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Production and Challenges of gum arabic in Ethiopia: Review

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Abstract
In Ethiopia gum arabic are collected from *A. senegal* and *A. seyal,* having large potential for production. However, obtaining precise quantitative information on actual annual production by gum type in the country is difficult because of poor documentation, parallel trade across borders and lack of forest product control offices. The aim of this review is to present the current existing situation of gum arabic production and its challenge in dry lands of Ethiopia and suggest possible measures. The review data has been obtained from electronic web knowledge, Scopus, Google Scholar and Science Direct databases. The study indicated that, gum arabic production mainly from natural exudates and tapping practices. Collection from natural exudates, tapping practices reduces and increases the quality and quantity of gum arabic product respectively. Many analyses show that, around 30,000 metric tons per year of natural gum production potential in Ethiopia. The contribution of gum arabic collection can be employment, income diversification, use as emergency food and support livestock production. Moreover, it could be help to fight against desertification and soil erosion, conservation and enhancement of biodiversity, improve soil fertility and provide opportunity for carbon sink. However, the problems of gum arebic are lack of infrastructure, deforestation, overgrazing resettlement, human induce fire, land use change, lack of quality awareness, uncontrolled trade and a sluggish transaction in export trade. Finally, the stockholders involvement need as intervention for maximization of gum arabic production, commercialization and farther value add processing in the country.
Keywords: Acacia senegal, Acacia seyal, Gum arabic, production

Introduction

Ethiopia is one of the countries well endowed with various species of *Acacia*, *Boswellia* and *Commiphora* that are known to produce gum arabic, frankincense and myrrh, respectively. Available estimates of the total area of oleo-gum resin bearing woodlands cover about 3.5 million ha of land in the country, with over 30,000-33,000 metric tons of natural gum production potential [Lemenih [1], 2]. According to different study report, gum and resins production are playing significant economic role both at the local and national level today in Ethiopia, and their contribution is growing every year [3-5].

Several recent studies indicated that the actual and potencial socio-economic, and ecological services obtained from gum and gum resin yielding species and the role they play in the livelihood of local society and nation at large is very significant [4, 6-8]. For instance, collection of gum-resin and sale was provide an income equivalent of 80 USD/household/year in the Liban zone of Somali National Regional State of Ethiopia; which ranked second after livestock in the livelihood of the pastoral community living in the area [4].

From gum-resin products one of exporting product in Ethiopia is gum arabic which is non aromatic gum and resins and in some reports refers to the gum collected from *A. senegal* (gum arabic) and *A. seyal* (gum talha), though the two are clearly collected and delivered separately since they are purchased on a different price basis [2, 9, 10]. Gum arabic from *A. senegal* is collected from two varieties in Ethiopia namely *A. senegal* var. *kerensis,* and *A. senegal var. senegal*. Areas in Ethiopia with good stocks of *A. senegal* and *A. seyal* are found in western, southern and south-eastern lowlands in areas often referred to as the 'gum belt'Lemenih and Kassa [11].

The major source of gum arabic (95%) is *A. senegal* (hashab), with the remaining 5%, from *A. seyal*, (gum talha) sold as an entirely separate product in Sudan [12-14]. However, in Ethiopian case the major source of gum arabic *A. senega*l it comprises about (70%) and *A.seyal* about 15-25% the remaining 5% collected from *A. polyacantha* and *A. drepanolobium* which is relatively low quality compared to the above species [10]. On the other hand, Alem [15] showed that the estimated potential of gum arabic obtained from *A. senegal* comprises about 52% and *A. seyal* 48% in Ethiopia.

However, the major gum producing species are declining both in terms of size (deforestation) and quality of stands (degradation) at an alarming rate associated with expansion of crop and livestock production as well as human settlement, overgrazing, fuel-wood and charcoal production and anthropogenic fire [3, 4, 16]. Moreover, the production and marketing of gum arabic is further constrained by remoteness of the woodlands, lack of roads, and inadequate transport facilities to the potential production areas [3]. For this end, the rationale of this review

is to present the current existing situation of gum arabic production and its challenge in dry lands of Ethiopia and suggest possible measure.

Gum arabic

The term `gum arabic' was coin by European traders, who imported the products from Arabian ports such as Jeddah and Alexandria, and most gum traders of the time were associated with Arab countries [17]. It is a pale to orange-brown solid, which breaks with a glassy fracture. The best grades have the shape of whole, round tears, orange-brown in color and with a matt surface texture; after processing to the broken or 'kibbled' state the pieces are much paler and have a glassy appearance[18-20] (Plate 1).

Photo 1: Gum arabic from *A. senegal* in Ethiopia (Source: [21]

The properties of this gum arabic is the combination of high solubility in water and low viscosity confers and it's highly valued emulsifying, stabilizing, thickening and suspending properties[22]. It contains neutral sugars (rhamnose, arabinose, and galactose), acids (glucuronic acid and 4–methoxyglucuronic acid), calcium, magnesium, potassium, and sodium [23, 24]. Finally, this gum arabic comes from gum cysts which develop in the bark Acacia species trees, in the tangential rows of the axial parenchyma strands of the phloem adjacent to the cambial zone [25].

Uses of Gum Arabic

Gum arabic is unique and natural product which is used extensively in *pharmaceutical preparations, food industries* such as in confections and sweetmeats, in the cosmetics industries, and for other industrial products such as *ink, paint, paper, matches* and *ceramic*,[23, 26]. Gum arabic is used in the food industry to fix flavours and as an emulsifier, to prevent the crystallization of sugar in confectionery products, as a stabilizer in frozen dairy products; its viscosity and adhesive properties find use in bakery products, and as a foam stabilizer and clouding agent in beer [27].

In the pharmaceutical industry gum arabic is used as a stabilizer for emulsions, as a binder and coating for tablets, and as an ingredient in cough drops and syrups[28]. In modern pharmacy, it is commonly employed as a demulcent in preparations designed to treat diarrhea, dysentery, coughs, throat irritation, and fevers. It serves as an emulsifying agent and gives viscosity to powdered drug materials; is used as a binding agent in making pills and tablets and particularly cough drops and lozenges [23].

Gum arabic is used in cosmetics as an adhesive for facial masks and powders, and to give a smooth feel to lotions. Industrially, gum arabic is applied as an adhesive, as a protective colloid and safeguarding agent for inks, sensitizer for lithographic plates, coating for special papers [28].

Natural gum arabic production potential in Ethiopia

Estimates show that, the total area of gum and resin bearing woodlands cover over 3.5 million ha of land in Ethiopia, of which about 30,000-33,000 metric tons of natural gum production potential. Out of the total estimated production, over 10,000 tons is export from our country [1, 2]. According to different scholar findings, estimated production potential of gum arabic is very high coverage in all region of the country (Table 1). However, obtaining precise quantitative information on actual annual production by gum type in the country is difficult. Several offices and private enterprises visited clearly indicated that, acquiring reliable data on annual

production of gum arabic produced in the south and southeast parts of the country are difficult. This is due to:

- Poor documentation from purchasing enterprises and producers.
- Borders trade with neighboring countries.
- Absence responsible office to quantify and/or control the production processes.
- Open access collection and uncontrolled trade of the product [1].

Table 1: Estimated potential annual production of gum arabic in Ethiopia

No	Regional state	Estimated production potential (tons)
1	Afar	6,000
2	Amhara	18,000
3	Beneshangule	7,000
4	Ethiopia Somali	No data
5	Gambella	11,000
6	Oromiya	10,000
7	Tigray	21,000
	Total	**73,000**

Source: [9].

Production and Handling of gum arabic

Production of gum arabic

Production and harvesting is seasonal and performed solely during dry seasons. Production during rainy seasons is not recommended due to rapid quality deterioration in connection to high moisture content and physiological activities of the tree changed to vegetative growth [9, 29]. Today's gum arabic production system in Ethiopia can be sub-divided into two: Production by deliberately tapping and Collection on naturally oozing.

Production by collection on natural oozes

Collection for most of the gum arabic, particularly those produced in the south, southeast and central rift valleys are produced from collection on natural exudates [1]. There are two harvesting seasons for the southern production and this is due to the bimodal nature of the rainfall [4, 5]. The collection mostly carried out by cattle herders, women and children from tree trunks and branches. Collections are not restricted to gums on trees but also fallen pieces are picked often from the ground which deteriorate the quality of the product [5].

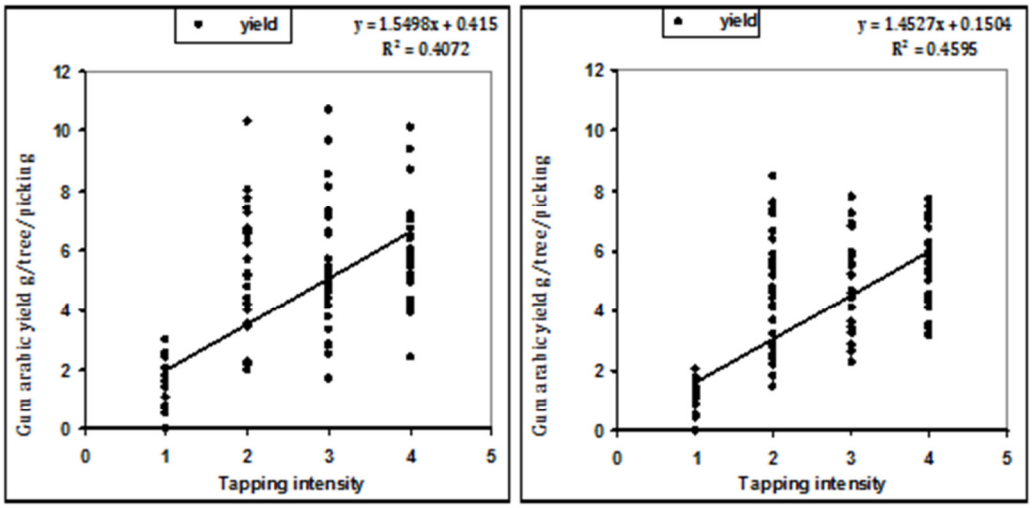
However, the production processes in the Borana differ from those in the northern part of Ethiopia in two perspectives. The first difference is in that while in the north artificial tapping is used for gum collection there is no such activity in the Borana. The second difference is the absence of organized collection i.e. cooperative form of collection which is most popular in some northern regions especially in Tigiray but, collection from natural exudation similar with that of southeast and central rift valley [7, 8]

The reason behind for the absence of artificial tapping is variably indicated. Some studies reported that abundance of the resources for the current market demand is more than enough so there is no reason to invest effort by tapping activities. Others reason is that farmers are unaware of the process of tapping for the production of good quality and quantity gum arabic [4, 5]

Production by deliberately tapping

Tapping is artificial wounding of stems and branches of trees for the production of gums arabic through shaving off the bark using sharp instruments, which are locally called Mingaf or Sonke [30]. The incision is done a length of 10-15 cm and width of 3 cm in the trunk of *A. senegal* tree [31]. Wounds are often made at the middle part of the tree on the eastern and western sides of the tree to allow sufficient exposure to sunlight for quicker drying of gums [32, 33]. When the stems and branches are blazed, gum begins to flow or ooze through the openings created by the wounds. These gum tears start to solidify and granulate upon exposure to wind and sun radiation.

In Ethiopia, tapping not commonly practiced for production of gum arabic but there is little tapping practice in northern part. Tapping and collection of gum arabic from *A. senegal* is carried out following a specific pattern starting from mid October up to until the onset of the rainy season, usually early June. Due to the mono-modal rainfall pattern in the north, production and collection is practiced for an extended 8-9 months each year. Thus tapping practices can increase quality and quantity of gum arabic product. For instance, according Tadese, Lemenih [21] finding report, gum arabic quantity and quality increases when we increases tapping spot up to eight tapping spot per tree (Figure 1 ant Plate 2). The number of wounds per tree should be limited. Too many wounding will result in smaller or dusty tears, which are generally regarded as inferior quality, damage the tree health and affects sustainability of gum arabic production [4].



(a) (b)

Figure 1: Correlation between yield of gum arabic and tapping intensity in the first picking (a) and second picking round (b) [21]

Photo 2. Tapped tree and the size of gum arabic tears that oozed from tapped spots [21]

Gum handling

Harvesting and Post Harvest of gum arabic

The tears picked by hand from the stems and branches where they have formed, and not by knocking to the ground where they can pick up dirt. Then they placed in an open plastic basket carried by the collector; this plastic sacks has been found to increase the risk of moisture retention and mould formation [34, 35]. However, in Ethiopia gum arabic is harvested both from natural oozing (Southern part) carried out by herder, women and children from tree trunks and branches and by tapping (Northern part) collection carried out by experienced collector compared to southern part of our country [9].

Post harvest handling of gums arabic undertake first the collected gum are seasoned in the field by spreading on temporary shade beds (Photo 3). Seasoning is essential to avoid clamping and maddening of the tears. [36, 37]. There is no grading system has been developed for this commodity but now a day a little cleaning or sorting is undertaken by private exporter of the gum arabic [2]. Higher cleaning and sorting are carrying out in Adama Natural gum processing and marketing Enterprise. There is a basic cleaning process, this cleaning process is labor intensive and includes such methods as: Crude sieving, Hand selection, Hand grading and

picking of bark etc. The main purpose of this cleaning process is the removal of sand, bark and any extraneous material [9].

Photo 3: Seasoning of gum arabic tears in the field (Source: Fitwi [38]

Quality of gum arabic

The main factors that constraining gum arabic trading/export in Ethiopia is the failure to guarantee consistent quality [2]. Importers prefer to obtain a trustworthy supply of raw materials (gum product) of consistent and predictable quality [39]. However the main problems that leading to quality deterioration is adulteration (mixing different species product), mostly because of attempts by producer and farmers to increases trade volume. As most of the gums look similar in terms of color (e.g. gum arabic of *A. senegal* and gum from *A. drepanolobium* or *A. mellifera*), it is difficult to discern them by visual inspection alone [9, 40].

Necessary measures is very essential to ensure gum quality before exporting the product like chemical characterization of each type, testing of each batch and labeling with information on locality and botanical origin [41]. Chemical characterization is essential because the batch of gum arabic product are a collection of different species, for instance from *A. senegal* and *A. seyal*, but they are exhibit intrinsically different physiochemical characteristics [13, 30, 42]. Attaining this form of quality control requires the establishment of commercial test laboratories and industry standards. Moreover, Farmers and retailers has to be trained to collect gum arabic from different botanical sources separately.

Most of these gum are not only tested for chemical composition but also subject to extensive toxicological control by importing countries, organizations and end users. This process demands quality assurance that exceeds simply labeling products with the botanical source and locality. Proper handling of the produce from collection to shipment is crucial to avoid toxicological contaminations. To meet these consumer requirements and stimulate strong market demand for gum arabic, exporters must comply with set chemical specifications [12, 43]. Research on chemical characterization of gum arabic in Ethiopia has been carried out only for *A. senegal*, although much remains to be done on other gum bearing species. Comparison between chemical characterization gum from *A. senegal* from Ethiopia Sudan and international specification is presented in the following (Table 2).

Table 2. Evaluation of gum arabic (A.senegal) from Ethiopia with other studies and international specifications

No	Quality parameter	Quality of gum arabic from Ethiopia	Quality of gum arabic from Sudan	International quality specifications
1	Moisture content %	15	13.5	13-15
2	Ash content (%)	3.56	4	2-4
3	Viscosity 10 gl^{-1} 7.5 gl^{-1}	0.9954 0.9552		
4	Intrinsic viscosity (ml/g)			
5	pH (25% sol.)	4.04	5.3	
6	Nitrogen content (% w/w)	0.35	0.29	0.36
7	Protein %	2.31	2.06	2.41
8	Specific rotation (degrees)	–32.5	-26.5	-26- -34
9	Tannin content (% w/w)	0	ND	
10	Gel (25% sol.)	Moderate	ND	
11	Ca (g/100g)	0.7	0.65%	
12	Mg (g/100g)	0.201	0.65%	
13	K (g/100g)	0.95	0.05%	
14	Na (g/100g)	0.014	0.01%	
15	Fe (g/100g)	0.001	2.7%	
16	P (g/100g)	0.6	0.21	
17	Pb (g/100g)	ND	ND	
18	Mn (g/100g)	ND	ND	
19	Co (g/100g)	ND	ND	
20	Cu (g/100g)	ND	0.004%	
21	Zn (g/100g	ND	ND	
22	Ni (g/100g)	ND	ND	
23	Cd (g/100g)	ND	ND	
24	Cr (g/100g)	ND	ND	

ND – Not detected; = Ranges of values for *A. senegal* var. *senegal* from two countries: Sudan, Ethiopia and international specification Source [13, 44].

Export of gum arabic from Ethiopia

According to recent data gum export from Ethiopia and the revenue from the sector are increasing year to year [45, 46]. The value of gum arabic in the world market has grown by 50% and 10% for the period 2001-2005 and 2004-2005, respectively [9]. Yet, there is no solely actual product of gum arabic at national level, even the information available only combine with other commodity (frank incense, opoponax and myrrh). These results create difficulty to know the actual quantity of gum arabic production per year [47] . The amounts of gum arabic export from the country generally increasing from year to year as shows in the bellow (figure 2).

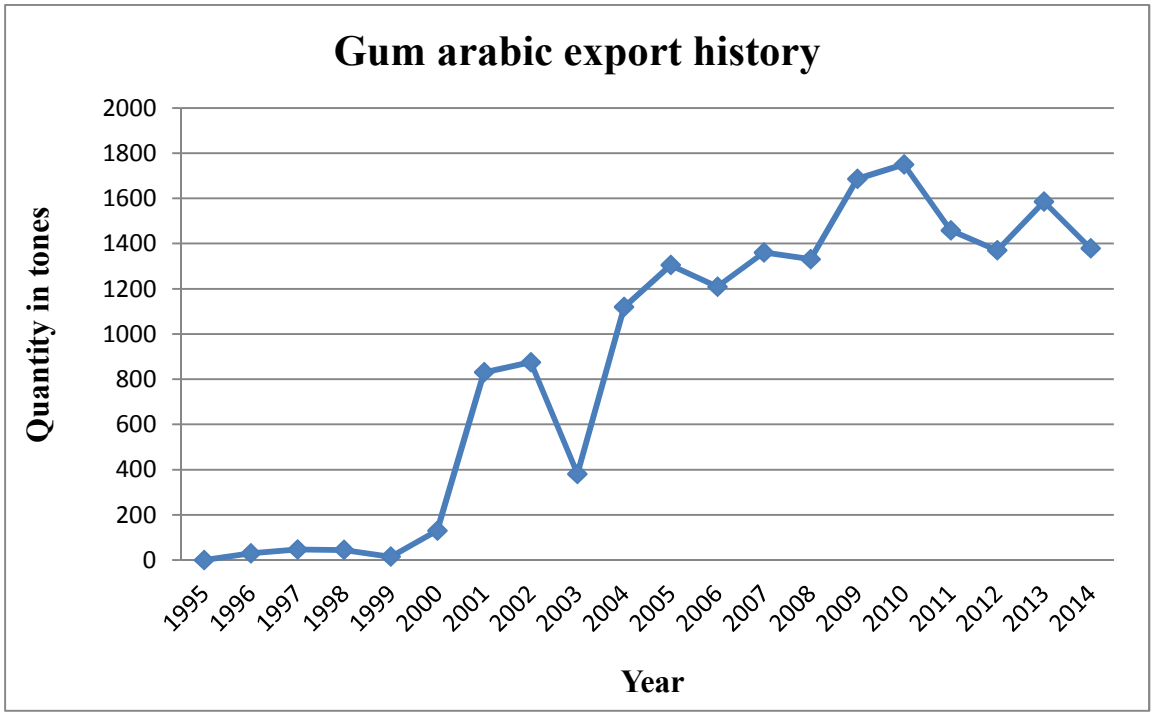


Figure 2: Amount of gum arabic (tone) export from Ethiopia. Source: [1, 9].

Importance of gum arabic production in Ethiopia

Dry land forests are notably important natural endowments of dry lands that have been and are still contributing to human welfare and environmental health [48]. Besides this direct and indirect support to the livelihood of 15-20% of the human population of the country [4]. The products have high market demand still exist for exportation. Consequently, this is receiving increasing interest of the State and the business community for increased production. The State has targeted dry land forests for diversification of its export goods to secure foreign currency [11]. Importance of some gum arabic production in Ethiopia are the following: Contribution to the local and national economy, employment, income diversification, contribution to live stock production and ecological significant.

Contribution to the national economy

One of the benefits delivered by gum arabic is foreign currency earning through export. The data shows that Ethiopia has exported 1971.7 tons of gum arabic during the last 7 years, which generated about 2,560,076.3 USD of foreign currency. This is equivalent to average annual earnings of 365,725.2 USD or (3,401,244.4 Eth Birr) [1]. This value does not include the unregistered large parallel trade across borders with neighboring countries. The contribution of this commodity to the national economy could have been more if the full potential of the sector were exploited.

Contribution to local economy

The gum arabic also contributes to the local economy and to rural livelihoods. Women in particular have been benefiting from the processing (clearing, sorting) and retailing of gum. The contribution of the sector to the local economy can be seen from several perspectives: employment, income diversification, use as emergency food and direct support to other economic sectors principally livestock production [45, 49, 50].

Employment

Photo 4: Women sorting and grading gums and resins (http://naturalgum.diytrade.com)

Employment opportunities have been generated throughout the year by gum arabic products include: tapping and collection, transportation, processing (cleaning and sorting), marketing and guarding of storage facilities [5]. For instance, money received by collectors in the collection of gum arabic 225 – 800 Eth Birr per quintal [11].

Income diversification

Gum arabic products are an important resource of income for households residing in producing areas. In some situations, gum arabic provides the only source of household income, while in others it stands as a safety-net [51-53]. For instance, a study made in Liban, southeastern lowland showed that the annual income from collection and sale of oleo-gum resin is the second most important means of household livelihoods [4]. The economic incentive provided by gum arabic has wider implications in the overall socio-economic conditions of households living in arid and semi-arid lowlands. The diversification of their economy implies potential minimization of the risks associated with frequent crop and fodder failures as a result of the common recurring droughts. For instance, in the below case study that has been done between Sudan (two district) and Ethiopia (two district) to assessment income generation from gum and resin resources in pastoral and agro-pastoral community which clearly shows income generation from collection and sale of gum and resin is the second and third most important household livelihood after crop and livestock production (Figure 3) [54].

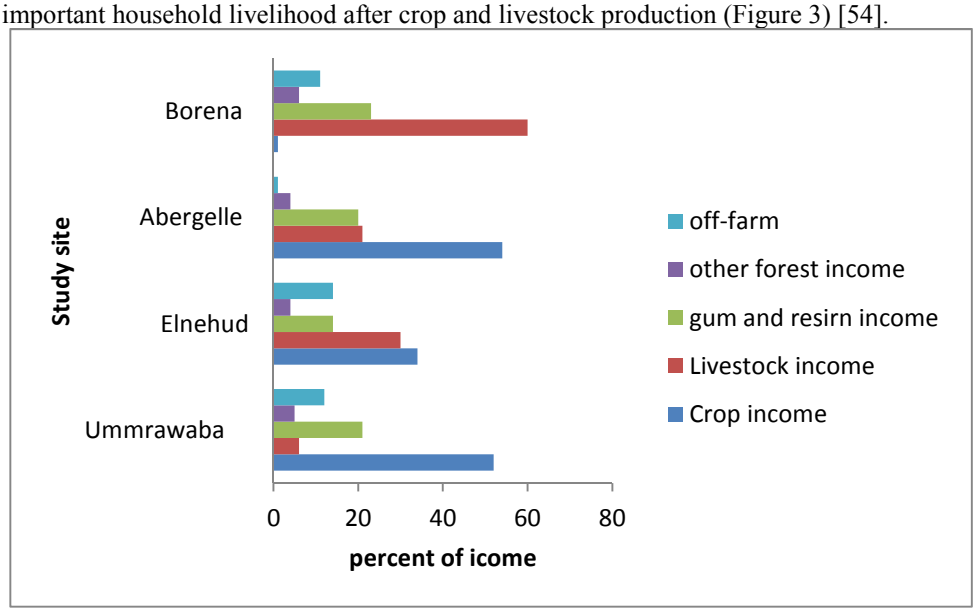


Figure 3: The major income sources in household across the study (Source: [54].

Contribution to livestock production

The gum producing vegetation also contributes to household food security through their support to other economic sectors, principally livestock production. Livestock production, which is the basis of the agro-pastoral and pastoral economy, is heavily dependent on fodder supplied from the woody plant biomass [44, 55]. Particularly in dry season, as well as during droughts, trees and shrubs are the only source of fodder for their livestock. The family *Mimosaceae* is known for their provision of nutritious fodder, and virtually all plants in this family are palatable to livestock [56-58]. Compared with annual grasses, perennial woody vegetation supply more fodder during prolonged drought periods, which makes them more useful in dry land regions [59, 60].

Contribution to Ecological significance

The gum bearing trees are characteristically plants of the drier low-lying semi-arid and arid lands [61]. According to Lemenih and Kassa [9], they offer better adaptation and mitigation options in the area. The vegetation resources could be:

i) help to fight against desertification and soil erosion;
ii) contribute to the conservation and enhancement of biodiversity;
iii) improve soil fertility; and
iv) provide opportunity for C-sink.

Finally, *Acacia species* can be managed to provide multiple purposes, both economical and ecological services [1]. Extraction of gums is little destructive to the tree and the vegetation ecosystem can global opportunities such as REDD+ (C- fund) and value added processing is possible and will further promote the return from the sector [11, 62].

Constraint of gum arabic production and commercialization in Ethiopia

Lack of infrastructure

As we know in dry land of Ethiopia lack of infrastructure by different reason: Remoteness as well as the rugged and undulating topography of the habitat where the gum producing species grow. In most report indicated because of this lack of access roads and infrastructure/ facilities such as residential quarters and inadequacy of transport facilities to the potential production areas have made mobilization of labor force, equipment and supplies, collection and transportation of harvested natural gums very difficult [2, 3, 5]**.**

Deforestation, Overgrazing, Resettlement and Human induce Fire

Farming semi-arid and arid lowlands where gum producing vegetation dominates are under increasing human pressure in Ethiopia. Native people settled in these areas coupled with continuous influx of landless immigrants and resettlement programs are endangering the populations and the habitat of gum producing vegetation in the country. For instance, between 2002 -2005 alone about 340,000 households have been officially resettled from three Regional States of Ethiopia (Tigray, Amhara and Oromia) [11].

Clearing of the woodlands for farming, settlement, and harvesting for fuel wood are becoming major threats to the future of the gum producing vegetation [63, 64]**.** For instance, BURRU [44] stated that in central rift valley decline the population of acacia Senegal and acacia seyal by expansion of farm land, use for high extraction for fuel wood, charcoal and intensive grazing, Similar reports exist for Gonder [63], and the Somali region [4]. On the other hand, in Borana Currently the introduced invasive/alien species and bush encroachments have also become a serious threat of the gum bearing species and at Yabello district hinder regeneration of some of the acacia species may due to the agro-pastoralist nature of the mode of life at the area which leads to a continuous trampling and free grazing which is decline the regeneration gum bearing species [5].

Moreover, in Ethiopia woodlands and bush lands are largely situated in the agro-pastoral and pastoral zones, where they support large livestock population [65]. The animals are allowed to graze freely in all types of forests without restrictions on numbers or seasons. Apparently, the ecological disturbances and damage caused by overgrazing, particularly the negative impacts on natural regeneration of woody species [8, 63, 66, 67].

Photo 5: Deforestation, overgrazing, Settlement and induce fire respectively in the woodland of Metema district[9].

Fire intensity and frequency has increased in most dry land areas due to increased influx of populations making the fires damaging than that occurs under natural [63]. The increased fire intensity is damaging the young succulent seedlings leading to their poor survival and damage dry land woody vegetation, the consequence intensive and frequency of fire leads to hamper gum arabic production [9].

Factors that affecting commercialization of gum arabic

The Location of the Resource Sites and Lack of Quality Awareness

Inaccessibility of gum producing regions since, they are located far from ports or market centers. In most cases the gum must be transported over 1000 km of rough roads to the capital for processing and packing, and then to the port of Djibouti for shipment, which ultimately raises the cost of production also deteriorate the quality of the product [1].

Lack of quality awareness and backwardness of production, storage, processing and transportation techniques are among the limiting factors for good prices and expansion of natural gum commercialization in Ethiopia. For illustration, one of the problem lack of quality is adulteration (collectors combine different species product to increase the volume of the product) and hence, poor quality, is one of the big problems affecting the market condition [1, 5]. Therefore, the need to improve the quality, particularly during production, storage and transportation .

Uncontrolled Trade and a Sluggish Transaction in Export Trade

Registered enterprises complained that lack of control on both domestic and export trade of gum products in Ethiopia is affecting the expansion of official commercialization of the product. The fact that unregistered traders do not pay tax therefore it affecting the competitiveness of registered taxpaying traders and is discouraging the later groups from expanding their commerce of gum products of the country [1].

Conclusion and Recommendation

Ethiopia is one of the countries well endowed with various species of *Acacia*, *Boswellia* and *Commiphora* that are known to produce gum arabic, frankincense and myrrh, respectively. According to the results of different scholars Ethiopia have huge potential of gum bearing woodlands and production of the product. However, acquiring reliable data on actual annual production, particularly for gums and resins produced in the south and southeast parts of the country are difficult. Today's gum arabic production system in Ethiopia can be divided into two: production by tapping practices and collection on natural oozing. Production of gum arabic has its own opportunities such as: a contribution to national economy, contribution to local economy and contribution of ecological significant. But, production and commercialization of gum arabic have numerous bottleneck currently and for future sustainable production.

The following recommendations are forwarded by considering this review:

1. The research should be done on physiochemical specification for all gum bearing species.

2. The responsible body should be solve the challenges that encountered on gum arabic production and commercialization in the country and
3. Value addition and industrialization near future should be consider.

References

1. Lemenih, M., *Production and marketing of gums and gum resins in Ethiopia.* Production and marketing of gum resins: Frankincense, Myrrh and Opoponax, 2005: p. 55-70.
2. Worku, T., *GUMS NATURALLY?! Export potential of Ethiopian GUMS.* 2005, Ethiopian Promotion Department.
3. Tadesse, W., G. Desalegn, and R. Alia, *Natural gum and resin bearing species of Ethiopia and their potential applications.* Forest Systems, 2007. **16**(3): p. 211-221.
4. Lemenih, M., T. Abebe, and M. Olsson, *Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south-east Ethiopia.* Journal of Arid Environments, 2003. **55**(3): p. 465-482.
5. Gizaw, A.W., *Population status and socio-economic importance of gum and resin bearing species in Borana Lowlands, southern Ethiopia*. 2006, Msc. thesis submitted to the school of graduate studies, Addis Ababa University, department of Biology Ethiopia.
6. Lemenih, M., T. Abebe, and M. Olsson, *RETRACTED: Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, Southeast Ethiopia*. 2004, Elsevier.
7. Chikamai, N., *Review and synthesis on the state of knowledge of Boswellia species and commercialization of frankincense in the drylands of Eastern Africa.* 2003.
8. Eshete, A., D. Teketay, and H. Hulten, *The socio-economic importance and status of populations of Boswellia papyrifera (Del.) Hochst. In Northern Ethiopia: the case of north gonder zone.* Forests, trees and livelihoods, 2005. **15**(1): p. 55-74.
9. Lemenih, M. and H. Kassa, *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia*. 2011: Cifor.
10. Desalegn, G. and W. Tadesse, *Socio-economic importance and resource potential of Non-timber forest products of Ethiopia.* Conservation of Genetic Resources of Non-Timber Forest Products in Ethiopia, 2004: p. 18.
11. Lemenih, M. and H. Kassa, *Management guideline for boswellia papyrifera.* 2008.
12. el Din, A.G.S. and M. Zarroug, *Production and commercialization of gum arabic in Sudan.* Domestication and commercialization of non-timber forest products, 1996: p. 176.
13. Kennedy, J.F., G.O. Phillips, and P.A. Williams, *Gum arabic*. Vol. 333. 2012: Royal Society of Chemistry.
14. Ibrahim, M.O.H., *Assessment of Gum Arabic Marketing System in Main Auction Markets of North Kordofan State-Sudan*. 2015, UOFK.
15. Alem, S., *International trade of different forest products in Ethiopia.* African Journal of Economic and Sustainable Development, 2015. **4**(4): p. 353-361.
16. Gemedo-Dalle, T., B.L. Maass, and J. Isselstein, *Plant biodiversity and ethnobotany of Borana pastoralists in southern Oromia, Ethiopia.* Economic Botany, 2005. **59**(1): p. 43-65.
17. Vasisht, K., N. Sharma, and M. Karan, *Current perspective in the international trade of medicinal plants material: an update.* Current pharmaceutical design, 2016. **22**(27): p. 4288-4336.
18. Sara, S.A., et al., *Towards Acacia seyal protocol in Sudan: Preliminary study pertinent to colour identification and physiochemical properties.* Bioactive Carbohydrates and Dietary Fibre, 2018.
19. Ali, B.H., A. Ziada, and G. Blunden, *Biological effects of gum arabic: a review of some recent research.* Food and Chemical Toxicology, 2009. **47**(1): p. 1-8.
20. Hadi, A., M.A. Elderbi, and A. Mohamed, *Effect of gum arabic on coagulation system of albino rats.* International Journal of PharmTech Research, 2010. **2**(3): p. 1762-1766.
21. Tadese, S., M. Lemenih, and M. Zewdie, *Effect of Tapping Intensity and Tree Diameter on Gum Arabic Yield of Acacia Senegal (L) Wild in Southern Ethiopia.* Forestry and Forest Products in Ethiopia, 2012: p. 114.
22. Coppen, J.J., *Gums, resins and latexes of plant origin. Non-wood forest products 6.* Rome: Food and Agriculture Organization of the United Nations x, 142p. ISBN, 1995. **661102982**.
23. Duke, J.A., *Handbook of energy crops.* 1983.
24. Al Alawi, S.M., M.A. Hossain, and A.A. Abusham, *Antimicrobial and cytotoxic comparative study of different extracts of Omani and Sudanese Gum acacia.* Beni-Suef University Journal of Basic and Applied Sciences, 2018. **7**(1): p. 22-26.
25. Makonda, F., *Gum arabic studies in Tanzania: production, utilization and economic potentials*. 2003, University of Wales, Bangor.

26. Booth, F.E. and G.E. Wickens, *Non-timber uses of selected arid zone trees and shrubs in Africa*. 1988: Food & Agriculture Org.
27. Cossalter, C., *Acacia senegal: gum tree with promise for agroforestry*. Acacia senegal: gum tree with promise for agroforestry., 1991(91-02).
28. Wickens, G.E., et al., *Role of Acacia species in the rural economy of dry Africa and the Near East*. 1995: Food & Agriculture Org.
29. Kuruwanshi, V.B., *Establishment of Sustainable Tapping Techniques For High Gum Production*. 2017, Indira Gandhi Krishi Vishwavidyalaya, Raipur.
30. Williams, P.A. and G. Phillips, *Gum arabic*, in *Handbook of Hydrocolloids (Second Edition)*. 2009, Elsevier. p. 252-273.
31. Wekesa, C., et al., *Gum arabic yield in different varieties of Acacia senegal (L.) Willd in Kenya.* African Journal of Plant Science, 2009. **3**(11): p. 263-276.
32. Adam, I.M., M.E.M. Ballal, and K.E. Fadl, *Effect of tapping direction in relation to sun light on gum arabic Acacia senegal (L.) Willd. yields in North Kordofan State, Sudan.* Forests, Trees and Livelihoods, 2009. **19**(2): p. 185-191.
33. Fadl, K. and J. Gebauer. *Effect of different tapping tools and different tapping positions on'talh gum'yield of Acacia seyal var. seyal in South Kordofan, Sudan*. in *Conference on International Agricultura*. 2004.
34. AbdAllah, E.E.A., *Development of an Automatic Control Strategy for Gum Arabic Spray Dryer*. 2017, University of Gezira.
35. Tieguhong, J.C. and O. Ndoye. *Development of trade and marketing of non-wood forest products for poverty alleviation in Africa*. in *Workshop on Lessons Learnt on Sustainable Forest Management in Africa, Uppsala, Sweden*. 2004.
36. Chretin, M., et al., *The current situation and prospects for gum arabic in Kenya: a promising sector for pastoralists living in arid lands.* International forestry review, 2008. **10**(1): p. 14-22.
37. Mujawamariya, G., K. Burger, and M. D'Haese, *Quality of gum arabic in Senegal: Linking the laboratory research to the field assessment.* Quarterly Journal of International Agriculture, 2012. **51**(4): p. 357-383.
38. Fitwi, G. *The status of gum arabic and resins in Ethiopia*. in *Report of the meeting of the network for natural gums and resins in Africa (NGARA): Proceeding*. 2000.
39. Belcher, B. and K. Schreckenberg, *Commercialisation of non‐timber forest products: A reality check.* Development Policy Review, 2007. **25**(3): p. 355-377.
40. Nussinovitch, A., *Plant gum exudates of the world: sources, distribution, properties, and applications*. 2009: CRC Press.
41. López-Franco, Y., et al., *Other exudates: tragancanth, karaya, mesquite gum and larchwood arabinogalactan*, in *Handbook of Hydrocolloids (Second Edition)*. 2009, Elsevier. p. 495-534.
42. Couteaudier, T.Y., *Export marketing of Sudanese gum arabic.* Sudan Multi Donor Trust Funds, Technical Secretariat, The World Bank, Khartoum, 2007.
43. Jani, G.K., et al., *Gums and mucilages: versatile excipients for pharmaceutical formulations.* Asian J Pharm Sci, 2009. **4**(5): p. 309-323.
44. BURRU, D.Y., *POPULATION STATUS OF ACACIA SENEGAL (LINNE) WILLDENOW AND ITS GUM QUALITY IN THE CENTRAL RIFT VALLEY OF ETHIOPIA.* 2006.
45. Gebremedhin, T., *Boswellia papyrifera (Del.) hochst. from Western Tigray: opportunities, constraints and seed germiniation responses.* 1997.
46. Babulo, B., et al., *The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia.* Forest policy and Economics, 2009. **11**(2): p. 109-117.
47. Kassa, H., B. Tefera, and G. Fitwi, *Preliminary value chain analysis of gum and resin marketing in Ethiopia*. 2011: CIFOR.
48. Teketay, D., et al., *Forest resources and challenges of sustainable forest management and conservation in Ethiopia.* Degraded forests in Eastern Africa: management and restoration, 2010: p. 19-63.
49. Shackleton, S., et al., *Opportunities for enhancing poor women's socioeconomic empowerment in the value chains of three African non-timber forest products (NTFPs).* International Forestry Review, 2011. **13**(2): p. 136-151.
50. Gebru, Y., et al., *Determinants of producers' participation in gums and resins value chains from dry forests and analysis of marketing channels in northwestern and southern Ethiopia.* Forests, Trees and Livelihoods, 2014. **23**(1-2): p. 54-66.
51. Worku, A., et al., *Socio-economic importance of gum and resin resources in the dry woodlands of Borana, southern Ethiopia.* Forests, Trees and Livelihoods, 2011. **20**(2-3): p. 137-155.
52. Lemenih, M., et al., *Diversity and dynamics of management of gum and resin resources in Ethiopia: a trade‐off between domestication and degradation.* Land degradation & development, 2014. **25**(2): p. 130-142.

53. Woldeamanuel, T., *Gum and resin-producing species in the drylands of Ethiopia: productive bricolage footprints on the landscape*, in *Forest-people interfaces*. 2012, Springer. p. 49-68.
54. Abtew, A.A., et al., *Contribution of small-scale gum and resin commercialization to local livelihood and rural economic development in the drylands of eastern Africa.* Forests, 2014. **5**(5): p. 952-977.
55. Kuchar, P., *Identification and characterization of Boresraceae, in the Southeastern Ethiopia.* Southeastern rangelands project technical paper. Addis Ababa, Ethiopia, 1995.
56. Tolera, A. and A. Abebe, *Livestock production in pastoral and agro-pastoral production systems of southern Ethiopia.* Livestock Research for Rural Development, 2007. **19**(12): p. 4-7.
57. Leminih, M. and D. Teketay, *Frankincense and myrrh resources of Ethiopia: I distribution, production, opportunities for dryland development and research needs.* SINET: Ethiopian Journal of Science, 2003. **26**(1): p. 63-72.
58. Farah, A.Y., *The milk of the Boswellia forests: frankincense production among the pastoral Somali*. 1994: EPOS, Environmental Policy and Society.
59. Kassahun, A., H. Snyman, and G. Smit, *Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia.* Journal of Arid Environments, 2008. **72**(7): p. 1265-1281.
60. Coppock, D.L., *The Borana plateau of southern Ethiopia: synthesis of pastoral research, development, and change, 1980-91*. Vol. 5. 1994: ILRI (aka ILCA and ILRAD).
61. Worku, M. and A. Bantihun, *Review the Significant of Non Timber Forest Product and Boswellia papyrifera Species in Ethiopia.* J Ecosys Ecograph, 2018. **8**(248): p. 2.
62. Marunda, C. and H.-N. Bouda, *Environmental services from the dry forests and woodlands of sub-Saharan Africa.* The Dry Forests and Woodlands of Africa, 2010: p. 231.
63. Eshete, A., *Regeneration status, soil seed bank and socio-economic importance of Boswellia papyrifera (Del.) Hoschst. In two woredas of North Gondar zone, Northern Ethiopia*. 2002.
64. Kindeya, G., *Ecology and regeneration of Boswellia papyrifera, Dry forest of Tigray, North Ehiopa*. 2003, Ph. D. Thesis, Georg-August University of Gottingem, Germany.
65. Tsegaye, D., et al., *Land-use/cover dynamics in Northern Afar rangelands, Ethiopia.* Agriculture, ecosystems & environment, 2010. **139**(1-2): p. 174-180.
66. Teketay, D., *Seedling populations and regeneration of woody species in dry Afromontane forests of Ethiopia.* Forest ecology and management, 1997. **98**(2): p. 149-165.
67. Ogbazghi, W. and P. Kostense, *The distribution and regeneration of Boswellia papyrifera (Del.) Hochst. in Eritrea*. 2001: Wageningen University.
68. Lele, U., et al., *The World Bank Forest Strategy.* World Bank, Operations Evaluation Department, Washington DC, 2000.