Table 2. Summary of major threats, their consequence and way forwards of biofuel development

Major threats	Consequences of the threats	Means of risk management
<u>Impact on food security</u> ▪ Shifting farm land of food crops to biofuel feedstock production ▪ Use arable land potential for expansion of food crop production ▪ Removing wild food plants and relatives of domesticated food crops ▪ Compete agriculture inputs such as fertilizer and water	▪ Reduce present and future food production and aggravate food insecurity ▪ Affect food availability from wild plant and animals ▪ Loss of gene of important traits to improve food crops ▪ Increase fertilizer demand ✓ Affect price of fertilizer use by farmers of low income	✓ Eschew feedstock production on agriculture land by out growers ✓ Identify potential arable areas and barring it from use for biofuel ✓ Alternative options of land use (production of food crops for export and import fuel) ✓ Exploit feedstocks that give reasonable yield without fertilizer ✓ Utilize the by-product (seed cake) as fertilizer ✓ Using drought and pest tolerant genotypes
<u>Land use change</u> ▪ Convert forest and woodland to monoculture biofuel feedstock production ▪ Convert large community grazing area to biofuel feedstock crops	▪ Loss of biodiversity ▪ Make worse soil erosion ▪ Have an effect on local hydrological system ▪ Disturb ecosystem function ▪ Aggravate effect of global worming ▪ Loss of productivity ▪ Affect national income earning from export of forest and woodlands ▪ Infestation of sporadic pest and disease	✓ Keeping biofuel investment land allocation outside forest and woodland ✓ Linking biofuel development with rehabilitation of waste land

Table 2. continued.

Major threats	Consequences of the threats	Means of risk management
<u>Impact on biodiversity conservation</u> ▪ Encroachment of wild life conservation areas ▪ Land use change of biodiversity hot spot areas ▪ Deforestation of forest and woodland ▪ Risk of transgenic planting material	▪ Local and/ or regional species extinctions ▪ Imbalance of ecosystem function ▪ Conflict between wild life and human ▪ Affect tourism and related income generation sectors ▪ Affect genetic constitute of some plant species ▪ Some species may become invasive ▪ Increase greenhouse gas emission	✓ Identifying and conserving biodiversity hot spot areas ✓ Conserving target species ✓ Allocating biofuel investment area outside forest, woodland and biodiversity hotspot areas ✓ Domesticating economically important wild plants and use for commercial purposes ✓ Strengthen National biosafety (quarantine of planting material) ✓ Consecutive monitoring and evaluation of biofuel projects
<u>Environmental Issue</u> ▪ Soil erosion ▪ Pollution (water, air) ▪ Risk of monoculture ▪ Increase of salinity ▪ Infestation of new pests	▪ Decline land productivity ▪ Silt development in water bodies ➢ affect irrigation and aquatic biodiversity ▪ Affect human, livestock and wild life health ▪ Pest and disease occurrence may lead to land use change	✓ Shun erosion prone area from biofuel feedstocks production ✓ Linking biofuel development with soil and water conservation technology ✓ Use biological pest and disease management to control pests ✓ Avoiding use of forbidden pest and insecticides ✓ Use diversified feedstocks and planting materials of wide gene pool ✓ Strength frequent environment assessment

Table 2. continued.

Major threats	Consequences of the threats	Means of risk management
Social threats ▪ Displacement ▪ Less of income generating by out growers ▪ Affect land tenure	▪ Cause conflicts ▪ High population movement to peri-urban area ▪ Food insecurity ▪ Affect future technology adoption ▪ Poor land management by farmers	✓ Large scale biofuel development should exclude settled areas and farmer lands ✓ Discontinue feedstock production on agriculture land by out growers
Some other concerns ▪ Organization Structural ▪ Knowledge gaps ▪ Less emphasis of research and development contribution ▪ Lack of implementations, monitoring and evaluation plans, standards and protocols ▪ Lack of national short term, medium term and long term achievable quantified biofuel production objective ▪ Lack of comprehensiv ▪ Less legal protection to foreign investors ▪ Misleading of investors by their consultants ▪ Biosafety of the workers and the nation	▪ Affect overall efficiency and effectiveness of biofuel development in the country ▪ Miss match of site to feedstocks ▪ Poor management of the whole production system ▪ Lack of high yielding and stress tolerant varieties and feedstocks ▪ Promotion of unevaluated technology ▪ Weak implementing efficiency by developers ▪ Weak feedback to amend the problems ▪ Allocation of land regardless of its use potential ▪ Utilize investors' property including land and money for their own use by some managers and workers ▪ Use of toxic varieties and unquarantined planting materials and so on	✓ Structuring different alternative energy programs under umbrella of alternative energy development ✓ Strengthen research and development ✓ Strengthen manpower by short term and long term training ✓ Develop implementation, evaluation and monitoring plans, standards and protocols ✓ Quantify national biofuel demand in short term, medium term and long term period ✓ Develop comprehensive national land use potential data ✓ Provide legal protection to foreign investors ✓ Develop national biofuel data base in respect to investors key need to provide ample and appropriate information ✓ Strengthen national and regional biosafety control.

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THE IMPACT OF *Prosopis juliflora* INVASION ON FEED RESOURCES AND LIVESTOCK FARMING IN AMIBARA WOREDA OF AFAR NATIONAL REGIONAL STATE

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Abstract

This study was conducted to assess the impact of the invasive woody plant, Mesquite (Prosopis juliflora) on feed resources, livestock farming and pastoralist livelihood in Amibara woreda of Afar Regional state. Mesquite (Prosopis juliflora) is an evergreen tree native to South and Central America. It was first introduced in Ethiopia some twenty five years ago. It is thought to have been introduced during the establishment of irrigation water development project at Middle Awash as wind break, shade and shelter. It is observed that Prosopis juliflora has been increasing in density as well as area coverage from time to time. The composition, density and frequency of endogenous browse and grass species of the invaded areas are diminishing due to its depressive effect. In addition, thickets of Prosopis limited access to waterways, paths and significantly affect the traditional mobility pattern. Its colonization on paths and temporary settlement areas poses a threat on livestock production and thereby on pastoral livelihoods. This paper summarizes pastoralists' and other local actors' perception towards Prosopis invasion and on policies/strategies gaps on Prosopis management and control. It also assessed the impact of Prosopis invasion on feed resources (grass and browse) and livestock farming, hoping that it would provide some clue for future development intervention in the control and management of Prosopis in Afar Regional state, particularly in Amibara woreda.

Key words: *invasion, pastoralists, perception Prosopis juliflora,*

1. Introduction

Afar Region is predominantly pastoral with 90% of its people dependent on subsistence livestock production. Livestock production in the Region depends on rain fed range, whose productivity appears to be declining as a result of recurrent drought, land degradation, encroachment by invasive plant species such as *Prosopis juliflora,* agricultural expansion and conflict (Esther and Swallow, 2005). Administratively, Afar Region is divided into 5 administrative zones which are sub-divided into 32 woredas. The *Prosopis* invasion exists in four of the five zones and 13 of the 32 woredas.

The invasive woody plant Mesquite (*Prosopis juliflora*), is an evergreen tree native to North and South America. It is an aggressive weed that causes great devastation to subtropical grasslands and is thought to have been introduced to Ethiopia during the establishment of irrigation water development project at the Middle Awash as wind break, shade and shelter (Abiyot and Getachew, 2006). It is observed that the species has been increasing in density as well as area coverage from year to year. Currently, this noxious tree is infesting agricultural as well as rengelands in the Region. The thorny nature of the plant, its remarkable ability to withstand adverse conditions, its non-browseable nature, and above all, the migratory way of life the Afar people have, paved the way for Prosopis juliflora to invade the most potential grazing and agricultural lands of the Region (Shetie, 2008), thereby impacting the livelihood of many involved in livestock and/or other agrictural production. Therefore, assessing the impact of such species on rural livelihoods will have significant importance for subsequent intervention programs. However, quantified information with respect to *Prosopis juliflora* invasion, particularly its impact on feed resources, livestock management practices and the pastoral livelihoods in Afar National Regional State (ANRS) is inadequate. To help in filling the information gap, this study was conducted in Amibara woreda of the ANRS. The specific objectives of the study were: to assess pastoralists and other local actors perception towards *Prosopis juliflora* invasion; to assess the impact of different levels of *Prosopis juliflora* invasion on dryland feed resources; and to assess the impact of *Prosopis juliflora* invasion on livestock mobility, herd structure and water resources.

2. Methodology

2.1 Study area

Amibara Woreda is one of the woredas of Zone 3 of the ANRS. It was selected for the study due to its being one of the most affected woredas with *Prosopis invasion*. Amibara Woreda shares boundaries with Dulecha Woreda and Awash Fentale Woreda in the West and South West; Awash Fentale Woreda and Oromia Regional State in the South and South East; Somali and Oromia Regional States in the East and Gewane Woreda in the North.

The Woreda is characterized by high temperature and low and erratic precipitation. The mean annual temperature of this area is 27.6ºC, and maximum temperature reaches 39°C in June, whereas the minimum temperature is 15°C in November. The mean annual rainfall is 562 mm and the mean annual relative humidity ranges from 40% in June to 59% in August, indicating that June is the hottest month and August is the wettest month of the year in the study area (WAS, 2006). The land area of Amibara Woreda covers 17% of the tolal land area of the ANRS. Amibara Woreda has a land area of 2941 km^2 and human population of 63,280 and and has population density of 13.7 persons / km2. The livestock population of the woreda is estimated to be 103,959 cattle, 122,526 goats, 48,043 sheep, 3888 donkeys, 39,995 camels (CSA, 2005).

2.2 Data collection and analysis

For community survey, three kebele were selected based on *Prosopis* invasion level. Accordingly, Serkamo kebele (highly invaded), Buri (moderately invaded) and Halidebe kebele (little /none invaded area) were selected. The invasion level of selected kebeles was determined based on the information obtained from development agents and discussion held with key informants. This was because information regarding *Prosopis* invasion was not available at Woreda Administrative Council or at Woreda Pastoral and Agro-pastoral Office. Lists of household heads of selected kebeles were obtained from elders in the respective kebeles. Formal survey was administered on randomly selected 90 households, thirty households from each kebele. Three group discussions (one at Buri and the remaining two at Serkamo kebele), and key informants discussions with elders, farm workers, extension agents and experts were held during the study.

Regarding the feed resource sampling, reconnaissance survey and transect walk was made to assess the intensity of *Prosopis* invasion on different land use types, before actual field data collection. Trunk circumferences of major browses were measured in the field for biomass yield estimation, and identification of feed plants was also made in the field. Those which cannot be identified on the field were collected and transported to Haramaya University for further identification and chemical analysis.

3. Results

3.1 Perception on *Prosopis juliflora* invasion

Prosopis juliflora was welcomed by pastoralists in Amibara during its introduction, attracted by its ability to reproduce and grow fast even in moisture stressed environments. Latter on, pastoralists developed a negative attitude towards Prosopis due to its fast expansion in grazing areas and its reported allelopatic effect. Pastoralists in Amibara Woreda today prefer to see complete eradication of *Prosopis*. *Prosopis juliflora* has colonized vast areas of rangelands and crop fields in Amibara woreda. Thickets of *Prosopis* limited access to water points and reduced size of grazing areas, and made conditions difficult for animals to graze. It also caused health problems both to human and livestock. Pastoralists interviewed emphasized the negative side of Prosopis outweighs the benefit obtained from it. According to Shetie (2008) about 76% of the pastoralist and agro-pastoralist respondents have negative attitude towards the plant. Majority of the respondents have recommended for its complete removal. But in the current study 100% of the respondents recommended the complete removal of Prosopis from the woreda.

Ato Mohamed Ibrahim, a pastoralist and resident in Buri kebele said "Prosopis" has increased conflict between Afar clans; individuals now shot each other for charcoal and/or money. Some clans try to make territory on the traditional communal land to get more money, which was not in our culture. Prosopis has destroyed our local trees and grasses directly by its allopathic nature and indirectly through money people get from charcoal making, A practice, which was discouraged in the area until recently was promoted as a means to control *Prosopis* on the rangelands. Our fathers used to punish a person who cut live trees for fuel wood or other purposes, only dried and fallen trees were used for many purposes. Today this culture was forgotten by few clans, and respected indigenous trees like Adayto and Gersa have been cut down for fuel wood consumption and for charcoal making. Charcoal makers use other important local plants to tie up charcoal sacks, thus, the remaining plants not used for charcoal making have been damaged due to this practice. Furthermore, a place once used for charcoal making will be of no more use. Even if, monthly I earn about 2000 Birr from charcoal sell, I still would prefer the complete eradication of *Prosopis* from our land".

Unlike pastoralists, experts and development agents do not perceive *Prosopis* as a devastating plant. Ato Gobena Hailu, a technical assistant at Worer Agricultural Research Center put his view as "I don't believe that *Prosopis* is a threat to the pastoral livelihood or for biodiversity in Amibara. Many tropical countries like India have been getting benefits from Prosopis. If it is properly managed, Prosopis could play a vital role to combat desertification in Ethiopia. It can provide feed for animals, timber and pole for construction and even the Prosopis invaded areas could be used for beekeeping. The only thing needed is proper and integrated management practice, to mitigate the current threats of *Prosopis* on the pastoral livelihoods." On the other hand, commercial farmers see the plant as a notorious weed that increases cost of weeding and machine operation. They also blame *Prosopis* for harboring insects like 'red spider' which highly affects cotton plant. Indeed they consider prosopis as a threat for middle and lower Awash irrigation schemes that increases their expense to control it. According to key informants "the Awash basin development authority hired about 15 people for a day to avoid *Prosopis* establishment on irrigation schemes around Melka Worer area."

There are differences in views between researchers and extension workers on the one hand and pastoralists on the other regarding *Prosopis* control as well as on management options to combat its expansion. In fact, unlike pastoralists, all development practitioners do not agree complete eradication of *Prosopis* from the Region. The use of *Prosopis* for commercial farms as a live fence is quite inevitable; on the other hand its negative impact on pastoralist livelihood is undeniable. Such differences in perception among pastoralists and local actors would therefore, make *Prosopis* control endeavors difficult.

3.2 Changing pattern of livelihood options

Result obtained from formal survey (Table 1) showed the change in livelihood means of pastoralists in Amibara. Despite dissimilarity in livelihood means of pastoralists in each selected kebeles, the livelihood means of pastoralists is increasingly pursued on other activities rather than livestock production. To mention the least, the primary livelihood means in Serkamo (highly invaded kebele) is land renting, whereas in Halidebe (none invaded kebele) primary livelihood means is crop production. Livestock production is the second livelihood means in two of the selected kebeles for the study (Serkamo and Halidebe). Other researches that have been carried out in the same area also support this fact. Bekele and Padmanabhan (2008) point out that the traditional land use arrangement in Afar pastoralists are being transformed due to many factors. For instance, the change in environmental conditions has influenced the change in pastoral livelihoods. This scenario is a reminder to policy makers and development organizations to amend their action plan and to identify the current status of targeted beneficiaries, to be successful, either in *Prosopis* control program or any other development activity in Amibara.

Table 1. Household income source of respondents

Livelihood means	Halidebe N=30						Buri N=30						Serkamo N=30					
	Livestok		Land rent		Crop		Livestock		Land rent		Crop		Live-stock		Land rent		Crop	
	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%
Primary	3	10	2	7	**25**	**83**	**24**	**80**	5	17	1	3	5	17	**24**	**80**	1	3
Second-ary	**27**	**90**	3	10	0	0	5	17	**16**	**53**	0	0	**20**	**67**	7	25	3	10
Tertiary	0	0	12	40	0	0	0	0	4	13	0	0	3	10	2	7	25	83

Fr= frequency N= Number of respondents

Various reports indicated that *Prosopis* plays a leading role in the afforestation of arid lands. Its capability to grow on degraded land under arid conditions has made it especially suitable for this purpose. Being a multipurpose tree, *Prosopis* plays important role in dryland agroforestry systems, controlling soil erosion, stabilizing sand dunes, improving soil fertility, and reducing soil salinity. Besides providing wood for fuel, and forage for animals, it could supplement food for humans and it is known to be good bee forage (Pasiecznik *et al,* 2001; Esther and Swallow, 2005). However, pastoralists in Amibara do not agree with the above mentioned uses of *Prosopis*. They argue that, fence made from *Prosopis* pole could not serve even for a single year. A traditional house made from *Prosopis* starts shading powder before serving for a year. The powder from the plant resulted in many eye illness to humans. Even its importance as a shade is not appreciable, because it harbors a biting insect locally known by the name 'Andela' and its thorny nature makes it hardly preferable. Pastoralists in Amibara do not deny its role as a fuel wood. The above mentioned drawbacks arise on its utilization however, hindered its role for pastoralist livelihood.

While conducting this study, the negative perception of pastoralists towards *Prosopis* was a challenge to enlist any benefits obtained by each household from *Prosopis.* Ultimately, through successive probing of respondents, group and key informants discussions, benefits provided by *Prosopis* for the community were listed, ranked and summarized (Table 2).

Table 2. Benefits obtained from *Prosopis juliflora*

Uses of Prosopis	Rank	Remark
As animal feed	4	It causes metabolic disorder, emaciation, etc.
Shade	7	Thorn causes injury, harbors biting insects
Fuel wood	1	Excellent
Charcoal	2	Excellent
Barn construction	5	Lack durability
Bark	3	Excellent use as a rope
Fence	6	Lack durability

3.3 Impact of *Prosopis juliflora* on feed resources

Prosopis juliflora replaced the local biodiversity in several spots of Amibara woreda, mainly in open grass and open shrub lands; threatened state and private farms; colonized water points and riversides. Various researches stated that *Prosopis* has a negative impact on pasturelands or arable fields because it responds positively to overgrazing. Denuded grassland ecosystems are subsequently converted to unusable bush lands. The invasion is aggravated by the aid of different dispersal agents such as wild animals, cattle, camels and goats (Hailu *et al.,* 2004).

In highly Prosopis invaded grazing areas of Amibara Woreda, it is difficult to observe any plant that could be used as a feed. For example, the number of plants used as livestock feed in open none invaded grass land were 40, and this number declined to 10 in moderately invaded open grass lands. The area within the canopy of *Prosopis* trees is almost bare, especially highly on invaded areas, unlike that of areas within the canopy of indigenous trees (personal observation). This may be due to the competition between *Prosopis* and herbaceous plant species for soil moisture and sunlight, which resulted in low production of the later found within *Prosopis* tree canopy. Moreover, other factors such as allelopatic effects from litter and livestock seeking more fresh and nutritious grass species could have influenced the grass cover and production of biomass within the canopy zone than in the nearby open areas (Tobosa *et al.,* 2006).

According to Shiete (2008), the distribution of *Prosopis* has increased in dense *Acacia woodlands,* forest lands (i.e., riverine forests) and agricultural lands of Amibara, due to repeated stumping of the plants or dissemination of seeds by browsers like camels and goats. Results obtained in this study also showed that *Prosopis* infestation rate is higher in open shrubland than any other land use types. Another study (Zeray, 2008), has also revealed that majority of the pastoralists in Amibara (85% of the respondents) assume that a half to three fourth of their pasture land were lost due to *Prosopis* invasion.

Valuable browses and grasses have been disappearing due to *Prosopis* invasion (Table 3). However, species that have disappeared in the *Prosopis* infested areas are still in existence in areas that are not yet infested by *Prosopis* (group discussion, Hallidege). Thus, *Prosopis* invasion indiscriminately affects all livestock species (browsers and grazers) in two ways; one by its suppressive impact on understory herbaceous growth and secondly by denying access to browsing and grazing areas. These grasses and browses are basically main feed items, and their unavailability will influence the livestock production system of the area.

The density of *Prosopis* differs in different land uses. The mean density was higher in open grassland which is 4800/ha and was lower in dense bushland 200/ha. But, regarding species composition, highest feed species composition was observed on none invaded open grasslands (Fig. 1), while the lowest was found in dense shrublands. Three levels of invasion have only been observed in open grassland from all land use types assessed during the study. There was no highly invaded dense shrubland as well as there was no open shrubland not invaded by *Prosopis* (Fig. 1). This result showed that *Prosopis* invasion has become one of the constraints that lower productivity of main grazing areas which can support livestock production as a source of feed and fodder. The reason why density of *Prosopis* was lower in dense shrublands (highly dominated by *Acacia senegal*), and higher throughout the open shrublands, needs further investigation.

Table 3. Endangered plants due to the invasion of *Prosopis juliflora*

No.	**Local names**	**Scientific names**	**Habit**
1	Adayto	*Salvadora persica*	Shrub
2	Gersa	*Dobera glabra*	Tree
3	Geronto	*Acacia oerfota*	Shrub
4	Hedayto	*Grewia tenax*	Shrub
5	kesolto	*Acacia nilotica*	Tree
6	Mederto	*Cordia Sinensis*	Tree
7	Eebto	*Acacia tortolis*	Tree
8	Ouda	*Balantles aegyptica*	Tree/shrub
9	Sagento	*Tamarix aphella*	Tree
10	Mellif	*Andropogon canaliculatus*	Grass
11	Is-isu	*Cymbopogon pospischilii*	Grass
12	Rareta	*Cynadon dactylon*	Grass
13	Keato	*Sedge species*	Grass
14	Koruff	*Tetrapogon villous*	Grass
15	Afaramole	*Lintonia nutans*	Grass
16	Hallel	*Ipomoea sinensis*	Forb
17	Bounkut	*Tribulus zeyher*	Forb

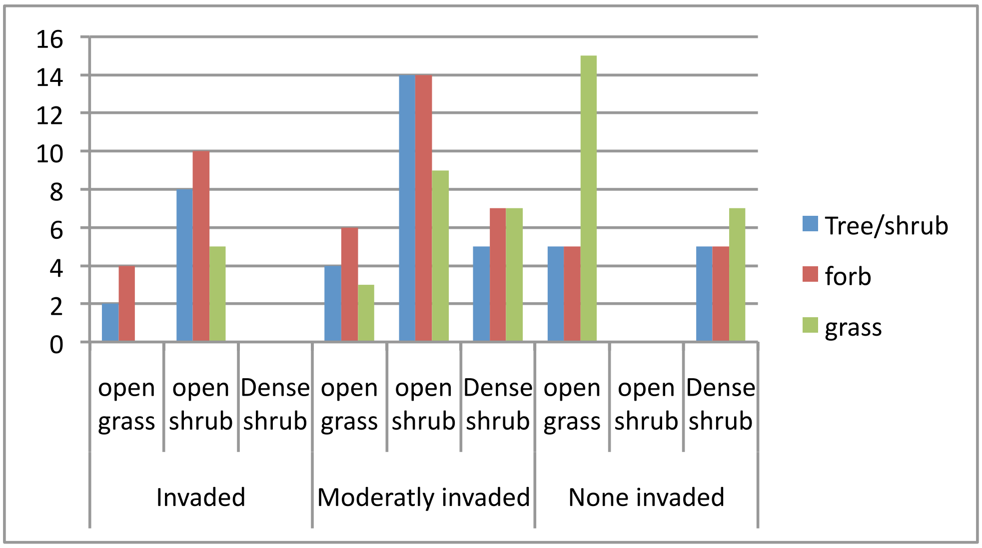


Fig. 1. Fodder/feed plants composition at different level of *Prosopis juliflora* invasion

3.4 Impact of *Prosopis juliflora* on livestock management practices

Prosopis invasion heavily threatened the livelihood of Amibara pastoralists. Its encroachment on water points has direct and indirect consequences. Directly, it causes loss of drinking water and indirectly increased predators attack on livestock by narrowing paths which leads to the water points. It also affects the traditional livestock mobility by closing paths and colonizing temporary settlement areas. Impenetrable thickets of *Prosopis* makes longer walking times to get to a desired destination and difficulty of walking at night; thus searching and getting for a lost animal from the herd is impossible in *Prosopis* invaded areas (group discussion at Buri kebele).

According to Senait et al (2007), *Prosopis* has seriously affected livestock health in Amibara Woreda. Intoxication of cattle after consumption of *Prosopis* pods has been reported in Brazil. Clinical signs, which are more prominent during eating and rumination are characterized by masseter muscle atrophy, involuntary movements and protrusion of the tongue, a dropped (slack) mandible, and tilting of the head during chewing. The disease also occurs spontaneously in goats. Clinical signs in goats were characterized by twitching of the lips, head tremors, salivation, and emaciation (Tabosa et al., 2006). The above noted clinical signs were also observed in Amibara when livestock species consume *Prosopis* pods particularly during the dry season. During group discussions pastoralists indicated that the neck of animals will be twisted when fed *Prosopis*, and eventually results in death of cattle, sheep and camel. The thornes of *Prosopis* penetrating into the skin of animals causes more physical injury than local Acacia thornes. Specially, camel cannot withstand *Prosopis* thornes as it used to thornes of local browses. A camel pierced by *Prosopis* thorne is unable to graze by walking around the range; curing the wound is difficult if not impossible, therefore, it will finally kill the animal. Camel calves who consumed Prosopis leaves happen to die immediately. According to pastoralists, the most susceptible species to *prosopis* is camel. In Prosopis invaded areas of Amibara, it became difficult to herd camel. Table 4 shows the diseases and injuries caused by consumption of *Prosopis* pod in their order of importance based on the results of group discussion.

In reality, *Prosopis* pod is not preferred by animals if there is appreciable amount of feed in the surrounding. That is why, animals who consume *Prosopis* suffer less during wet seasons, and this fact shows that forage development activities could alleviate disease and injury problems associated with *Prosopis* consumption.

Table 4. Diseases and injuries caused by consumption of *Prosopis juliflora* pod

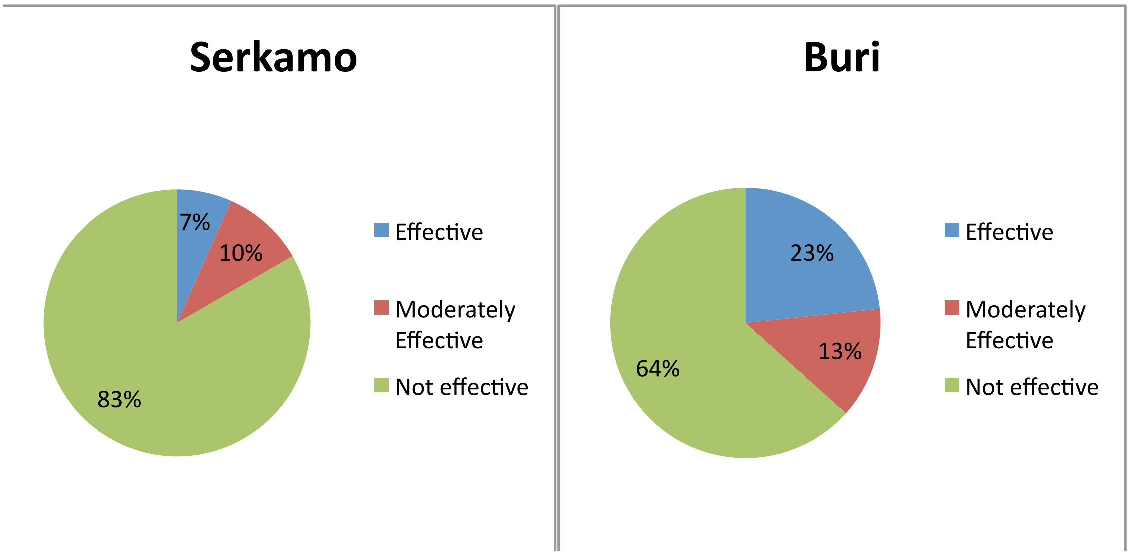
Diseases/ Injury	**Highly affected animals**	**Rank**
Twisted (wry) neck	Cattle, goat	4
Diarrhea	Cattle, goat, sheep and camel	1
Constipation	Cattle, goat, sheep and camel	3
Wound by thorns	Camel	2
Loss of appetite	Goat, sheep	6
Emaciation	All	5
Death	Kid, lamb and calf	7

3.5. Policy and strategy gaps

Government policies can shape responses to invasive species. Government policies may create incentives or disincentives that affect how people utilize invasive species and the extent of utilization (Perrings *et al*., 2002). Appropriate and integrated strategy is quite inevitable and urgent to curb *Prosopis* invasion into new areas. Lots of attempts have been implemented by different organizations, to minimize the expansion of *Prosopis* into new areas or to mitigate its negative effect on pastoral livelihoods as well as on biodiversity. However, most of the *Prosopis* control endeavors neglected or did not mention the role of clan leaders in their action plan; despite clan leaders having the power to mobilize the pastoral communities. Majority of the respondents did not believe that the *Prosopis* control endeavors implemented by different organizations in Amibara are effective (Fig. 2). 'In the absence of joint community rules for management and/or control of *Prosopis*, it is unlikely that individuals will invest in controlling and/or eradicating *Prosopis* in the communal grazing lands' (Esther and Swallow, 2005).

Most of the programs/projects aimed to control *Prosopis* invasion in Amibara, mainly focus on cutting down or clearing of *Prosopis* from the already invaded areas. Methods used to reduce the expansion of *Prosopis* to none invaded areas or other potential uses of invaded areas were seldom incorporated in their action plans. Moreover, the control methods they intend to implement were not stated well for different land use systems. For example, a joint *Prosopis* control program which was designed by FARM Africa *Prosopis* control program and Amibara woreda pastoral office in October, 2009 has planned to clear 50 ha of *Prosopis* invaded land within a day. But, the project did not mention specific site where the campaign is going to be held, how it gets priority and for what purpose it could be used in the future. Furthermore, owner of the land and the owner's responsibility or role to avoid reinvasion was not mentioned clearly (FARM Africa, 2009).

Fig. 2. Effectiveness of previous *Prosopis* control programs



The draft plan prepared by Ethiopian Institute of Agricultural Research in March, 2009, has similar shortcomings. The draft action plan did not consider pastoralist way of life (mobility) in its *Prosopis* control programme. For example, oversowing of indigenous plants on the rangelands to restore local plant species was intended to be done in June and July months, while at this time, livestock from all corners of Amibara will be gathered at Hallidege (the main areas that needs rehabilitation) for wet season grazing. Therefore, the effectiveness of the draft action plan to rehabilitation or replacement of native plant species will be in question. In addition, places which were indicated in the action plan for *Prosopis* control program implementation (areas around Worer Agricultural Research Center) are farm and settlement areas, which have limited the role for livestock production. Thus, pastoralists would benefit little from the plan, and its role in the conservation of biodiversity would be minimal, unless some amendments are made on the action plan. The above mentioned and other *Prosopis* control strategies could not address or mitigate the threats posed by Prosopis on pastoralist livelihoods.

4. Conclusion and Recommendation

Without proper plan, and well designed strategies prepared by the collaboration of all stakeholders, the conversion o**f** *Prosopis* invaded lands back to its original condition or maintaining local biodiversity, and mitigation of *Prosopis* threats on human/livestock health, would be very difficult and very costly in terms of money, time and logistic resources. Therefore, considering the following points; while preparing *Prosopis* invasion control plans will be helpful to address problems, which have been threatening the pastoralists and their livestock.

- *Prosopis* control measures must involve all stakeholders, consider socio-cultural settings, livestock mobility, and should consider clans and land use types (e.g., levels of invasion).
- There is a marked, but recent shift in livelihoods options. So*,* *Prosopis* control strategies or any other development interventions should look into the emerging economic scenario before implementing previous action plans on the ground or while preparing new development pla*ns.*
- Perception differences between pastoralists and local actors towards *Prosopis* need to be reconciled for effective management program. Communities see Prosopis as enemy that must be eliminated, whereas development practitioners are still looking for ways that could reduce the existing threats of *Prosopis* on

- livelihoods and maximize its role. These arguments need to be compromised.
- Designing utilization options /potential uses/ of invaded areas *per se* would minimize *Prosopis* control costs.
- Though, land ownership is clan based, most of the *Prosopis* control programs did not consider the clan scenario around invaded areas prior to their action. So, participating clan leaders in the *Prosopis* control programs might help to get better results.
- The purpose/future use of areas cleared from *Prosopis* should be known ahead of implementing control actions, to avoid unnecessary cost due to reinvasion of cleared areas.
- Methods of indigenous plants propagation and best ways of planting them on degraded lands should be studied for successful rehabilitation.
- Without participatory appraisal of plans and well designed strategy, the conversion of *Prosopis* invaded fields to original crop fields and efforts to minimize or eradicate Prosopis threats on human/livestock health would be very difficult.
- Rehabilitation of degraded grazing lands and forage development programs can help to maintain the existing range as well as to curb *Prosopis* expansion into new areas, because Prosopis has positive correlation with degradation.

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