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Review Paper

Status, socio-economic contribution and conservation constraints of gum and resin bearing species in East Africa - A review

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Abstract

Various papers published on the theme related to gum and resin bearing species in different journals and proceedings were collected and strictly assessed to fetch relevant information. The aim of this paper was reviewing the growing knowledge on the status, constraints associated to resource development, conservation and the collection techniques of gum and resins in woodland forests and their importance to support the livelihood and national income in Ethiopia. Gum and resins are important resources for securing a rural livelihood and marketed for earning cash income in the international market and create considerable job opportunities for communities. However, the population of gum and resin bearing trees are under high pressure due to continuous tapping, fire, intensive tapping, overgrazing, shifting cultivation and inappropriate land use system. But, they can be propagated by vegetative or by seed. Gum and resins are collected by tapping and natural oozing. Tapping enhances yield and quality of gum and resins. Inaccessibility of the area where the gum producing species grow, deforestation, overgrazing, improper tapping, resettlement, harvesting for fuel wood and land use change are constraints for conservation and development of the habitat of gum and resin species.

Keywords: Gum and resins, degradation, woodlands, conservation constraints.

Introduction

Dry woodland provides several goods and services for peoples at local and international level such as fuel wood, pole and post, non-timber forest products, environmental services etc.[1]. In addition, most rural people obtain medicine, shelter, food, fuel and cash income from forests[2]. For instance, in Zambia forest products contribute on average 20.6 percent of total household income[3]. However, the coverage of dry woodland is dwindling over time. For example, some of the species such as *Boswellia* and *acacia senegal* which is found in dry woodland has poor regeneration status due to human-induced factors[4]. Thereby, the species are decreasing alarmingly[4-6].

However, developing and implementing specific policies which focus on conservation of dry woodland forests and putting appropriate institutional arrangements in place may improve the status of woodland forest[7].

Dry woodland forests provide non-timber forest products (NTFPs) which play substantial role in supporting national economy as well as securing local livelihood. For instance, in India 70% of forest export income and more than 50% of forest revenues comes from NTFPs. Another study in Peru revealed that extraction of NTFPs is by far better than timber harvest. In addition, according to Mekonnen et al.[7], in Ethiopia income obtained from gum and resin accounts from 4% to 38% household income share in different provenance based on the status of the resource found there.

Acacia, Boswellia and Commiphora species are most common gum and resin bearing plant species. Gum and resin products obtained from these species have been traded in international and domestic markets. Gum collected from *Commiphora, Boswellia,* and *acacia* species are traded under the name of myrrh, frankincense and gum arabic respectively[8]. The aim of this review is to assess the existing knowledge on the status of gum and resin bearing tree and the importance of these resources to support the livelihood and national income. In addition, it focuses on collection techniques of gum and resins and the constraints associated to resource development and conservation.

Distribution and ecology of gum and resin producing trees

Distribution of gum and resin bearing species covers most of Africa countries and some Asian countries. For example, it founds in Gambia, Mauritania, Ghana, Senegal, Cote d'Ivoire, Burkina Faso, Mali, Nigeria, Niger, Central African Republic, Cameroon, Zaire, Chad, Rwanda, Ethiopia, Sudan, Somalia, Kenya, Uganda, Mozambique, Tanzania, Pakistan, Oman, and India[9]. These species grow on dry rocky hills, sandy valleys.

The species are drought resistant species. They tolerate high daily temperatures, dry wind, and sandstorms[10].

In Ethiopia gum and resin bearing species cover nearly 2.9 million ha[11]. Greater than sixty gum and resin producing trees are found in the country[5]. They grow in dry areas of the country, from 600-1700m above sea level, receives lower than 900mm rainfalls per annum and 20-25°C temperature[9].

Natural regeneration and population status of gum and resin bearing species: According to studies, seedlings and saplings of gum and resin bearing species were lacking[13,12]. This is because the extensive human encroachment[15], continuous tapping, fire, intensive tapping, and overgrazing[12-14].

Moreover, the regeneration of gum and resin bearing species is declined due to shifting cultivation and inappropriate land use system[16]. As a result, *Boswellia papyrifera*, one of gum bearing species, is greatly reduced and categorized as endangered species[17] and the population is unstable and declining at alarming rate[12,14,16,18]. Abtew et al.[14] observed population structure of some gum and resin bearing tree species are dominated by mature individuals with lack of seedlings and saplings.

Higher number of medium height individuals than smaller and taller *Boswelliapa pyrifera* individuals and also the diameter class distribution was highly skewed[18]. Additionally, crown diameter and depth indicates that most of *Boswelliapa pyrifera* individuals are medium size trees. This depicts that the species has regeneration problem. However, studies on natural regeneration have showed that better regeneration was observed in protected forests compared to open forests. Additionally, in closed areas stem and crown diameter of *Boswelliapa pyrifera* is higher compared with free grazed areas[15]. Therefore, effective natural regeneration could be achieved by excluding animal grazing and human encroachment.

Population structure of gum and resin-bearing species differs species to species. For instance, species such as *C. africana, B. Microphylla and C. confusa* exhibited inverted J-shaped curve. They have too many seedlings, saplings and decreased number individuals at higher height classes[19,20]. On the other hand, Species such as *A. senegal and Commiphora* myrrh have too many individuals in the middle class compared to lower and higher height classes[19,21]. For example Marade and Xila (local name) species, more individuals were found in higher height classes. Didita and Megngistu[19] revealed that seedlings and saplings of *B. neglecta, C. baluensis and C. guidoti* were not found, but dominated by mature individuals.

Various studies have demonstrated that gum and resin species are under threat in several geographical locations due to human induced fire, continuous tapping, overgrazing and climatic change[14]. For instance, Rijkers et al.[22] and Ogbazghi et al.[18] reported tapped trees produce three times less sound seeds than untapped trees. Germination of seeds decreased with increasing tapping regime[14]. Study in Eritrea advocated seeds collected from untapped trees had 80% germination and seeds collected in tapped tree had less than 6% germination rate[18].

Factors affecting regeneration of gum and resin bearing species: According to Abtew et al.[14], some of major causes for population and regeneration reduction of gum and resin bearing species are: Death of trees naturally. Intensive tapping, tapping constantly without giving recovery time, Deep tapping, and Damage caused by insect attack and fire. Moreover, the significant risks for successful natural regeneration are livestock browsing, prolonged frequent drought periods[4,15,17] change of ownership[17].

Vegetative Propagation of gum and resin bearing species: According to different studies, the population structure of some gum and resin bearing trees such as *Boswellia papyrifera, Acacia Senegal, Commiphora* species have either bell-shaped or J-shaped. It indicates that the forest is not in a normal condition which means it has a sustainability problem. It has therefore been suggested by various studies the species germinate readily and also there is no dormancy problem (e.g. *Boswellia papyrifera, Acacia Senegal*). Additionally, vegetative propagation could also be a promising approach[15,17]. Prpagating through stem and branch cutting showed prommising result[23,24].

However, planting material size affects the survival of vegetative propagated *Boswellia papyrifera* tree[24]. A length of two-meter planting material has better survival rate compared to one and 1.5-meter planting material. Additionally, planting season has influence on the survival rate of planted stem and branch cuttings. For instance, *Boswellia papyrifera* cuttings collected in may have higher survival rate followed by March[24]. The major constraints of the survival of *Boswellia* seedlings are mortality from drought or animal browsing[26]. According to various studies, it has been suggested that planting larger (diameter) and taller cuttings could tolerate drought and browsing would be a good working technology.

Social and Economic Contribution of Gum and Resin Bearing Species

Contribution of gum and resin to Local livelihood: Rural households have a tradition of harvesting forests for subsistence and cash income[25,27]. According to Grimes et al.[11], income produced from NTFPs in Ecuador was much more than another kind of land uses. Additionally, in Somali regional state gum and resin contributes to 32.6% of annual household income[8]. Moreover, in some gum and resin producing areas the contribution of gum and resins was greater than three times crop farming[15].

At local level gum and resin products are used for different purposes such as medicines to treat livestock and human disease, bad smell removal, fumigation of houses, worship places[8]. Lemenih and Kassa[28] reported around 10,000 metric

tons per annum (equivalent to US$12 million) is consumed locally, nearly 60% is used for religious purpose. It contributes up to fourteen percent of household's average annual cash income[7].

Furthermore, these species provide fodder requirements to their livestock[29] and also they are the basis of aromatic gum resins, myrrh and frankincense[30]. In addition, gum and resin bearing trees provide various goods and services such as nectar for bees, used for food and beverages, pharmacological uses[30]. In rural parts of Ethiopia, gum and resin exploitation is one of employment generating activity. Therefore, it is an important source of income for the rural people[31,17]. Gum and resin used as safety-net for securing livelihood of local communities when food shortage occurs. For example, in north-eastern Kenya, farmers and pastoralists used products of frankincense and myrrh as a source of income to overcome environmental problems like drought[32]. Generally, gum and resins are one of NTFPs product, which supports the livelihoods of 15–20% Ethiopia's population directly and indirectly[33].

Contribution of gum and resins to national economy: Gum and resin products have a substantial share of the national economy. For instance, Ethiopia, which had massive amount of dry forests and woodlands, which is dominated by diverse Acacia, Commiphora, Boswellia, and Sterculia species[7]. Worku et al.[20] and Lemenih and Teketay[34] reported dry forests and woodlands provide considerable amount of gum and resin products besides to maintaining environment. According to Mekonnen *et al*[7] the production potential of the country is more than 300,000 tons of gums and resins per year[7].

Gum and resin products are marketed for earning cash income[33,34]. For example, between 1997 and 2010 Ethiopia generated more than USD 72 million by exporting nearly 6,174 gum arabic and 33,865 tons of and tons of other gums products. Additionally, in 2007/08 fiscal year, more than $7.7 million were gained via exporting 4612 tons of gums and resins[28]. The amount of gum and resin export was increased overtime (Figure-1)

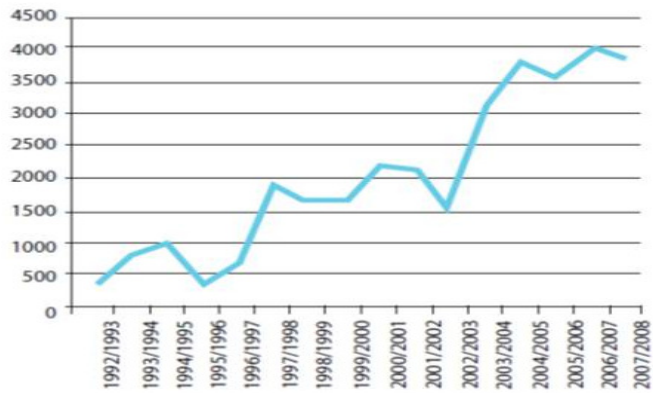

Figure-1: amount of gum and resin exports in Ethiopia from 1992 to 2008[28].

Gum and resin create employment opportunities for peoples who want to involve in tapping and collection, transportation, processing, marketing of frankincense and guarding[36]. For instance, in Ethiopia companies involved in gum and resin trade generates employment chances for the rural and urban people. Along with production and marketing chains these companies create chances for 35,000 people each year[28]. Ethiopia and Somalia are the top producers and exporters[37]. They benefited from international market by exporting gum and resin[5].

Uses of gum and resin products: Gum and resins are used as raw material in creams and perfumery, pharmacology, detergents, beverage, cosmetics, liqueurs, paints, food, flavouring, adhesive and dye manufacturing industries[5,30,38]. Gum which is collected from *Boswellia and Commiphora* species is used as raw materials in pharmaceuticals and food industries. Their special chemical compositions and non-toxicity makes them suitable to use them in modern therapies[39]. On the other hand, gum collected from *Acacia species* is used as stabilizing, thickening, suspending and emulsifying agent in food and drink industries. Moreover, it is used in printing and textile industries for film forming and sizing agent. In addition, it is also used in pharmaceuticals for the purpose of cream and lotions suspending, emulsifying agents and tablet-binding agent[30].

Gum and resins are used in the confectionery industry. It has a long custom of using gums in wine, soft drinks, and also it is used in chewing gum. Additionally, it is used in beer to assist lacing and as a foaming agent[40]. According to Maier et al.[41] gum arabic is used in blusher as an adhesive agent and in liquid soaps as a foam stabilizer.

Additional uses of gum and resin bearing species: Ecologically gum and resin bearing species are too much important, because they survive and grow where other species are unable to survive[42]. Thereby, the species are used for conservation and sustainable development of dry land ecosystems[34]. According to different literatures they are best for desertification control and economic development[42]. In addition, gum and resin bearing species are used for fulfilling subsistence requirement, increasing land productivity, improving the economic condition of people who depend on them[32].

These species have diverse ecological and economic benefits[14]. Wood of gum and resin bearing species is used for poles, timber, fuel wood, charcoal making, for preparing matchboxes, plywood and boards. In addition, the leaves of these species are used for animal feed in dry-season, and the flower is also used as a source of nectar for bees. Furthermore, the roots, leaves and bark of these species are used in traditional medicine[42].

Gum and Resin Production, Constraints and Opportunities

Gum and resin collection: Gum and resins are collected by tapping and natural oozing[23]. For example, in Ethiopia tapping

and collection carried out from mid-September to June (end of dry season)[43]. *Acacia* species which is 4 to 18 years of age are tapped in February and March. Gum and resin trees bear yield when they are in abnormal condition due to stress like damage, moisture scarcity[23]. Tapping is practiced to enhance yield as well as quality of gum. Tapping yielded more yield than untapped trees[44] (Figure-2). Similarly, study in Kenya reported tapping improved productivity of gum arabic by 77.42% when it compared to natural oozing[45]. Dagnew[23] observed individual tree provide an average of 250g of gum per tree per season. However, the yield of gum and resin is negatively related to tree size. Smallest gum and resin trees, from 3.0-6.0cm diameter class, yielded higher product compared to larger trees(larger diameter classes)[45,46].

Figure-2: Amount of oozed gum Arabic from tapped spots[46].

As reported by Ballal et al.[44], gum production increases from first round to second round collection and decreased slightly in the third round, and then fell subsequently. Gum yield increases associated with an increment of daily temperature and stress on the tree[38]. Yield of gum and resin increases with increasing tapping intensity[46].

Challenges and opportunities of sustainable gum and resin production: Some of the factors which affect production trends of gum and resins are institutional, socio-economic, policy, administration and marketing factors[16].

Opportunities for gum and resins sector: According to Mekonnen et al.[7] and Lemenih and Kassa[33] some of opportunities for sustainable development and utilization of the gum and resins are: These species gain a better recognition for their livelihood contribution to rural community and role in national economy. The presence of a long custom and native knowledge concerning the biology and silvi culture of the species. Availability of strong interest for products at both local and international market. Existence of high interest in cosmetics and pharmaceutical industry for organic products. Existence of resource conservation and development activities by regional governments. Recently regional governments are started taking action in organizing farmers in gum and resin cooperatives.

Challenges/constraints: Lack of access to roads/infrastructures, irregular conflict among users and lack of efficient services for collectors are the main constraints of gum and resin production[5,33]. In addition, little interest to involve in small scale industries for value-added processing is another factor which hinders the production of gum and resins. According to different authors, excessive firewood harvesting, expanding encroachment and lack of trained labour force in tapping and collection affects the quality and quantity of products[16,32].

Furthermore, climate change, improper tapping practices, intensive grazing, agricultural expansion and high intensity of forest fire are pressing factors of successful gum and resins production and utilization. In addition, weaknesses of gum and resins subsectors such as lack of quality control, poor handling, ambiguities in ownership and access rights lead to unsustainable exploitation resource[33].

Challenges for development and conservation of gum and resin species: Inaccessibility and remoteness of the area, where gum producing species are growing is the main constraint for conservation and development of the habitat of these species[5]. Additionally, factors including deforestation, overgrazing, improper tapping, resettlement, harvesting for fuel wood and land use change are the major threat to biological resources[5,38]. Studies showed that more than half percent of tapped *Bosswellia* species are often damaged[37]. Additionally, Gebrehiwot et al.[15] reported as a result of land use change and encroachment over 177,000ha of *Bosswellia* dominated forest is lost within 20 years.

Inadequate/insufficient trained person, physical facilities and budget constraints are the root causes for degradation of gum and resin bearing species[5]. Moreover, climate change, cultural transformations and change of ownership are some of which hamper/threatens sustainable management of the resource[33]. Additionally, conflicting policies, programmes and strategies such as economic, resettlement, and rural development influenced the development of the resource[33].

Conclusion

Dry woodland forests provide NTFPs which play a substantial role in supporting national economy as well as securing a local livelihood. Gum and resins are part of NTFPs harvested from *Acacia, Boswellia and Commiphora* species, and contributes a

significant share of annual cash income of households. At local level these products are used for different purposes such as medicines to treat livestock and human disease, bad smell removal, fumigation of houses, worship places. Additionally, these products are also used as raw material in creams and perfumery, pharmacology, detergents, beverage, cosmetics, liqueurs, paints, food, flavouring, adhesive and dye manufacturing industries. Moreover, gum and resin products are marketed for earning cash income in the international market and create considerable job opportunities for communities. Furthermore, they are best for desertification control and increasing land productivity. Each part of gum and resin bearing tree is used for various purposes such as medicinal, timber, pole, fuel wood and the leaves are used for animal feed.

These species are mostly distributed in Africa and widely used for different purposes. Due to continuous tapping, fire, intensive tapping, overgrazing, shifting cultivation and inappropriate land use system jeopardise sustainability of the recourse. Coupled with inaccessibility and remoteness of the area where the gum producing species grow are the main constraints for conservation and development of the species. These and related aspects affect the sustainability of the resource. However, one the advantage of these species for conservation and development is that the species don't have germination problem. In addition, these species can be propagated by vegetative propagation. Gum and resins are collected by tapping and natural oozing. These species bear yield when they are in abnormal condition due to stress like damage, moisture scarcity. Thereby, tapping is improved gum yield and quality. This resource could be sustainably managed by introducing sustainable taping technique, preventing overgrazing, developing appropriate land use system and applying a forestation activities because the species doesn't have germination problem.

References

1. Chidumayo E.N. and Gumbo D.J. (2010). The dry forests and woodlands of Africa: managing for products and services. Earthscan.

2. Kaimowitz D. (2003). Not by bread alone… forests and rural livelihoods in sub-Saharan Africa. In Forests in poverty reduction strategies: capturing the potential. EFI Proceedings, 47, 45-63.

3. Jumbe C.B., Bwalya S.M. and Husselman M. (2008). Contribution of dry forests to rural livelihoods and the national economy in Zambia. *World Bank and CIFOR*.

4. Eshete A., Teketay D., Lemenih M. and Bongers F. (2012). Effects of resin tapping and tree size on the purity, germination and storage behavior of Boswellia papyrifera (Del.) Hochst. seeds from Metema District, northwestern Ethiopia. *Forest Ecology and Management*, 269, 31-36.

5. Tadesse W., Desalegn G. and Alia R. (2007). Natural gum and resin bearing species of Ethiopia and their potential applications. *Forest Systems*, 16, 211-221.

6. Lemenih M., Feleke S. and Tadesse W. (2007). Constraints to smallholders production of frankincense in Metema district, North-western Ethiopia. *Journal of Arid Environments*, 71(4), 393-403.

7. Mekonnen Z., Worku A., Yohannes T., Bahru T., Mebratu T. and Teketay D. (2013). Economic Contribution of Gum and Resin Resources to Household Livelihoods in Selected Regions and the National Economy of Ethiopia. *Ethnobotany Research and Applications*, 11, 273-288.

8. Lemenih M., Abebe T. and Olsson M. (2003). Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south-east Ethiopia. *Journal of Arid Environments*, 55(3), 465-482.

9. Bekele A., Birnie A. and Tengnäs B. (1993). Useful trees and shrubs for Ethiopia: identification propagation and management for agricultural and pastoral communities. *Regional Soil Conservation Unit/SIDA. English, Nairobi*.

10. Cossalter C. (1991). Acacia senegal: gum tree with promise for agroforestry. *NFT Highlights*.

11. Grimes A., Loomis S., Jahnige P., Burnham M., Onthank K., Alarcón R., Cuenca W.P., Martínez C.C., Neill D. and Balick M. (1994). Valuing the rain forest: the economic value of nontimber forest products in Ecuador. *Ambio*: 405-410.

12. Eshete A., Teketay D. and Hulten H. (2005). 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*, 15, 55-74.

13. Khamis M., Uhlig H.S. and Phoris H. (2001). Management of Boswellia papyrifera stands for resin production in Jebel Marra area, west Sudan: present situation and future prospects.

14. Abtew A.A., Adam Jürgen P., Tarig E-SM. and Yahia O.A. (2012). Population status of Boswellia papyrifera (Del.) Hochst in the dry woodlands of Nuba Mountains, South Kordofan State, Sudan. *Agriculture & Forestry,* 54(08) (1-4), 41-50.

15. Gebrehiwot K., Muys B., Haile M. and Mitloehner R. (2002). Boswellia papyrifera (Del.) Hochst: a tropical key species in northern Ethiopia. *In Conference on International Agricultural Research for Development*. Deutscher Tropentag, Kassel-Witzenhausen.

16. Hagazi N. (2012). Trends and challenges of frankincense: the case of North Western and Western zones of Tigray Region, Northern Ethiopia. *Forestry and Forest Products in Ethiopia*.

17. Abiyu A., Vacik H. and Glatzel G. (2006). Population viability risk management applied to Boswellia papyrifera (Del.) Hochst in North-eastern Ethiopia. *Journal of the Drylands*, 1(2), 98-107.

18. Ogbazghi W., Rijkers T., Wessel M. and Bongers F. (2006). The distribution and regeneration of Boswelliapapyrifera (Del.) Hochst. in Eritrea. Tropical Resource Management Papers, No. 35 (2001); ISSN 0926-9495. Also published as thesis (2001), Wageningen University ISBN 90-5808-368-3

19. Didita M. and Mengistu B. (2012). Regeneration of Gum and Resin Bearing Species in Rayitu and Sawena Disricts of Bale, Southeast Ethiopia. *Forestry and Forest Products in Ethiopia,* 134.

20. Worku A., Lemenih M., Fetene M. and Teketay D. (2011). Socio-economic importance of gum and resin resources in the dry woodlands of Borana, southern Ethiopia. *Forests, Trees and Livelihoods*, 20, 137-155

21. Adem M., Worku A., Lemenih M., Tadesse W. and Pretzsch J. (2014). Diversity, regeneration status and population structure of gum-and resin-bearing woody species in south Omo zone, southern Ethiopia. *Journal of Forestry Research*, 25, 319-328.

22. Rijkers T., Ogbazghi W., Wessel M. and Bongers F. (2006). The effect of tapping for frankincense on sexual reproduction in Boswellia papyrifera. *Journal of Applied Ecology*, 43, 1188-1195.

23. Dagnew Y. (2006). Population status of Acacia senegal (Linne) willdenow and its gum quality in the central rift valley of Ethiopia. MSc Thesis. The Department of Farm Forestry, Wondo Genet College Of Forestry, School of Graduate Studies Awassa University, Awassa, Ethiopia.

24. Abiyu A., Dejene T., Eshete A. and Sisay K. (2016). Vegetative propagation of Boswellia papyrifera: Time of collection and propagule size affect survival and establishment. *Journal of Arid Environments*, 133, 122-124.

25. Belcher B., Achdiawan R. and Dewi S. (2015). Forest-Based Livelihoods Strategies Conditioned by MarketRemoteness and Forest Proximity in Jharkhand, India. *World development*, 66, 269-279.

26. Negussie A., Aerts R., Gebrehiwot K. and Muys B. (2008). Seedling mortality causes recruitment limitation of Boswellia papyrifera in northern Ethiopia. *Journal of Arid Environments*, 72, 378-383.

27. Babulo B., Muys B., Nega F., Tollens E., Nyssen J., Deckers J. and Mathijs E. (2008). Household livelihood strategies and forest dependence in the highlands of Tigray, Northern Ethiopia. *Agricultural Systems*, 98, 147-155.

28. Lemenih M. and Kassa H. (2011). Gums and resins of Ethiopia. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

29. Kuchar P. (1995). Identification and Characterization of Boresraceae, in the Southeastern Ethiopia. *Southeastern rangelands project technical paper. Addis Ababa, Ethiopia*.

30. Desalegn G. and Tadesse W. (2004). Socio-economic importance and resource potential of non-timber forest products of Ethiopia. Ethiopian Agricultural Research Organization.

31. Chikamai B. and Odera J. (2002). Commercial plant gums and gum resins in Kenya: sources of alternative livelihood and economic development in the drylands. *Executive Printers*.

32. Hassan B., Glover E.K., Luukkanen O., Chikamai B., Jamnadass R., Iiyama M. and Kanninen M. (2011). The Role of Boswellia And Commiphora species in Rural Livelihood Security and Climate change adaptafion in the Horn of Africa: case study of northeastern Kenya. *International Journal of Social Forestry*, 4, 86-112.

33. Lemenih M. and Kassa H. (2011). Challenges, opportunities and actions for sustainable gum and resin production. *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia*: Center for International Forestry Research (CIFOR), Bogor, Indonesia.

34. Lemenih M. and Teketay D. (2004). Natural gum and resin resources: Opportunity to integrate production with conservation of biodiversity, control of desertification and adapt to climate change in the drylands of Ethiopia. 5-6.

35. Lemenih M., Abebe T. and Olsson M. (2003). Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south-east Ethiopia. *Journal of Arid Environments*, 55, 465-482.

36. Chikamai N. (2003). Review and synthesis on the state of knowledge of Boswellia species and commercialization of frankincense in the drylands of Eastern Africa.

37. Farah A.Y. (1994). The milk of the Boswellia forests: frankincense production among the pastoral Somali. EPOS, Environmental Policy and Society.

38. Eshete A. (2002). Regeneration status, soil seed bank and socio-economic importance of Boswellia papyrifera (Del.) Hoschst. In two woredas of North Gondar zone, Northern Ethiopia. MSc Thesis, Swedish Universit of Agricultural Sciences, Skinnskatteberg, Sweden.

39. Michie C.A. and Cooper E. (1991). Frankincense and myrrh as remedies in children. *Journal of the Royal Society of Medicine*, 84, 602-605.

40. Verbeken D., Dierckx S. and Dewettinck K. (2003). Exudate gums: occurrence, production, and applications. *Applied Microbiology and Biotechnology*, 63, 10-21.

41. Maier H., Anderson M., Karl C., Magnuson K. and Whistler R. (1993). Guar, locust bean, tara, and fenugreek gums. In Industrial gums, 181-226. Academic Press.

42. Stiles D. (1988). Arid land plants for economic development and desertification control. *Desert. Control Bull*, 17, 18-21.

43. Girmay F. (2000). The status of gum arabic and resins in Ethiopia. In Report of the Meeting of the Network for Natural Gum and Resins in Africa (NGARA) 29th-31st May, Nairobi, Kenya, 14-22.

44. Ballal M., El Siddig E., Elfadl M. and Luukkanen O. (2005). Relationship between environmental factors, tapping dates, tapping intensity and gum arabic yield of an Acacia senegal plantation in western Sudan. *Journal of Arid Environments*, 63, 379-389.

45. Wekesa C., Makenzi P., Chikamai B., Lelon J., Luv A. and Muga M. (2009). Gum arabic yield in different varieties of Acacia senegal (L.) Willd in Kenya. *African Journal of Plant Science*, 3, 263-276.

46. Tadese S., Lemenih M. and Zewdie M. (2012). 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,* 114.