Conservation of Genetic Resources of Non-Timber Forest Products in Ethiopia

Proceedings of the First National Workshop on Non-Timber Forest Products in Ethiopia, 5 – 6 April 2004, Addis Ababa, Ethiopia

Edited by

Wubalem Tadesse
Michael Mbogga

Ethiopian Agricultural Research Organization

International Plant Genetic Resources Institute

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Edited by

Wubalem Tadesse
Michael Mbogga

Copyedited and Designed by

Matebu Tadesse
Ethiopian Agricultural Research Organization

Ethiopian Agricultural Research Organization (EARO)
Forestry Research Center (FRC)
P.O.Box 30708
Phone: (251) 1-460451
Fax: (251) 1-460345
Email: forestery_res@telecom.net.et
Addis Ababa, Ethiopia

and

International Plant Genetic Resources Institute (IPGRI)
Phone: (39)0661180
Fax: (39) 0661979661
Email: ipgri@cgiar.org
http://www.ipgri.cgiar.org
Rome, Italy

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Welcome Address

Dr. Wubalem Tadesse

Dear Dr. Abera Deressa, Deputy Director General of EARO,
Invited Guests and Colleagues,
Ladies and Gentlemen,
It has been repeatedly reported that forest resources in Ethiopia are vanishing at an alarming rate as a result of the ever-increasing demand for fuel wood, cropland and grazing land stimulated by rapidly growing human and animal populations. The loss of forest resources and vegetation cover results in high rates of soil erosion, loss of soil fertility, degradation of water resources and depletion of biodiversity. These consequences, in turn, adversely affect agricultural production and productivity, leading to poor economic performance and accelerated poverty in the country.

Many products have traditionally been extracted from forests, but, over time, they became increasingly marginalized as the emphasis in forest management shifted to timber production. However, in recent years, forests have been increasingly recognized as rich source of many valuable biological resources, not just timber. Natural and plantation forests provide a wide range of non-timber forest products (NTFPs) with great value for many different groups of users. NTFPs include natural gums, spices and condiments, medicinal and edible plants and essential oils.

In Ethiopia, non-farm income is an important element in the livelihood of the poor society. In several areas where population density and natural resource depletion are high, and where agriculture cannot possibly remain the only source of income. Observations show that, in many areas, own crop production is no longer the main source of income for the poor rural households. Therefore, it is essential for rural households to look for non-farm activities like NTFPs to supplement cultivation.

Dear Dr. Abera,
Dear invited guests and colleagues,
Proper management, utilization, commercialization, research and dissemination of NTFPs help to conserve our endangered forest resources, and improve the livelihood of rural people and the national economy of the country. Research on NTFPs is being conducted in different Federal and Regional research centers, higher learning institutions and NGOs. With the main objective of bringing together the researchers from different institutions and discussing research results on conservation of NTFPs and identify gaps for future activities, this Workshop was organized under the theme ***Conservation of Genetic Resources of Non-Timber Forest Products in Ethiopia.***

Fifteen papers relevant to the theme were prepared by various disciplines and research institutions. Ten of them were presented at the Workshop; and group discussions followed.

Finally, I would like to acknowledge International Plant Genetic Resources Institute (IPGRI), for financing the Workshop. My special thanks goes to Mr. Michael Mbogga, Associate Expert of Forest Genetic Resources of IPGRI, for his enormous efforts from the very beginning of the idea of this meeting to the last minute, facilitating funding, reviewing each paper etc. Thank you Mick! Now, I call upon Dr. Abera Deressa to officially open the Workshop. Thank you!

Opening Address

Dr. Abera Deressa
Deputy Director General, Ethiopian Agricultural Research organization

Dear Colleagues,
Participants of the Workshop,
It gives me great pleasure, indeed, to welcome you to this National Workshop on conservation and genetic resources of non-timber forest products, 5–6 April, 2004.

It is well known that urban and rural people in Ethiopia have been dependent on natural resources for long time and this dependence will to some extent continue for several years to come. Ethiopia is endowed with diverse natural resources including the natural vegetation composed of high forest, deciduous mixed forest and woodlands. Due to the diversity of its plant resources, Ethiopia is recognized as one of the centers of diversity for crop species. These natural resources provide valuable service to the community.

Forests provide food and feed. They are source of sawn wood, poles and bamboo that have vital importance in house construction and in a wide range of necessities from furniture to farm implements. In addition to these, wood, leaves, twigs and branches, which are obtained from forests, are important source of energy. Forests also have important roles in protecting watersheds, and irrigation structures, in reclaiming degraded lands, controlling erosion and acting as a buffer against environmental changes as climate, biodiversity and fresh water preservation.

The other important benefit from forests comprises non-timber forest products (NTFPs). The most important NTFPs in Ethiopia include spices; honey and wax; bamboo and reeds; wild date; natural gum; edible plant products like leaves and shoots, fruits, seeds, tubers, mushrooms, edible oil, fat and fodder; fibres; bark; simple sugar products; essential oils; tannins and dyes; medicine and various extractives.

These NTFPs contribute to improvement of the livelihood of rural communities by providing food, medicine, additional income, and employment opportunities. They also contribute for foreign exchange earnings of the country. In addition, sustainable management and utilization of NTFPs complement wood-based management and offer a basis for managing forests sustainably, thereby supporting biodiversity conservation.

Despite the enormous socio-economic and environmental contributions of this natural resource, it has been subjected to rapid destruction for various reasons. Research and development institutions have to work hand in hand to overcome resource degradation. Therefore, it is high time to consider the importance of developing and adopting appropriate technologies suitable for proper conservation, development and utilization of this resource. This effort is in line with the current rural resource development policy and strategy of the Ethiopian government, which is giving due emphasis to the urgency and importance of conservation and rehabilitation of natural resources of the country. This policy also gives due consideration to the importance of focusing on products that have market value and contribute to improve the well being of the local community and economy of the country.

Research and development are essential to enhance the contribution of NTFPs in this country. EARO has developed Forestry Research Strategy with emphasis to the importance of addressing the issue of forest resource conservation and development. In the Strategic Plan, research on NTFPs has been identified as one of the focus areas of forestry research. In addition, curtailing natural resource degradation has been identified as a major strategic issue in the three-year (2004–2007) Strategic Plan Management (SPM) of EARO. In the SPM, it has also been clearly shown that special emphasis would be given to strengthening the forestry research capability.

I believe that this Workshop was organized timely and I hope it would assess the potential the country has with regard to NTFPs, the major constraints faced and the solutions to be taken. In providing solutions, I believe that the participants would indicate where technologies that help address the major issues can be obtained. This information obviously would help to identify problem areas as well as to prioritize and design appropriate research plan to generate technologies useful for the community.

I would like to ensure you that EARO has a long tradition of conducting collaborative research and is ready to work in collaboration with all its stakeholders in any agricultural research areas. I hope the workshop would fulfill its objectives and provide valuable information for future research and development works.

Wishing you all successful deliberations in the coming two days, I now declare the workshop open.

Thank you.

Genetic Conservation of Ethiopia's Non-timber Forest Poduct Source Species

Mbogga Michael[1] **and** *Wubalem Tadesse*[2]
[1]*International Plant Genetic Resources Institute, P.O. B0x 30677, Nairobi, Kenya.*
[2]*Ethiopian Agricultural Research Organization, Forestry Research Center, P.O. Box 30708, Addis Ababa, Ethiopia*

Introduction

During the last 10–20 years, human interest in non-timber forest products (NTFPs) that appeared relevant to the growing focus on rural development and conservation of natural resources has grown (Arnold and Perez, 2001). Indeed, NTFPs seemed to offer hope that their presence in the forest would act as an incentive to conserve the forest (Lawrence, 2003), at the same time contributing to community development. This was based on the perception that these products are more accessible to rural populations and especially to the rural poor (Saxena, 1995), and that their exploitation is more benign than timber harvesting (Myers, 1988). Moreover, there is an assumption, often implicit, that making forests more valuable to local users can encourage forest conservation (Plotkin and Famolare, 1992; Evans 1993). It is now widely accepted that this has not been the case in many situations, calling for a redress in our approach to NTFPs conservation and use.

Despite the fact that NTFPs contribute to tropical forest conservation and poverty alleviation was regarded as very promising, recent studies have cleared, however, that the alleged commercialization-conservation/development link in the NTFPs debate needs reconsideration (Ros-Tonen and Wiersum, 2004). The exploitation of forest resources has a differentiated effect, depending on the type of species and the parts being harvested (Arnold and Perez, 2001). The effect of uncontrolled exploitation of NTFPs from natural population can also have adverse effects not only on the species exploited but also on other associated species. This is why approaches to conservation of NTFPs source species that are sources of non–timber forest products need to be tailored to individual species and areas. Although some NTFPs play a role in rural livelihood strategies and can contribute to sustain forested landscapes in various tropical forest areas, there is no uniform picture as regards the actual importance of NTFPs to rural livelihoods (Ros-Tonen and Wiersum, 2004).

This paper set the stage for discussions at a meeting held 5–6 April 2004 in Addis Ababa on the genetic conservation of species that are sources of important NTFPs in Ethiopia. The meeting was organized by the International Plant Genetic Resources Institute (IPGRI) in collaboration with the Ethiopian Agricultural Research Organization (EARO) and brought together 40 scientists engaged in NTFP-related activities in the country. Discussions centered on three main themes; the major NTFPsof the country, genetic conservation of the different NTFPs source species; and what needs to be done to promote conservation of the species as well as to ensure optimum benefits to the local communities that heavily depend on them.

NTFPs and community development

NTFPs were regarded as providing a very good opportunity for sustainable forest management and community development in the last two decades. There has been increasing recognition of their contribution to household economies and food security, to some national economies and particularly to environmental objectives, including the conservation of biological diversity (Arnold and Perez, 2001).

The role of NTFPs to the livelihoods of rural communities is likely to continue as long as the resources are exploited on a sustainable basis. This in itself is not likely to result in tremendous community development since these rural communities have been using these resources for centuries. On the other hand, exploitation of NTFPs for commercial purposes contributes to local economies—hence contributing to community development. The only drawback to this scenario is that commercialization also results in overexploitation and depletion of the resources. Therefore, a balance has to be stricken between resource sustainability and benefits of exploitation of products, particularly for the export market.

Effect of harvesting NTFPs on genetic diversity of the NTFP-source species

Human activities in forests modify the size and age of directly harvested and associated species, thus potentially altering genetic structure and levels of genetic diversity (Ratnam and Boyle, 2000). Genetic variation is a necessary element in the maintenance of other levels of diversity and its conservation is a precondition for future evolution and adaptability of local populations and of entire species (Namkoong *et al.,* 1996). Changes in genetic variation, whether natural or human-induced, have a bearing on the survival of a species. Forest level events due to deliberate forest management and utilization practices or due to inadvertent changes which result from climate change or accidents can be expected to induce certain kinds of changes to genetic processes that in turn affect the evolution and sustainability of forests (Namkoong *et al.,* 1996).

NTFPs extraction can affect the genetic diversity of the population being exploited, especially if flowers or fruits that show deferential traits harvested–resulting in different degrees of pressure (Peters, 1994). Since the nature of NTFPs varies widely, and the form of harvesting can involve whole individuals, reproductive parts like flowers, fruits and nuts or non-reproductive parts such as leaves, bark and branches, the likely genetic effects will also be highly variable (Ratnam and Boyle, 2000).

Harvesting of fruits or flowers tends to have a more direct or dramatic effect on regeneration and genetic diversity than harvesting of leaves, bark or other non-reproductive parts of the plants. Namkoong *et al.* (1996) concluded that the main effects of harvesting whole individuals would be via genetic drift and indirect selection. In contrast, harvesting only reproductive structures would most likely affect gene flow, the mating system and direct selection.

Throughout Africa, numerous medicinal plant species are becoming increasingly scarce due to a rise in trade to meet the demand from growing urban populations (Marshall, 1998). For example, favored species such as *Dalbergia melanoxylon* have declined in Kenya and South Africa through harvesting to supply the woodcarving trade (Shackleton, 1993; Cunningham, 2000). Bark extraction has caused serious damage to wild populations of *Prunus africana*, including trees inside forests of high conservation value (Cunningham *et al.,* 2002). *Warburgia ugandensis* is another tree species threatened by exploitation of its roots, barks and shoots for medicinal purposes in East Africa. *Boswellia papyrifera* is one of the threatened species in Ethiopia due to over exploitation or improper tapping of its frankincense and lack of regeneration (Abeje, 2002).

Unless harvesting is controlled, some species will therefore become genetically impoverished or depleted more rapidly than others (Arnold and Perez, 2001). Exploitation of NTFPs from the wild in many respects and depending on the plant part harvested can help for sustainable utilization of the species. However, this requires understanding growth and reproductive characteristics of the plants and the application of harvesting practices that permit adequate reproduction or regeneration of the individual organism (Sunderland *et al,* 2004). Domestication of the species in question is another alternative in cases where exploitation of NTFPs from the wild cannot be sustainable.

Non-timber forest products in Africa

Although NTFPs play a major role in the rural economy of Africa, information on their overall contribution is patchy and incomplete at best, except for a few species and products of commercial importance (FAO, 2003). The lack of systematic efforts to conserve and manage resources is a major concern and it is in only a few cases that efforts have been made to cultivate species that yield NTFPs. African forests are a source of a variety of NTFPs such as fruits, gums and resins, honey and beeswax, medicinal and aromatic plants, dying and tanning materials, bamboo, and bush meat. These products are of critical importance to the livelihoods of rural communities and, in some situations, account for a significant share of household income (FAO, 2003) as a source of food. Increased demand has not necessarily led to improved management including domestication, and a substantial proportion of products are collected from the wild, hence resource depletion is a major problem (FAO, 2003). Further, Africa has not been able to take advantage of its wealth of raw material and traditional knowledge and investing on processing—undermining opportunities for employment and income generation.

Important NTFPs in Ethiopia

Due to its varied ecological and climatic conditions, Ethiopia is home to some of the most diverse flora and fauna in Africa. NTFPs in Ethiopia cover a wide range of products and are most extensively used to supplement diet and household income, notably during particular seasons in the year, and to help meet medicinal needs. They are largely important for subsistence and economic buffer in hard times.

These products contribute to the improvement of the livelihoods of rural communities by providing food, medicine, additional income, and employment opportunities and foreign exchange earnings of the country. In addition, by complementing wood-based management, they offer a basis for managing forests in a more sustainable way, thereby supporting biodiversity conservation. Historically, early forestry work tended to ignore this fact; it was mainly focused on managing forests for the continued supply of timber. The significant value and importance of NTFPs is felt more in dryland areas where few alternatives of resources exist for supporting the livelihoods of local communities because of difficult environmental conditions (EARO, Unpublished).

In Ethiopia, non-farm income represents an important element in the livelihoods of the poor. In several areas, where the population density and depletion of natural resources are high, agriculture cannot possibly remain the only source of income. Observations show that, in many areas, crop production is no longer the main source of income for poor rural households (RESAL, 2000). Therefore, it is essential for rural households to look for non-farm activities like productive exploitation of NTFPs to supplement agricultural production.

The most important NTFPs in Ethiopia include coffee; spices and condiments; honey and wax; bamboo; reeds; natural gums such as gum arabic, frankincense and myrrh; edible plant products like leaves and shoots, fruits, seeds, tubers, mushrooms, edible oil, and fat; fodder; fibers; bark, simple sugar products; essential oils; tannins and dyes; resins; latex; ornamental plants and giant/long grasses (EARO, Unpublished).

Spices harvesting is practiced in many forest areas of southern Ethiopia, such as Sheka, Keffa, Bench Maji, South Omo and Gamo Gofa Zones (Jansen, 1981). Commercial spices such as *Aframomum corrorima* (Korerima) and *Piper capense* (Timiz) are found as indigenous species in Shekicho-Keficho and Bench Maji forests and woodlands.

Beekeeping is an ancient tradition in Ethiopia with annual production of about 24,000 tones of honey. This is a third of the total honey production in Africa. The density of hives is estimated to be the highest in Africa. An estimated 4–10 million traditional beehives and some 10 000 modern boxes exist in the country (Vivero, 2001). The main products of the beekeeping industry are honey and wax. Honey is almost exclusively consumed locally, while a considerable proportion of wax is exported.

Ethiopia is one of the few tropical countries well endowed with diverse plant species that yield economically valuable gum and aromatic resins such as gum acacia, frankincense and myrrh (Wubalem *et al.,* 2003; Mulugeta and Demel, 2003). The commercial use of natural gums is an age-old activity in Ethiopia. Ethiopia has been one of the major producers and exporters of natural gums from different indigenous tree species of the genus *Acacia, Boswellia* and *Commiphora*, which are found in different agro-ecological zones of the country (Vollesen, 1989).

Ethiopia has 67 % of Africa's bamboo resources which is about 7 % of the world total (Kassahun, 2002). It has about 1 million ha (Luso Consult, 1997; Kassahun, 2002) of highland bamboo. *Arundinaria alpina* accounts 150, 000 ha, out of which 130, 000 ha is natural and 20, 000 ha human made bamboo plantations owned by framers. Lowland bamboo is dominant with coverage of 700,000–850,000 ha. Bamboo provides food, fodder, furniture and building materials (scaffoldings), industrial inputs, medicinal plants and fuel. Solid bamboo has been tested as a concrete reinforcement to substitute steel and the results have revealed success.

The overall socio-economic and ecological importance and contribution of NTFPs in Ethiopia is significant, diversified and valuable. The harvesting, commercialization and transformation of certain NTFPs by the rural poor can be a means of shifting efforts away from the unsustainable exploitation of ecologically sensitive forest products. The NTFPs are among the main coping mechanisms that poor households and the nation have. Thus, their importance should not be overlooked or underestimated.

Genetic conservation of NTFPs source species in Ethiopia

Currently, little consideration is given to the conservation of genetic resources of important NTFPs source plant species. There have been efforts to increase harvest of products particularly from the wild. Most research works focused on processing and adding value to the products. Genetic resource conservation can be made an integral part of the species promotion program. It is evident that programs target products; the Natural Gum Processing and Marketing Enterprise (NGPME) is one of such programs concerned with production and marketing of gums and resin in the country. Such a program can be very instrumental in efforts to promote the genetic conservation of major gum and resin producing species, particularly *Boswellia papyrifera* which is currently threatened in some parts of the country.

Suggestions on how to promote conservation of the NTFPs source species as well as ensure optimum benefits to the local communities are thus important. Recent efforts are mainly focused on NTFPs enterprise development. These assessments would need not only baseline surveys of the extent of the resources but also regular monitoring of the performance of the species. This would be coupled with efforts to promote the domestication of species, especially those that are threatened as a result of exploitation of NTFPs. This monitoring would consider assessment of the genetic variability in the species. Efforts would be made to ensure high genetic variation in the different species.

Research should be carried out to develop technologies that assist for an efficient and effective utilization and processing of NTFPs and enable to meet international standard by improving the quality of NTFPs. This would reduce waste of resources and improve value addition and hence increase revenue from the products.

Public awareness needs to be created about the contributions of NTFPs at local and national levels to promote sustainable utilization of the products for national and community economics and environmental conservation. Efforts targeting selected NTFPs source species can be more effective than efforts with mandates spreading to all NTFPs yielding species. Programs need to address the biological and ecological aspects of the species and the socio-economic context in which the species are used. Enhancing the capacity of the local communities to manage and process the different products from trees for value addition is very important. This needs to follow activities aimed at domestication of priority species, which need to be carried out as a collaborative activity between regional agricultural bureaus and the local communities.

Domestication of NTFPs source species

Overexploitation of NTFPs has led to market expansion and supply shortages, which in turn led to cultivation of trees for the same products (Simons and Leaky, 2004). One of the most fundamental elements of a tree domestication program is the sourcing and development of germplasm (Simons and Leaky, 2004).

Successful domestication of NTFPs source species greatly depends on the species in question. Species that can easily be integrated with existing cropping systems are more likely to be domesticated faster than species that require large areas for their cultivation. Farmers will only consider domestication when the benefits of doing this are more than the benefits from growing other crops. Several other factors influence the success of a tree/species domestication program.

Once domestication programs are to be embarked on, it is important to ensure that species planted on-farm have optimum representation of the genetic diversity of the species to ensure good yields and adaptation to changes in the environment. It is also important to seriously consider matching the ecogeographical conditions of germplasm sources to conditions of areas where planting takes place. Detailed genetic studies may be too costly but morphological characterization may be used in this case. However, in cases where a domestication program focuses on a few species to be used over wide areas, it may be imperative to invest in molecular characterization of germplasm from different sources to ensure that this is adequately represented in domesticated stands.

The role of international research centers

The International Plant Genetic Resources Institute has, for more than a decade, been engaged in promotion of the conservation and sustainable use of genetic resources of NTFPs source species. The work has concentrated mainly on bamboo and rattan in Asia, the Pacific and Oceania. The effort has contributed to the identification of species and establishment of collections of these two valuable species. The other has been on tropical fruits, still in Southeast Asia. Other centers that are better placed for significant contribution in this area include the World Agroforestry Center (ICRAF) which has done a lot of work on the domestication of tree species. The Center for International Forestry Research (CIFOR) has the mandate for all forest-related researches and tries to promote the sustainable management and utilization of forest and tree resources. People and Plants International, formerly People and Plants Initiative, helps to promote the benefits of NTFPs to rural communities and helps them devise sustainable utilization measures of these resources. Several others that focus on one species or a given range of products can also be instrumental. For instance, the International Network for Bamboo and Rattan (INBAR) is entirely devoted to the promotion of conservation and use of bamboo and rattan. The Food and Agricultural Organization of the United Nations has a unit of non-wood forest products. It works with relevant government departments for the conservation and sustainable utilization of their NTFPs.

These organizations are bound to take different approaches to activities relating to NTFPs. The approach taken will greatly depend on the problem at hand. This could be through large international or regional projects such as FAO's Acacia Operation supported by the Italian Government, or limited to bilateral underrating between the Organization and any given state. Regardless of which approach is taken, it is the duty of relevant national institutions to point out areas in need of urgent attention.

The role of markets

Trade patterns are historically deep-rooted in Africa and have heavily influenced the economic development of the continent (Sunderland *et al.,* 2004). NTFPs have always made a significant part of the trade. Trade in NTFPs helps to improve income of local communities. However, exploitation of NTFPs for the market has in many cases contributed to their depletion from forests—leaving rural communities in a worse off state that they were in prior to commercialization of the products.

Since the 1990s, promotion of NTFPs to improve livelihoods of rural people and to promote conservation of forests were based on exaggerated claims of economic potential (Sunderland *et al.,* 2004) to rural communities and a limited evaluation of the complexity of economic, social and market-oriented issues surrounding NTFPs (Lawrence, 2003).

In their analysis of 61 cases of NTFPs around the world, Pérez *et al.,* (2004) found that product use is shaped by local markets and institutions, abundance of resources and the relative level of development.

There are cases where market of NTFPs has promoted the conservation of a species and also those where exploitation for the market has resulted into depletion of population of the species of interest. *Vitellaria paradoxa,* which is valued shea butter, is used by local communities as cooking oil, cosmetic and a drug. The bulk of it finds its way to the international market. Farmers deliberately maintain *V. paradoxa* trees onfarm mainly for their fruits and nuts (Teklehaimanot, 2004). The species has influenced the management of vitellaria trees in parklands of West Africa. Maranz and Wiesman (2003) indicated that vitellaria populations have been established in new areas by migrants and that considerable genetic selection might have occurred under the traditional savanna management practices of indigenous peoples.

Prunus africana is valued for its bark which is a source of extractives used to treat benign prostate cancer. The bark of *P. africana* is exploited largely for export. This species has been heavily exploited in its natural range that farmers in East Africa and Cameroon have now started planting *Prunus africana* on their land.

Species that are traded only at the local or village level are not mainly influenced by market forces. Therefore, it is imperative to take strong methods of promoting genetic conservation of species products of which are traded internationally. Resources from trade in the products can be used to implement conservation programs.

Conclusion

Like in many rural communities, NTFPs play a vital role in the livelihoods of communities in Ethiopia through contributing to food security and household income. These products, particularly frankincense, contribute to the national economy as well. Almost all products are harvested from the wild and as population pressure increases, there will be shortages. This calls for sustainable management of natural populations of important species as well as promotion of domestication activities for these species. This requires concerted efforts to manage diversity in the wild, assess and monitor diversity for domestication programs to ensure that planted species adapt to changes in the environment as well as yielding optimum quality and quantity of products. This needs to be complemented with efforts to process and market the products locally, regionally and internationally. In some cases, the market drives the domestication and conservation of the most important species.

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Socio-economic Importance and Resource Potential of Non-timber Forest Products of Ethiopia

***Getachew Desalegn*[1] *and Wubalem Tadesse*[2]**

[1]***Ethiopian Agricultural Research Organization, Forestry Research Center, Forest Products Utilization Research Program, getachewma@yahoo.com, PO Box 2322, Addis Ababa, Ethiopia.***

[2]***Ethiopian Agricultural Research Organization, Forestry Research Center, Forest Genetic Resources Research Program, wubalemt@yahoo.com PO Box 30708, Addis Ababa, Ethiopia.***

Summary

There is a growing need for and awareness about the different aspects of non-timber forest products (NTFPs). They contribute to improving the livelihoods of rural communities by providing food, fodder, medicine, additional income; cultural, socio-economic, environmental and ecological values; employment opportunities and foreign exchange earnings. The significant value and the importance of NTFPs is felt more in dryland areas of the world including Ethiopia where fewer alternative resources exist for supporting the livelihoods of local communities, pastoralists, because of the difficult environmental conditions. There are several indigenous trees, shrubs, herbs, wildlife resources and many other NTFPs in the vast arid and semiarid lowlands and highlands (natural and plantation forests, farmlands and homesteads, and watersheds and marginal lands) of Ethiopia, known to yield socio-economically and ecologically valuable NTFPs. Ethiopia is home to a wide range of NTFPs available from various multipurpose plant species and products, the majority of which are still less known, less managed and underutilized. This paper presented the socio-economic importance and resource potential of the most important and potential NTFPs such as frankincense, myrrh, gum Arabic, bamboo, spices, medicinal plants, edible plants, essential oils, honey and bees wax and civet which are useful for household and national economy. It also addressed the major gaps, research focus, research activities and status of the National NTFPs Research Project of Ethiopian Agricultural Research Organization. The objective of the paper was to: (i) give some highlight on potential NTFPs of Ethiopia and their socio-economic and environmental importance and (ii) bring to the attention of researchers, botanists, agriculturists, conservationists, farming communities, policy makers, and other stakeholders, issues about biodiversity in relation to NTFPs with the clues and mandate of developing integrated and suitable scenarios on planning strategies and thematic areas for increased emphasis on genetic conservation, regeneration, research and development, promotion, processing, grading, marketing, commercialization and sustainable utilization of NTFPs.

Introduction

It is believed that natural forests of Ethiopia once covered about 42 million ha (about 40 %) of the country's land area of 110 million ha; this forest cover now accounts to only about 4.07 million ha (3.56 %) (WBISP, 2004). Forests and woodlands of Ethiopia act as sources of raw materials for wood-based energy (70 % of the total energy needed), construction, wood-based industries, non-timber forest products (NTFPs), employment, environmental protection, ecological maintenance, aesthetics, eco-tourism, food, feed, cash, and medicine, but to mention few. However, these very useful and versatile resources are vanishing at an alarming rate, estimated at 150 000–200 000 ha per year, as a result of the ever increasing demand for wood and farm, pasture, and settlement land. For the year 2004, demand for wood was estimated at about 70 million m^3 of wood, whereas supply was estimated at about 13 million m^3, projecting a deficit of 57 million m^3 (about 530 %).

Among the factors of forest destruction and degradation are transformation of forestlands into crop and grazing lands and other land use systems, and recurrent forest fire stimulated by rapid growth of human and animal populations (EFAP, 1994; EARO, 1999).

The overall cultural, socio-economic, environmental, ecological and biodiversity importance of NTFP has been overlooked although NTFPs play a significant role in the daily life and well being of millions of people in many tropical countries including Ethiopia. Most of the world's rural and poor people in particular, including women who are more responsible for household activities, and pastorlists, depends heavily on NTFPs as sources of food, fodder, traditional medicines, gums, resins, fuel, roof thatch and construction materials, mulch, off-farm income and employment, and a number of services which mostly have no assigned monetary values. These products are particularly important in relieving 'slack periods' in the agricultural cycle, and providing a buffer against risks and household emergencies and seasonal fluctuations by contributing to the fulfillment of daily needs and providing employment and income (FAO, 1995).

In addition to local subsistence, NTFPs are also important raw materials for small and large-scale industrial processing, including for internationally traded commodities such as, foods and beverages, flavorings, essential oils and medicines which can be found on local, regional, national as well as international markets. Internationally traded NTFPs, such as frankincense, gum Arabic, honey, bees-wax, bamboo, rattan, cork, forest nuts and mushrooms, oils, aromatic and essential oils, spices, many edible plants, and plant or animal parts for pharmaceutical products fetch higher prices than NTFPs traded on national markets and thus contribute to the economic development of the countries producing them. Presently, at least 150 NTFPs are significant in terms of international trade (FAO, 1995; ITTO, 1999). NTFPs often have a combined value much greater than the value of timber (WWF, 1989).

The term 'non-wood forest products (NWFPs)' includes all goods of biological origin and environmental and socio-cultural services other than wood derived from forests, trees outside forests, other woodlands and allied land uses (FAO, 1995; Vantomme, 1995; Chikamai, 1998). The technical phrase 'non-timber forest products (NTFPs)' emerged as a general expression for the multiple and diverse array of resources. It includes all marketable and subsistence commodities of biological (plant and animal) origin for human consumption, industrial use and services (tourism, recreation, shade and shelter, ecological balance, biodiversity, amenity and environmental values) other than timber derived from renewable forest resources and biomass, trees outside forests, other woodlands and allied land uses bearing promise for augmenting household food security, income, trade and employment. The later definition has been applied in this paper.

NTFPs have been increasingly recognized and attracted considerable global interest in the past 15 years due to their socio-economic, cultural and environmental contributions to increasing: (i) household income and national economies (foreign currency), (ii) food security, (iii) employment opportunity, (iv) sustainable forest management and environmental objectives such as the conservation of biological diversity (FAO, 1995; Chikamai, 1998.)

The flora of Ethiopia has been estimated between 6000 and 7000 species of higher plants (Tewolde Berhan, 1991 cited in Desalegn 2000; Zemede and Mesfin, 2001, and Mirutse, 2001), and about 10–12 % of these are estimated to be endemic (Vollesen, 1989; Mirutse Giday, 2001). The diverse vegetation and ecological conditions are among the factors that support such a rich flora, which is now under threat (Zemede and Mesfin, 2001). More than half (51 % or, 620 000 km^2) of Ethiopia's total land area is arid to semiarid and is home to 12 % of the population, with marginal or insignificant agricultural potential (Mulugeta and Demel, 2002; Wubalem *et al*., 2003). Ethiopia is home to a wide range of NTFPs available in the vast arid and semiarid lowlands and highlands of the country, known to yield economically valuable products. However, some of the most important species such as *Boswella papyrifera (*Kindeya *et al*., 2002*)* and *Acacia senegal* are on the verge of extinction unless integrated measures on regeneration, conservation and rational utilization are taken very soon.

So far, little effort has been made on research, sustainable development, and management to explore the vegetation resources that provide these valuable commodities to the country. The current knowledge and information available about the biology, ecology, distribution, management, resource base, production potential, collection, tapping, volume of production and effective processing, grading, marketing and economic uses of the various *Acacia Boswellia* and *Commiphora* spp. and numerous other NTFPs resources of the country has not been adequately assessed and documented.

The challenge now is how to conserve, regenerate and rationally utilize these potential and multi-purpose resources of the country. The area of NTFPs has to receive considerable attention due to increasing scarcity of species such as *B. papyrifera, Commiphors* spp. and *A. senegal*, and also due to the significant role they play in the livelihoods of rural communities, in trade and industry, and in sustainable management of forests. Thus, reliable, integrated, participatory and advanced methods have to be devised on sustainable regeneration, propagation, production, and processing, marketing and rational utilization of NTFPs from the different species of Ethiopia.

The main objectives of this paper were to: (i) give some highlight on potential NTFPs of Ethiopia, their socio-economic and environmental importance, (ii) bring the attention of researchers, botanists, agriculturists, conservationists, farming communities, policy makers, and other stakeholders to the biodiversity of NTFPs, with the clues of developing integrated suitable scenarios on planning strategies and thematic areas for increased emphasis on genetic conservation, regeneration, research and development, promotion, processing, grading, marketing, commercialization, domestication and sustainable utilization of NTFPs.

Socio-economic importance of NTFPs

There is a growing need for and awareness about the different aspects of NTFPs; they contribute to improvement of the livelihoods of rural communities and the nation by providing food, fodder, medicine, and additional income and through their cultural, socio-economic, environmental and ecological uses, employment opportunities and foreign exchange earnings of Ethiopia. NTFPs have been considered with five thematic areas in the Forestry Research Strategy of Ethiopian Agricultural Research Organization (EARO) (EARO, 1999).

The drylands of Africa, which occupy about 80 % of the countries that make up the Inter-Governmental Authority on Development (IGAD) including Ethiopia and between 30–90 % of other countries, are home to a wide range of NTFPs. The significant value and the paramount importance of NTFPs is felt more in the dryland areas of the world including Ethiopia where fewer alternative resources exist for supporting the livelihood of local communities/pastoralists because of the difficult environmental conditions which result from scanty and erratic rainfall, high evaporation and poor soils (Chikamai, 1998). Sustainable development and management of the drylands in particular and all NTFPs in general lies in the rational utilization of the existing resources.

The Global Agenda 21, approved by the UN Conference on Environment and Development (1992), which provides a global plan for action, has recognized the role of NTFPs in sustainable forest management (FAO, 1995). Given certain basic conditions, NTFPs can help communities to meet their needs without destroying the forest resource (FAO, 1995). FAO (1995) also indicated that NTFPs are important to three main groups: (i) rural populations (the largest group) who have traditionally used these items for supporting their livelihood and for social and cultural purposes, (ii) urban consumers (smaller group but increasing faster) who purchase these items, and (iii) traders and product processors, whose numbers in the NTFPs sector increase as urban markets for these products grow.

Despite the rapidly growing demand for different NTFPs for their various importances, NTFPs have largely been overlooked in mainstream conservation and forest policies (Guillen *et al*., 2002). Without sound knowledge of the resources and regular monitoring of the different activities surrounding these resources, harvesting of certain NTFPs can have a disastrous impact that can not be noticed until it is late to remedy (FAO, 1995). Currently, only limited data is available on the resource base, management, utilization and marketing of NTFPs. Unlike for timber and agricultural products, no regular national monitoring and evaluation of the resources and the socio-economic contribution of NTFPs has been carried out in each country.

Since the early 1990s, NTFPs have been assumed to effectively contribute to the preservation of tropical forests and the improvement of forest dwellers' economic situation by raising awareness of the value of natural resources (Schröder, 2000). Since 1991, the Forest Department of FAO, in view of the growing recognition of their socio-economic importance, has embarked on a major program for the promotion and development of NTFPs. The Program targets to improve the utilization of NTFPs as a contribution to sustainable forest management and to the conservation of the biological diversity of forest resources, and simultaneously to improve food security for rural people (FAO, 1995; Spore, 2000). The Program is composed of the following main elements: (i) gathering, analysis and dissemination of key technical information on NTFPs; (ii) full appraisal of the socio-economic contribution of NTFPs to rural development; and (iii) improving networking among individuals and organizations dealing with the promotion and development of NTFPs (FAO, 1995).

NTFPs have the following most important socio-economic contributions at international, continental (Africa) and national (Ethiopia) levels.

At international level

- About 140 million people live within or on the margins of forests relying on them for fuel, firewood and raw materials for clothes, buildings and medicines, out of which about one million (1–2 %) are tribal-hunters-gatherers groups who have a vast and irreplaceable knowledge of the forests in which they live (WWF, 1989).
- The World Health Organization (WHO) estimated that 80 % of the population of the developing world use NTFPs for health and nutritional needs (FAO, 1995; Vantomme, 1995; Chikamai, 1998; ITTO, 1999). About 20 % of modern allophatic medicaments are plant origin (FAO, 1995). Out of the 50 000 medicinal plants, two-thirds are harvested from the wild but 4000–10, 000 of them may be endangered (Anonymous, 2004). In 1990s, more than 150 NTFPs were significant for international trade, apart from that was traded at national and local levels; value ranged US$ 5–10 billion (FAO, 1995; ITTO, 1999).
- The total value of the world trade in NTFPs is 11 billion US$, of which about 60 % is imported by EC, USA and Japan (Vivero, 2001).
- World trade in natural honey is 300 000 tones, valued at US$ 300 million. Ethiopia is 4th in bees wax and 10th in honey production (Vivero, 2001).
- Annual world trade value of essential oils and spices from tropical forests exceeds US$ 1 billion (WWF, 1989).

- Members of the Samakae Community Forest in Thailand consider themselves 50 % self-sufficient on the products of the forest for their daily living needs. In 1996, approximate export values of NTFPs including bamboo, rattan, gums and resins, medicinal plants, spices, industrially useful insects, agar-wood, etc., was US$ 18 million (FAO, 1995; ITTO, 1999).
- There are about 18 million forest dwellers in Philippines who are dependant primarily on the collection and sell of NTFPs (bamboo, rattan, gums and resins) for their livelihood (FAO, 1995; ITTO, 1999).
- The number of people involved in NTFPs in Brazilian Amazon was 200 000 in 1995; the value of six products being US$ 65.4 million. Brazilian nut extract is the second most significant product next to Rubber tree (*Hevea* Spp.); it generates revenue of US$ 10–20 million each year (WWF 1989; ITTO, 1999).
- About 7500 ha cloud forest reserve protects the forests in a watershed above Tegucigalpa, the capital city of Honduras, which provides 40 % of the city's drinking water. If the forest was to disappear and the water supplied from another source, the economic value of the reserve has been estimated at US$100 million (13300 US$ ha^{-1}) (WWF, 1989).
- In India, NTFPs worth US$135 million per year (WWF, 1989). The economic contribution of NTFPs exceeds 70 % of the total value of forest-based exports and 13 % of total exports (Lele *et al.,* 1994). About 80 % of forest dwellers depend on NTFPs for 20–25% of their food requirements. On a national basis, 50 % of the revenue and 55 % of the employment in the forestry sector is attributable to NTFPs, which provide 50 % of income to 30 % of the rural population (Lele *et al.*, 1994).

At continental (Africa) level

- They are the only readily available and affordable sources of human and livestock health care for more than 500 million people and hundreds of millions of livestock In Sub-Saharan Africa (IK Notes, 2001).
- In South of the Sahara, about 15 million people could be engaged in such forest product activities. Non-farm earnings are substantial to African farmhouseholds and such earnings range from 22 % to 93 % depending on the countries, cash and in-kind income. The sample average share over the 25 case studies was 45 % (Vivero, 2001).
- In six countries surveyed recently in Southern and Eastern Africa, about 763,000 persons were employed in small-scale production or trading of four types of forest products: grass, cane and bamboo products (42 %), woodworking (27 %), other wood products (11 %), and other forest products trade (20 %) (Vivero, 2001).
- In Zimbabwie, small-scale forest-based enterprises, which mostly are based on NTFPs, employed 237, 000 people in 1991, compared to 16,000 employed in conventional forestry and forest industries for the same year (Spore, 2000).
- Eco-tourism is the world's largest industry annually growing at around 5 %. About 35 % of Kenya's GDP comes from its annual 800,000 tourists. Africa has the world's most spectacular displays of wildlife and wonderful landscapes but, according to the World Tourism Organization, it receives only 1.8 % of global tourism (Vivero, 2001).
- NTFPs sold annually in local or regional markets in Cameroon account for more than 150, 000 UREO and about 3000 metric tone *Prunus africana* bark and bark products exported since early 1990s earned US$ 220 million per year (Spore, 2000).
- Sudan supplies 80 % of gum Arabic the world mainly from *A. senegal* with 30, 000 tone annual production (Chikamai, 1998; Vivero, 2001).

At national (Ethiopia) level

- More than 80 % of the Ethiopian population depends on traditional medicine from NTFPs for its health care practices (FAO, 1995; Desalegn, 2000; Mirutse, 2001).
- Field and herbarium studies on wild flowering plants of Ethiopia furnished 203 wild food plant species consumed by the community (Zemede and Mesfin 2001).
- In southern Ethiopia, some wild food plants such as *Arisaema* and *Huernia* spp are considered as typical famine foods, even if they are aggressive weeds, and are purposely cultivated on farm fields for use at times of food shortage. Other wild food plant species used during famine or any other period are *Sterculia africana, Dobera glbra, Partulaca quadrifolia* and *Cadaba* spp., *Solanum nigrum, Solanum khasianum, Syzygium guineense, Moringa oleifera, Piliostigma thonningii, Balanites aegyptiaca, Balanites rotunda,* and *Amaranthus* spp (Vivero, 2001).
- Azene *et al.* (1993) identified 199 multipurpose tree and shrub species that are used for food and medicine (123 species), fodder (108 species), as well as for other purposes like fibers, resins, tannins, and oils (117 species).
- In Pawe Wereda of Benishangul Gumuz Regional State, 18 types of plant- and animal-origin NTFPs are extracted from 108 plant, and 13 animal and fungi species. About 21 % of the annual income of the average farmer comes from either direct consumption or sale of these NTFPs. Medicinal plants, edible forest products, aromatic plants, and grasses are the main income sources in the Werdea (Yohannes *et al*., 2002), and women do most of the NTFPs collection.
- Ethiopia is 4th in bees wax and 10th in honey production in the world. Honey production in Borena Zone of Oromia Region roughly accounts for 10 % of poor household's annual food needs while wild foods are critical to the households' survival since they contribute approximately 15 % of a household's needs in bad years; and 5 % in good years (Vivero, 2001).
- Harvesting and cultivation of wild spices is widespread in many areas of Southern Ethiopia, namely Sheka, Kaffa, Bench-Maji, South Omo and Gamo Gofa (Jansen, 1981). The total supply of spices from Shekicho-Keficho Zone to the regional and national markets in 1999 was about 1, 208 metric tone (MT) (Vivero, 2001).
- Total size of woody vegetation in Ethiopia that can yield natural gum and resins is very large (about 2, 855,000 ha) (Wubalem *et al.,* 2003). In the period 1992–2001, Natural Gum Processing and Marketing Enterprise (NGPME) produced a total about 14675.6 tone natural gums (gum oilbanum/frankincense, gum Arabic, oppoponax, Karaya/*Sterculia setigera and* myrrh) and earned about 102, 330,882 Birr, which is about 12.8 million US$ equivalent from both domestic and foreign markets (Wubalem *et al*., 2003).

    - Frankincense exported in 1996–2000 reached 2714.5 metric tone with a value of around 28.7 million Birr in foreign currency (Vivero, 2001).
    - In 1998, annual production of myrrh was 85.3 tone and that of oppoponax was and 8 tone (Girmay 2000).
    - Average annual production quantity of gum Arabic for *A. senegal* is 250–300 tone, out of which around 150–200 tone comes from the North and 100 tone from the South of the country. The annual production quantity of *A. seyal* is 50–100 tone (Chikamai, 1996).
    - Exploitation of olibanum is one of the top employment opportunities in remote parts of Ethiopia, where the number of seasonal workers engaged in tapping and grading is estimated to range 20,000–30,000 workers per year at national level. In addition, it is a very important source of income for most rural people (Girma, 1998).

- There is possibility to safely and sustainably harvest 3 million tones of oven-dry biomass of bamboo from one third of the total stock (1 million ha) every year (Luso Consult, 1997).
- There is still a huge resource of coffee, chat, honey and other NTFPs and organic products in the natural forests of the country, with high socio-economic and ecological importance but indeed without sustainable management, significant domestication, commercialization and rational utilization.

Resource potential and production trends of major NTFPs

The NTFPs of Ethiopia are diverse and the majority of them are still less known, less managed and underutilized. The most important NTFPs in the country include gum Arabic (from *A. senegal* and other species); frankincense (from *Boswellia* spp); myrrh (from *Commiphora* spp); wild coffee, spices and condiments; traditional medicine; wild honey and bees wax; bamboo (*Arundinaria alpina* and *Oxytenanthera abyssinica*); reeds (*Arundo donax*); wild palm (*Phoenix reclinata*); food from wild edible plants and their products (fruits, seeds, edible oil); essential oils from aromatic plants; fat; fodder; fibers; tannins and dyes; ropes; resins; latex; ornament; panel products produced from giant or long grasses; roof thatch for local house construction; byproducts after liquidating lumber; wild edible and non-edible animal products; and various other extractives, flavorings, sweeteners, balsams, and pesticides. NTFPs can be major sources of feedstock and energy for forest industries and others.

The harvesting, commercialization and transformation of certain NTFPs by the rural poor can be a means of shifting efforts away from the unsustainable exploitation of forest products such as frankincense, myrrh and gum Arabic, wildlife heritage, and endangered hardwood and softwood timber that are obtained from ecologically sensitive species NTFPs especially frankincense, myrrh, gum Arabic, bamboo, spices, medicinal plants, edible plants, essential oils, honey and bees wax, civet and other wildlife resources other than bees and civet to improving household and national economy, have significant potential and contribution.

Natural gums/Exudates

Natural-gum-bearing tree species are found in many lowland areas in different administrative regions of the country. They form one of the most widespread vegetation types of the country (*Boswellia, Acacia, Commiphora* species). True frankincense and gum Arabic-bearing species are widely found in the former Gonder, Wellega and Gojjam, and sparsely in Wello, Shewa, and Tigray (gum olibanum with the highest quality and gum Arabic) provinces, and Oromia (gum Arabic and black incense of Borena), Benshgangule Gumuz (gum Arabic), Somali (gum olibanum-ogaden and gum myrrh), Gambella and Afar Regions (gum myrrh and oppoponax), and Southern Nations, Nationalities and Peoples Region (myrrh-Sidamo and gum Arabic) (Vivero, 2001).

These economically important natural gum-andresins producing tree and shrub species are available in remote areas[1], with poor facilities. This makes their harvest, regeneration and

[1] Natural gum and resins producing species are mostly available scattered in lowland, less/inaccessible, undulating topography and remote and steep slope areas (areas with hot, warm, dry and moist temperatures, high evapo-transpiration, high water requirement, malaria-prone, relapsing fever and dysentery, less health centres/facilities for labourers).

management very hard and difficult. The degradation and cutting of the woodlands for charcoal and agriculture is severely affecting acacia resource at an alarming rate. *Boswellia* and *Commiphora* spp. are less used for fuelwood and fodder compared to *Acacia* spp

Ethiopia is one of the major producers and exporters of natural gums from the different indigenous tree species such as *A. senegal*, *B. papyrifera* and *C. myrrh*, which are found mostly along the boarders and in different agro-ecological zones of the country (Vollesen, 1989; Azene *et al*., 1993). The production and marketing of natural gum in Ethiopia is an age-old activity, at least 4000 years. However, it is reported that organized collection of natural gums on a commercial basis began around 1948. Around 1960, a company called 'Tigray Agricultural and Industrial Development Limited was established and began a systematic and controlled tapping and collection. In 1977/78, the NGPME was nationally structured under the Ministry of Agriculture. Currently, private organizations such as Guna Trading House S.C., Ambasel Trading House S.C., Sehul Project S.C. and Ali Ghalib Ahmed are also undertaking processing and marketing of natural gums in Ethiopia (Girmay 2000).

Total coverage of woody vegetation in Ethiopia that can yield natural gum and resins is very large (about 2, 855,000 ha) (Wubalem *et al*., 2003). In the period 1992–2001, NGPME produced a total of about 14675.6 tone natural gums (gum oilbanum/frankincense, gum Arabic, oppoponax, Karaya/*Sterculia setigera* and myrrh) and earned about 102, 330, 882 Birr, which is about 12.8 million USD equivalent from both domestic and foreign markets (Wubalem *et al*., 2003).

The major products from natural gums have a significant international market share: Frankincense/olibanum constitutes 80 % of total output of resins of this type, gum Arabic 14 % and myrrh 6 %. Natural gum harvest in the year 1999 amounted 7,000 metric tone and nearly 3 million Birr was paid to harvesters and cleaners (Vivero, 2001). The different types of natural gums have different uses (Table 1).

Table 1: Uses of Frankincense, myrrh and gum Arabic (natural gums)

Tree species	Product		Major uses of the products
	Common name	Local name	
Acacia, Boswellia and *Commiphora* spp.	Natural gums-Oleo-gum resins*	Yetefetro -Mucha	• Source of exportable international commodities to generate foreign currency, income for the local people and the country, employment opportunities, raw material for socio-cultural activities and medicine as well as ecological/biodiversity importance. • In industries as adhesives/ water-soluble glues, confectionery, perfumes, food products, beverages, wood preservatives, soap, pulp, dyes and printing inks, rubber, ceramics, cosmetics, leathers, detergents, fertilizers, explosives, latex coatings, metallurgy, paper, petroleum product, pharmaceuticals, chewing gum, tooth paste, plasters, plastics, textiles, glass.
A. senegal var. *senegal***, *A. seyal, A. Polyacantha* and *A. drepanolobium* (Chikamai, 1996 and 1998)	Gum Arabic	Mucha	• As thickening, stabilizing, emulsifying and suspending agents in food and drink industries; • As tablet-binding agents and cream- and lotions-suspending and emulsifying agents in in pharmaceuticals • As film forming and sizing agents in printing and textile industries. Also used in ceramics, paints, inks, textiles, adhesives (Chikamai, 1996).
*B. papyrifera****, *B. pirottae*, *B. rivae*, *B. ogadensis*, *B. neglecta* and *B. microphylla* (Chikamai, 1998)	Frankincense/ incense/ olibanum/ gum-resin/Aromatic products	Itan/Etan	• Frankincense and myrrh are phytotoxically safe raw materials in industries like pharmaceuticals and food industries, are use in folk medicines, flavoring, beverages and liqueurs, cosmetics, detergents, creams and perfumery, paints, adhesives and dyes manufacturing. • Widely used in unprocessed form, incense is valued for its sacred and ceremonial uses in Orthodox, and Catholic Churches as well as in the Muslim religion, and in traditional coffee ceremonies to produce aromatic smoke.
C. myrrha (Nees) Engl, syn. C. molmol** *C.habessinica/C. abyssinica*, *C. africana*, *C. incisa, C. guidotti/ C. erythraea, C. borensis* (Chikamai, 1998)	Gum myrrh	Kerbe	• Myrrh is highly reputed and commonly used in Arab medicines for the treatment of some inflammatory conditions, as an antipyretic, anti-septic, stimulant, anti-infection, anti-bronchial complaints and mouth wash. It is also used to cure different stomach problems including stomach cancer; to cure tumors of spleen, liver, stomach, breast, head, nose and eye; crude myrrh is dispensed throughout Eastern Africa and Saudi Arabia as an anti-inflammatory and anti-rheumatism drug.
C. pseudepadi *C. holtziana*,	Gum oppoponax	Abekede	• The extract from *C. pseudepadi is used* as tick repellent. • *C. holtziana* yields scented/perfumery *myrrh* or *oppoponax*

- All gum and resin exuding plants; **- True gum; ***- True frankincense; ****- True myrrh.

Frankincense/ gum olibanum

Boswellia is one of the 17 genera in the family Burseraceae, which is estimated to encompass 500–600 species worldwide (Vollesen, 1989; Kindeya *et al.,* 2002). In Ethiopia, only the

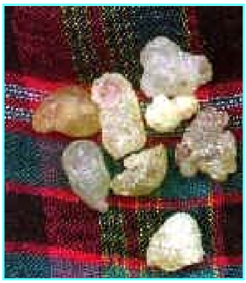
Boswellia and *Commiphora* genera have been recorded with a total of 58 species (Vollesen, 1989). *Boswellia* is composed of about 20 species in the dry regions of tropical Africa, including Ethiopia. These include *B. papyrifera,* the common/true incense tree species; *B. papyrifera,* a tree that grows up to 12 m high, found at 950–1800 m altitude, widely distributed in large amounts in Tigray, Gondar, Wellega and Gojam and sparsely spread in Wello and Shewa (Vollesen, 1989; Girma, 1998); *B. rivae,* distributed in Sidamo and Gamo Gofa); *B. ogadensis (*endemic) found in Acacia-Commiphora bushland (Hararghe, Bale, Sidamo, Gamu Gofa); *B. pirottae (*endemic), *B. rivae*, *B. neglecta* and *B. microphylla*. *Boswellia* is widely distributed from West Africa to Arabia and South to Northeast Tanzania, India and Madagascar (Vollesen, 1989; Azene, *et al*., 1993; FAO, 1995). It is centered in Northeast Africa where about 75 % of the species are endemic, including two in Ethiopia and five in Socotra (Vollesen, 1989).

Resins (also called olibanum Tigray type) are mainly obtained from *B. papyrifera* through tapping (Fig. 1). Most of the production originates from northwestern part of the country, Tigray and Gonder in particular (Girma, 1998). Frankincense is the dried*,* gummy exudation obtained from various tree species of the family Burseraceae. It is available in small tears or lumps of white-yellowish or yellow-reddish color, with a slight smell. Women carry out the cleaning and grading processes. Gumdrops of export type frankincense are classified in seven grades according to their size and purity. The grades for gum/olibanum and the price in the international market in the year 1997 were: 1^{st} grade Tigray type (black gerzo) (455.6 Birr q^{-1}), 2^{nd} grade Tigray type(1340 Birr q^{-1}), 3^{rd} grade Tigray type (1038.5 Birr q^{-1}), gum Humera type (871 Birr q^{-1}), gum Harar/Sidamo type (670 Birr q^{-1}) and gum seyal (not available with the first four for export) and the rest types were used for local market (Girma, 1998).

Figure 1. Tapping *Boswellia papyrifera* tree

***Boswellia papyrifera* tree**

Frankincense



Tapping

Frankincense is produced and exported by very few countries worldwide. Somalia and Ethiopia are the major producers and exporters (FAO, 1995). In India, resinous gum obtained from *B. serrata* is also traded as frankincense under the name 'Indian olibanum or Salai' (FAO, 1995; Murthy *et al.,* 1977). World annual production of frankincense ranges 2500–3000 tone (Chikamai, 1998). In 1994, both Frankincense and myrrh had a value of $ 6000–7000 US t^{-1} (Chikamai, 1998) and Ethiopia exported 300 tone; about one tenth of the world's export. Exploitation of olibanum is one of the top employment opportunities in the remotest parts of Ethiopia. The number of seasonal workers engaged in tapping and grading at national level is estimated to range 20,000–30,000 workers per year. In addition, it is a very important source of income for most rural people (Girma, 1998).

At present, only NGPME exports gum olibanum, myrrh and oppoponax, and not gum Arabic that is exported by private companies. The commercial product is available in different qualities from dust and siftings to tears; and it fetches \$ 0.6–1.5 US kg^{-1} depending on the quality, size, color and species origin (Vivero, 2001), and this amount is now increasing. In the period 1996–2000, the amount of exported frankincense gum reached 2714.5 metric tone, producing an equivalent of more than 28.7 million Birr in foreign currency (Vivero, 2001). Germany imports a significant amount of Ethiopian incense gum (more than half of the total exports) and France has also a great demand for its perfumery industry. Value-added processing into different forms like kibbled and powder in the country, through micro-enterprises or producer's cooperatives, will be one area that could be developed since this offers the possibility of increasing the income sources, as well as modest gains in foreign exchange for the national economy.

Reliable data on the production and utilization of exudates in Ethiopia is not available. The national average annual output of exudates during 1978–1991 was 1500 tone. Since 1992, annual production has leveled to over 2000 tone, with nearly 50 % of the production absorbed by export markets.

Myrrh

The genus *Commiphora* constitutes 150–200 species that grow up to 3 m high (Vollsen, 1989) and are reputed for their commercially valuable resins such as gum/true myrrh (*Commiphora myrrha* syn. *C. molmol*) incense, and gum oppoponax depending on the species. This resin is obtained from a small shrub, *Commiphora myrrh,* which is principally found in Ogaden, Bale and Sidamo areas (Girma, 1998). Several *Commiphora* spp. produce myrrh, which are used locally. The chief commiphora gum of high economic importance is myrrh, produced by *C. myrrha*. This is an important commercial item in southern and southeastern Ethiopia. *C. guidotti* produces gum oppoponax, which is of commercial value.

Annual production of myrrh and oppoponax in 1998 was 85.3 and 8 tone, respectively. The most expensive gum myrrh is amongst gum and resins with cost of \$ 3.2 US kg^{-1}; other gums cost \$ 0.6–1.5 US kg^{-1} (Girmay, 2000; Vivero, 2001).

Gum arabic

Gum Arabic is an important NTFP obtained from natural stands and plantations of *A. senegal*—a multipurpose African tree belonging to subfamily Mimosoidae of Leguminosae family, highly valued for centuries for gum Arabic production*. A. senegal* grows 2–6 m high; occasionally upto 15 m high. It occurs in significant amounts in Gojam and Gondar along the Sudan border (NFTA, 1991). Today, *A. senegal* is grown in Africa primarily for gum, but also plays secondary roles in agroforestry systems, restoring soil fertility, and providing fuel and fodder (NFTA, 1991). This tree occurs naturally on sandy soils with 5–8 pH. It occurs in the 'gum belt', which is about 7100 km long and 300 km wide (Central Sudan, Nigeria, Mali and West Ethiopia) where annual precipitation is around 300–600 mm (Vivero, 2001) and in altitudinal range of 100–1700 m in Sudan to 1950 m around Nakuro, Kenya (NFTA, 1991; DFC 2000). The gum belt is located from East Africa (Ethiopia) to West Africa (Senegal) including Tanzania. Seventeen *Acacia* spp. in Africa were identified as producing gums, which are collected by local communities either for export or domestic use (Chikamai, 1996).

Areas in Ethiopia with significant stands of *A. senegal* are found in the western and southern parts of the country, i.e., in West Tigray Zone; Amhara, Benshangul Gumuz, Gambella and SNNP Regions; and Borena Zone in Oromia Region. Commercial gum Arabic from Ethiopia is produced mainly from *A. senegal* var. *senegal*, *A.seyal* var. *seyal* and *fistula*, *A. polyacantha* (in Sheraro and Metema Districts) and *A. drepanolobium* (in Sidamo, Yabello District), which are, distinguished only on the basis of different production areas. *A. senegal* produces the highest quality gum Arabic. Gum of lower quality, also sold under the name of gum Arabic, is obtained from natural stands of *A. seyal* (in Arero and Negelle Districts), a species widely found in the Rift Valley Depression, especially on sites subject to annual water logging.

Gum Arabic has been used for at least 4000 years (NFTA, 1991). It is dried exudation from the stems and branches of *A. senegal* or closely related species. Gum Arabic Ethiopia produces from *A. senegal* is generally of two types: Humera (Kordofan) type—produced from *A. senegal* var. *senegal* in the northern and northwestern parts in the areas of Humera and Sherero in Tigray Region and in Gonder and Wello in Amhara Region; and Sidamo type—(characterized by high viscosity) produced from var. *kerensis* in the southern (Sidamo, Oromi Region) and southeastern parts (Fike and Hamero areas in Oromiya and Afar Regions) (Chikamai, 1996). Annual production never exceeds 300 t and has declined due largely to the loss of trees, which have been cut down for fuel wood and charcoal production.

Africa is the world leading producer and exporter of gum Arabic, the main producer and supplier countries being Sudan (80 %), Chad and Niger (NFTA, 1991). The annual per hectare yield of producer countries ranges 30 to 40 kg in open stands and reaches 100 kg in dense stands. The price for good quality gums ranges 3–3.5 USD Kg^{-1} (Vivero, 2001).

Average annual production from *A. senegal* is 250–300 tone, about 150–200 tone of which comes from the North and about 100 tone from the South. *A. seyal* gives 50–100 tone per year (Chikamai, 1996). Annual production of gum Arabic from *A. senegal* and *A. seyal* species in the period 1988–1999 was 300–400 tone. *A. senegal* comprises about 70 % and *A. seyal* about 15–25 % of the species that contribute up to 95 % of the total gum entering international trade. The remaining 5 % which is relatively low quality gum is contributed mainly by *A. Polyacantha* and *A. drepanolobium* (Chikamai, 1996). The current world annual production is around 40,000 tone (Chikamai, 1998), but Ethiopia's share in the world market is negligible (100 MT in 1999). In the period 1992–1999, NGPME produced about 474.8 tone gum Arabic with mean annual production of 59.35 tones. The highest annual production (148.5 tone) was in 1995 while the least (3.6 tones) was in 1999 (Wubalem *et al*., 2003).

Medicinal value

Plants are an indispensable source of preventive and curative medicinal preparations against human and livestock ailments. Ethiopia is endowed with a wealth of plant species with high potential to produce herbal and plant-derived drugs. Though most of the plants that are commonly used for medicinal purposes are herbs, the trees, shrubs and wild life too are important (Vivero, 2001). The indigenous knowledge (IK) related to the quantity, species selection and use of plants, animals and their products is different from one ethnic and religious group to another (Girma, 1995; Desalegn, 2000). Traditional medicine as one of the most important NTFPs has an important place in the health care of the Ethiopian population. It is estimated that more than 80 % of the people in Ethiopia rely on some form of traditional medicine for their human and livestock health care needs (Dawit and Ahadu, 1993 cited in Mirutse, 2001). More than 95 % of traditional medicine preparations are of plant origin (Dawit, 1986 cited in Mirutse, 2001); products from wild animals and minerals as well are used as primary source of health care.

Medicinally important plants have been recorded in the country in Jansen, 1981; Desalegn, 2000; Zemede and Mesfin, 2001; Mirutse, 2001). There are 35,000 medicinal plants in the world and over 600 species of medicinal plants on record, constituting about 10 % of Ethiopia's vascular flora; i.e. 6000–7000 species (Dawit, 1986 cited in Mirutse, 2001; FAO, 1995). They are distributed all over the country, with greater concentration in the South and Southwest. The woodlands of Ethiopia are a major source of most of the medicinal plants followed by the montane grassland/dry montane forest complex of the plateau. Other important vegetation types for medicinal plants are the evergreen bushland and rocky areas. There are over 1400 tropical forest plants with the potential to fight cancer (WWF, 1989).

Ethiopia has a long history of traditional health care based largely on rich though un-standardized pharmacopoeia used by both the local population (especially women) and traditional health care practitioners (THPs). The Ethiopian Traditional Medicine Practitioners Association established in 1987 has 9000 healers, vendors and collectors, who are estimated to be more than 80, 000 at the country level (Desalegn, 2000). Medicinal plants and knowledge of their use provide a vital contribution to human (about 40 million people) and livestock health care throughout the country.

Through an ethnobotanical survey conducted on Zay people of Ethiopia, information was collected on the use of 33 medicinal plants for human and livestock health care (Mirutse, 2001). Most of the remedies are harvested from wild, prepared from a single species and are mainly taken orally. Jansen (1981) explained 12 species and condiments, and 12 medicinal plants of Ethiopia. A total of 25 plant species that are used in combination or alone to treat 15 human and livestock diseases were recorded in the Shinasha area (Desalegn, 2000). In Dire Dawa-Jigjiga area of Eastern Ethiopia, 14 vascular plants of medicinal value have been identified. In Gara Ades forest in Eastern Ethiopia, 36 NTFPs have been identified as source of food, fodder, medicine, fuel wood, utensils, and agricultural and other purposes, where about 89% of the products are traded by women (Un-published report).

Medicinal plants and knowledge of their use are a thread that links education and knowledge of institutions, health and population issues, sustainable development, environmental and cultural issues, gender, and rural, urban and private sector strategies (IK Notes, 2001). The efficacy of *Hagenia abyssinica* and *Glinus lotoides* L. for the treatment of tapeworm, and *Phytolacca dodecandra* as a molluscicide in the control of schistosomiasis has been scientifically determined, but the friendliness and efficacy of many others in the treatment of various diseases remained unexplored (IK Notes, 2001).

Ebmelia schimperi, Myrsine africana and *Tamarindus indica* are widely used in traditional herbal medicine (Amare, 1976; Zemede and Mesfin, 2001). *Hagenia abyssinica, Securidca longepedunculata, Clerodendrum myricoides, Cucumis aculeatus,* and *Warburgia ugandensis* are among the threatened species and *Dracaena steudneri* is becoming scarce species of Ethiopia due to environmental degradation and overexploitation (Fassile and Getachew, 1996 cited in Mirutse, 2001). The use of traditional medicine is increasing more than ever before because modern medicine has become very expensive and beyond the reach of most people. The value and role of traditional health care systems may not diminish in the future because they are both culturally viable and an important way of getting relief from various diseases, and because they are free and/or affordable.

Medicinal plants can also be used for food and other purposes for humans and livestock. However, important information is lacking for most species regarding regeneration, parts used, specific uses, price and dose. This large gap needs thorough research. An estimate of the threat to medicinal plants and animals can be made from the type of plant and the parts used. Harvesting the root of a tree poses more threat than collecting the fruits and seeds, and this can be more threatening than using the leaves and other parts (FAO, 1995; Vantomme, 1995). Killing animals for medicinal or other purposes will result in the threat of the species as well.

Environmental degradation, deforestation, population growth, agricultural expansion, over harvesting, uncontrolled hunting, lack of proper management and unsustainable utilization are principal threats to medicinal plants and animals in the country (IK Notes, 2001). According to IK Notes (2001), the loss from plant and animal extinctions could result in significant socioeconomic and biodiversity losses to Ethiopia, and could even be of global significance. Therefore, the uncontrolled use of plants, particularly their roots and the whole plant, can easily lead to their destruction. Some of them are already endangered. Improvements in the management can be realized through ethnobotanical research, which calls for close collaboration between local healers and professionally trained personnel; and respect by researchers of certain obligations to the local healers (Chikamai, 1998).

Edible wild plants and plant products

In Africa, trees have been traditionally important in emergency cases, especially in times of drought, famine and wars. They provide food when crops fail and cash income from products (Vivero, 2001). There are numerous forest plants with potential edible parts like (fruits, seeds, leaves, roots and tubers) that can either be directly consumed or processed in food industries (Vivero, 2001). Wild plants seem more commonly consumed staple crops wide spread in food-insecure areas. Famine food plants include some wild-food plants like *Arisaema* spp and *Huernia* spp that are purposely cultivated on farm fields to be available and used at times of food shortage, even if they are aggressive weeds. Multipurpose wild food plant species used during famine or other food-shortage periods are *Sterculia africana, Dobera glbra, Partulaca quadrifolia, Cadaba* spp., *Solanum nigrum, Solanum. khasianum, Syzygium guineense, Moringa oleifera, Piliostigma thonningii, Balanites aegyptiaca, Balanites rotunda* and *Amaranthus* spp. (Vivero, 2001).

Information on wild edible plants of Ethiopia is scattered in botanical monographs, glossaries, and informal notes as well as in the rich oral tradition of the different communities. The delay in the production of a complete documentation on modern flora of Ethiopia and the insufficient ethno botanical investigations partly account for the prevailing incomplete knowledge on the wild edibles of the country (Zemede and Mesfin, 2001). According to these authors, the edible plants of Ethiopia are estimated to constitute about 8 % of the higher plant species in the country where about 25 % of these are cultivated as food crops and the remaining 75 % are categorized as wild, semi-wild or naturalized. Field and herbarium studies on wild flowering plants of Ethiopia furnished 203 wild food plant species consumed by the Ethiopian communities. These account for about 3 % of the higher plant species and 50 % of the wild edible plants in the country, and comprise about 550 herbs (37 %), 635 shrubs (32 %), and 655 trees (31 %). Species with edible fruits contributed to 61.6 %, with edible leaves 27.7 %, stems 14.4 %, roots 13.3 %, and seeds 10.3 %. About 15 % of these species are considered famine foods. *Carissa edulis, Solanum nigrum, Zizyphus mauritana* and related species and *Tamarindus indica* are more frequently consumed all over the country (Zemede and Mesfin, 2001).

Works on conservation and efficient utilization of wild edible plants, including mushrooms, have never been undertaken in Ethiopia. There neither is conservation program focused to these plants. Many species are endangered due to habitat destruction and genetic erosion. *Cordeauxia edulis* (Yeheb) is an example of a promising species that has been threatened because of over utilization in times of food shortage in southeastern Ethiopia and beyond—Kenya and other countries (Abebe, 1991 cited in Zemede and Mesfin, 2001).

There are a lot of edible wild animal species. There is uneconomic utilization of this resource due to lack of information on rotation age, lack of awareness, and unfriendly attitude due to cultural influences. Therefore, there is a need for rigorous domestication, conservation and utilization strategies to promptly address farmers' short-term needs (Chikamai, 1998).

Bamboo

Bamboos are renewable natural resources, a unique of giant arborescent perennial woody grasses, in which the woody culms arise from underground rhizomes. Since most bamboos have tree-like morphology and attain tree size at maturity, they are named tree-grasses (Kassahun, 2000). Bamboos have shrub- or tree-like habits, yet members of the grass family Poaceae/Gramineae (Dransfield, 1980; Kassahun, 2000) and Bambusaceae (Phillips 1995;

Tamolang *et al.,* 1980). They belong to the subfamily Bambusoidae, characterized by woody, mostly hollow culms with internodes and branches at the culms nodes.

Ethiopia has a high potential of bamboo resource, about 1 million ha (Luso Consult, 1997; Kassahun, 2000) of highland bamboo. *A. alpina* accounts 150, 000 ha, out of which 130, 000 ha is natural and 20, 000 ha is plantation bamboo owned by framers. Lowland bamboo is more dominant, it covers 700,000–850, 000 ha. Ethiopia has 67 % of Africa's bamboo resources and more than 7 % of the world (Kassahun, 2000). The African/mountain alpine bamboo, *A. alpina* (Kerkeha) K.Schuml, syn. *Yushane alpine*, and the monotypic genus *O. abyssinica* (Shimel) A.Rich. Murno are the only indigenous bamboo species in the highlands of West and Southwest Ethiopia. These species are indigenous to Ethiopia and endemic to Africa, confined to the Sub-Saharan Region. The species are found in Borie and Jemjem in Sidamo; Keffa-Mocha, Masha, Andracha, Bonga, Metu, and Gesha in Illubabor; Bale mountains; Fincha in Wollega; Jibatna-Mecha, Shenene, Indebire and Hossana in Shewa; Indiana in Gojam; Metema in Gondar; and Wello. They are distributed also in lowlands in West and Northwest Ethiopia, such as Pawe/Metekel, Assossa, Manbuk, Gambella, and Metema areas (Leyikun and Melaku, 2000). *A. alpina* is dominant in the region often referred to as 'high forests' at an altitude of above 2400 m. *O. abyssinica* is common and dominant in lowlands. Bamboo land savannas are found in hot valleys of the major drainage rivers such as the Blue Nile, Tekeze, Omo and Gojeb (Amare, 1992; Kassahun, 2000).

For favorable growth, hollow highland bamboo requires 20–30 °C mean annual temperature, 700–1000 mm mean annual rain fall. Solid bamboo requires 40–50 °C mean temperature, and 700–1200 mm mean rain fall; and can grow in stony, unfertile soils and is drought-resistant (Leyikun and Melaku, 2002). These bamboo forests of Ethiopia are now decreasing rapidly due to construction of new road, clearance for large-scale-export crop production (coffee, tea, cotton) and burning to facilitate grass growth.

Average annual stem (oven-dry matter) increment of unmanaged natural bamboo forests of Ethiopia is 8.5–10 t ha^{-1}. This is a higher production rate than reports from bamboo forests in tropical Asia and elsewhere. It is, thus, possible to harvest 3 million tone oven-dry biomass annually on a sustainable basis from the 1 million ha bamboo land in Ethiopia, assuming selective felling of three or more years old culms (Kassahun, 2000). This biomass could be used to supply part of the particle board, fiber board, pulp, furniture, construction and energy requirements of the country, which are presently gained mainly form *Eucalyptus globulus* and other selected but endangered species.

Bamboo is a source for food, fodder, furniture and building materials (scaffoldings), industrial inputs, medicine and fuel. Solid bamboo has been tested as a concrete reinforcement to substitute steel and the results revealed success. They are also preferred materials for shade construction in plant nurseries. In this way, rural people meet part of their needs and supplement their income. Moreover, bamboo has high soil conservation potential since it forms a complex root network. Bamboo is a multipurpose and drought-resistant species (particularly the lowland species) (Kassahun, 2000). Bamboo is widely used in large quantities for pulp and paper production in India and China (Vivero, 2001).

However, the present use of bamboo in Ethiopia is low, mainly limited to hut construction, fencing, and, to a lesser extent, production of household and office furniture. Whole bamboo culms serve as vessels for water transport/ferrying and storage, baskets, agricultural tools, beehives, bamboo weaving and mat, household utensils, fuel and charcoal, sticks, and various artifacts (Kassahun, 2000; Vivero, 2001). The rural people living near bamboo forests also consume bamboo shoots in Ethiopia. In Ethiopia, the bamboo materials used for local construction and furniture have been strongly attacked by biodeteriorating agents such as termite, beetles and fungi. This susceptibility of bamboo to biological and physical deterioration led to its neglect (Kassahun, 2000) and its utilization is low. Research-based protection and rational utilization measures are urgently important to reverse the situation. Its potential for industrial use has yet to be popularized, as it is presently undertaken in many tropical Asian countries. It is believed that appropriate regeneration; management and rational utilization of bamboo resources of Ethiopia could enable generate high income to the local community, reduce pressure on forests and contribute to stabilize structure and composition of forest resources.

Despite the continuously growing demand for bamboo as source of materials for construction, industry, energy, food and feed, its potential is almost unexplored. Based on studies carried out in Ethiopia (Luso Consult, 1997), it would be possible to harvest safely one third of the total stock every year on sustainable basis (3 million tone oven-dry biomass). This could be used to supply part of the particleboard, fiberboard, pulp, furniture, construction and energy requirements of the nation.

However, although this precious resource is abundantly available in Ethiopia, it is not only neglected, but also is being decimated mainly for agricultural expansion under the rapidly increasing population pressure. In the past, the bamboo forest remained out of sight in the more inaccessible areas. But they are now being cleared at high rate for agricultural expansion. In addition to the low durability of bamboo, lack of scientific knowledge on the production, property, and uses and utilization methods of bamboo is among the main reasons for its current neglect.

Honey and beeswax

The Ethiopian climate and the extended flowering season are favorable for apiculture. Due to its varied ecological and climatic conditions, Ethiopia is home to some of the most diverse flora and fauna in Africa. Its forests and woodlands contain diverse plant species that provide surplus nectar and pollen to foraging bees. Beekeeping is an ancient tradition in Ethiopia. The density of hives is estimated to be the highest in Africa. It is believed that an estimated 4–10 million traditional hives and some 10, 000 modern box hives exist in the country. Honey production in Ethiopia is mainly based on traditional methods using hives made from naturally occurring materials suspended in trees to attract swarms of local bees. The main products of the beekeeping industry are honey and wax. Honey is mainly used for local consumption, while a considerable proportion of wax is exported. It is estimated that the annual turnover of the apiculture industry varies between 26 million US$ and 64 million US$ (Girma, 1998). In 1996, a total of 3, 862 tone of honey, worth $ 12, 015, 000 US was exported from Ethiopia. Honey and bees wax also play a considerable role in the cultural and religious life of Ethiopians.

Annual production of honey amounts to 24,000 tones, equal to about one third of the total honey production in Africa. World honey trade is of the order of 300 000 tones, valued at US$ 300 million. Germany, USA and Japan are the major world markets. Ethiopia ranks 10th in honey production in the world. Around 20 % of the total domestic production is used as table honey in rural areas, 55–60 % is used in the production of “tej” (mead) (a local beverage), much of the remaining part is sold in local markets and a considerable amount is also exported. Annual production of wax is estimated at 3 200 tones. This estimate does not include bees wax produced in remote areas where it is usually wasted. Thus, after China, Mexico and Turkey, Ethiopia is the fourth largest wax producer and one of the five major wax exporters to the world market. On average, 3000 tone of honey and 270 tones of wax were exported annually during 1984–1994, and generated respective income of 237 000 and 2 million US$ per annum to the national economy (Girma, 1998). The potential for honey and wax production has been seriously reduced by the destruction of the natural vegetation, which provides the sources of nectar (EFAP, 1994; Girma, 1998; Vivero, 2001).

Besides, honey has miraculous medicinal values. Diets in which honey and milk are the main items prolong life. Honey taken with other foods is nutritious and improves complexion. Honey helps to treat or cure wounds and sores since it has absorbing property and speeds up tissue growth, is effective remedy for burns and an excellent cure for inflammation of the eye.

It facilitates digestion by stimulating the secretion of gastric juice, gets rid of wind and improves appetite; it is particularly good as laxative since it eases the bowls. It remedies gastritis and gastric ulcers by reducing hyperacidity and saving patients from heartburn and belching, it has good effect on the heart since it contains much easily assimilated glucose. It is sweet that children like honey more than sugar. People with colds are advised to take honey with boiled milk and lemon. It causes patients to sweat a great deal and relives them of pain. Honey helps in treating a runny nose. Honey has been used against diseases of the lungs; it gets rid of sputum and sooths cough. People suffering from exhaustion and headache are advised to drink a glass of water in which honey and lemon juice are dissolved. Honey is useful to cure kidney, brain and lever problems. It helps to improve memory, sharpen the wits and loosen the tongue. It has harmful effects of sugar on teeth but has active antibiotic properties and thus disinfects the mouth (Fisseha and Mazengia, 1981).

However, the potential of honey and wax production has been seriously reduced by the destruction of the natural vegetation that provides the sources of nectar. The main resource base for beekeeping forests and woodlands has been seriously degraded. To avert the situation, eucalyptus plantations have been established in some localities and constituted a new and complementary honey resource. In many places, beekeepers themselves have endeavored to redress the situation by planting good honey plants such as *Vernonia amygdalina* and *Salvia* species near their hive colonies. Productivity of honeybees is very low, averaging to only 5–6 kg of honey and 1 kg of wax per hive per year. However, in areas where improved technology has been introduced, an average honey yield of 15–20 kg per hive per year has been recorded (EFAP, 1994; Girma, 1998).

Wild life resources other than bees and civet

Hunting still provides a portion of meat consumption in some lowland areas of Ethiopia (SNNPR and Oromia, Borena). However, unlike many other countries, most Ethiopians do not consume animals like ducks, pigs, stork, ostrich and birds, due to food habit and cultural/religious reasons.

Despite the underdevelopment of game hunting—commonly called safaris—in many areas in Ethiopia so far, game hunting has considerable potential in some areas (mainly SNNPR); some bush species like big antelopes, gazelles and warthogs are targets. There are few safari companies operating in the country, but only one of them is running a controlled hunting area. Should those companies take into consideration local peoples' interests and should they share some benefits with those communities, game hunting could be an interesting alternative income source for those rural people living in remote bushland and forest areas. There seems to be an incipient fur business in Bale Mountains, Borena Zone, based on the great diversity of moles, rats and other rodents (some of them endemic species).

Research and ecotourism

In recent years, non-extractive activities such as research and eco-tourism have emerged as important sources of income that can encourage conservation. Research on biological resources (or biodiversity research), funded by international pharmaceutical firms or research agencies, is proceeding in many developing countries under agreements that provide the source countries with support for building their own research capacities (Vivero, 2001). Tourism is a leading economic activity in much of Africa, especially in the East and South, and is centered on protected areas (ITTO, 1999). Africa has the world's most spectacular displays of wildlife but, according to the World Tourism Organization, receives only 1.8 % of global tourism. Kenya's about 35 % GDP comes from its annual 800, 000 tourists (Vivero, 2001). Eco-tourism refers to low-impact tourist services to sites of natural and cultural interest (i.e. wildlife/games and birds, landscape, cultural and historical places and site seeing/recreation, edible wild animals and their products); it is the fastest-growing sector in the tourism industry worldwide, and if carefully managed, can return income to local communities and motivate conservation.

Like forest-based extractive enterprises, these non-extractive activities require policy support through enforceable forest tenure and access, development of people's skills and legal mechanisms for ensuring that benefits return to local communities.

Spices

Harvesting and cultivation of wild spices is common in many areas of southern Ethiopia such as Sheka, Kaffa, Bench-Maji, South Omo and Gamo Gofa (Jansen, 1981). The total supply of spices from Shekicho-Keficho Zone to regional and national markets in 1999 was about 1, 208 MT (Vivero, 2001). There is less government control since the business is entirely carried out by private dealers. Commercial species such as *Aframomu angustifolium* (Korerima) and *Piper capense* (Timiz) are found as indigenous species in Shekicho- Keficho and Bench Maji forests and woodlands (Jansen, 1981; Vivero, 2001).

Previously, Ethiopia was well known for its considerable exports of korarima capsules to the world market, mainly as a substitute for the Indian cardamom. However, the supply greatly fluctuated during the past few decades that the total annual Korarima export decreased to less than 60 tones in the years 1994–1998, fetching only about US$ 2.1 million (Wondifraw and Wannakrarioj, 2004). Accoding to these authors, this situation could mainly be ascribed to the reduction of production as a result of the ever increasing destruction of the natural habitat, which is even threatening the mere existence of the crop in the country. The same is true for *P.capense* (Personal observations). There is a strong need to promote improved utilization of spice plants in Ethiopia, and the Regional Forestry Action Program of SNNPR has estimated the financial requirement to carry out those activities at 4.4 million Birr.

Essential oils and aromatic plants

Essential oils are volatile compounds found in many plant parts. They have been used for thousands of years in perfumeries/cosmetics, pharmaceuticals, foods and beverages, adhesives, rubber and plastic, polishes, solvents, textile making, paints, pastes and printing, toiletries and as a more recent innovation, in bio-pesticides (FAO, 1995; Vivero, 2001). The market is well established, at an estimated 1.2 billion Euro per year. Essential oils can be extracted from geraniums, pepper, cinnamon, ginger, and cloves. As an agro-industry, the essential oil sector could play an important role in the nation's agricultural economy. Great potential exists for many ACP countries to produce and market essential oils. The most important aspects to be considered to benefit from essential oils are consistency of supply of plant materials, quality control, protecting plant diseases and technology selection (Vivero, 2001). Oil-bearing plants[2] play an important role in the traditional nutrition of Ethiopians. They are major source of energy and proteins. Traditionally, pure oil is prepared for medicinal uses, for tanning leather and wood, and for greasing hair and body. The annual world trade value of essential oils and spices from tropical forest plants such as *Carraphon, Cassia, Cardamom* and *Cinnmon* spp.exceeds US$ 1 billion (WWF, 1989).

Civet farming

[2] They are crops in most cases, with some essential oils extracted from wild species from the forest even though their genetic pool can be easily improved by using the wild germplasm of wild specimens or wild relatives.

Civet musk for the perfume industry has been produced in Ethiopia for many centuries. It is mentioned as Ethiopia's export item from the 15^{th} century through the Eritrean Port of Massawa. Today, it is a small traditional cottage industry mainly in the lower parts of the western highlands and Sidamo in SNNPR (Graham 1997 cited in Vivero, 2001). Musk is extracted from the male civet every 9–12 days, with each animal producing up to 1 kg annually; US$ 165 worth. The average number of civets per farm is about 15, making civet farming a profitable venture for a smallholder.

Research activities, status, gaps and needs

Research activities and status on NTFPs of Ethiopia

The information base on NTFPs and their socio-economic importance in Ethiopia is not well documented. There is one newly emerged national NTFPs Project responsible for the collection, study and documentation of all NTFPs resources in the country. So far, there are some individual and group efforts. These include efforts by (i) the Natural Gum Processing and Marketing Enterprise (NGPME) and other private firms focusing on natural gums tapping and marketing aspects, (ii) the newly emerged National Project of Ethiopian Agricultural Research Organization (EARO), Forestry Research Center (FRC), Forest Products Utilization Research Program (FPURP) and (iii) Regional agricultural offices that are undertaking regeneration, resource assessment, development and management, and other activities.

There are 21 completed and on-going trials and resource assessments undertaken by federal and regional institutions, NGOs and higher learning institutions, out of which 12 are on natural gums and resins, on tapping of *B. papyrifera* and on different NTFPs in FRC of EARO.

Gaps and research focus

In the past, no prior attention was given for research and development of NTFPs resources still available in the forests of Ethiopia. The potential is being reduced due to low regeneration, lack of conservation activities, irrational utilization, and threatened species composition and distribution in the forest ecosystems and other habitats. There are only a few research and development activities undertaken and undergoing in specific NTFPs. Therefore, researchers, conservationists and other stakeholders have to search alternative resources and cash-earning possibilities to rural populations of Ethiopia by using NTFPs, which could contribute to sustainable conservation and utilization of the resources. Many efforts have been expected from researchers, NGOs, government agencies and the private sector to tailor activities to local conditions by providing marketing expertise for reaching local, national and international markets. Coalitions of the different stakeholders will be essential links from producing through harvesting and processing to consumers and traders.

The major gaps or constraints and research foci are the following.

- Inadequacy of information on NTFPs species type, composition and distribution in the forest ecosystem and other related habitats, on regeneration, present collection, processing and utilization practices.
- Insufficiency of information about socio-economic and ecological importance of NTFPs.
- Poor recognition of the contribution of NTFPs.

- Lack of knowledge on appropriate technologies for production, harvesting, extraction, processing, grading, marketing and utilization of NTFPs.
- Lack of information on properties, suitability and proper utilization of indigenous and home-grown exotic NTFPs species.
- Inadequacy of knowledge and information on using potential NTFPs as alternative or substitute feed-stocks by forest industries, construction and other sectors.
- Inadequacy of knowledge and technologies on biomass-based energy generation from NTFPs and efficient utilization.
- Inadequate research undertakings in NTFPs.
- Lack of sufficient trained human power and facilities
- Lack of knowledge on protection measures of biotic and abiotic degrading agents of NTFPs.
- Illegal encroachment from humans and animals, wind fall, insect attack/whitish worm, termites, recurrent fire, improper tapping, clearing, debranching by local farmers for fire wood and charcoal, overgrazing, trampling and browsing which may lead to low stock and hamper natural regeneration.
- Lack of joint forest management systems and participation of the different stakeholders.
- Geographic inaccessibility of economically important NTFPs such as natural gums and resins, which makes their harvest, regeneration, management and rational utilization very hard and difficult.
- Lack of grading and certification systems for forests and NTFPs.
- Absence of strategies and continuous action plans for the development, sustainable utilization and conservation of the respective resource bases.

Research needs

Different areas of research were identified. The greatest need is for up-to-date information on the resource base, present scale and methods of production and markets for the major products and value-added NTFPs. This has to include the size and productivity of the resource, the extent to which it may be under-or over-utilized (and therefore condition of meeting any increased demand), regeneration capacity and health state of the NTFPs. Without this knowledge and information, it is impossible to know the scope for increasing production, types and grades of NTFPs in demand, customers' quality requirements, deficiencies in quality of present consignments, etc.

Conclusion and recommendation

The overall socio-economic and ecological importance and contribution of NTFPs in Ethiopia is significant, diversified and valuable. There is still a huge resource of wild coffee, chat, honey and other NTFPs species and organic products in the natural forests of the country, with high socio-economic and ecological importance, but, indeed, without sustainable management, significant domestication, commercialization and rational utilization. NTFPs bearing high potential and contribution to household and national economy include Frankincense, myrrh, gum Arabic, bamboo, spices, medicinal plants, edible plants, essential oils, honey and bees wax, civet and other wildlife reswources.

The harvesting, commercialization and transformation of certain NTFPs by the rural poor can be a means of shifting efforts away from the unsustainable exploitation of ecologically sensitive forest products such as Frankincense, Myrrh and gum Arabic, wildlife, and endangered timber species. The NTFPs are among the main coping mechanisms that poor households and the nation have, and thus, their importance should not be overlooked. However, production, processing and trading of NTFPs activities are associated with poor and stagnant rural economic conditions. Value added processing is not carried out. Therefore,

- it is better to draw some guidelines and strategies to effectively address the constraints and aspects of sustainable management and rational utilization of NTFPs in Ethiopia.
- efforts need to be integrated by involving all stakeholders and interested groups and there should be adequate networking and follow up on what and where has been done.
- Selection and introduction of appropriate production and development technologies should gain attention.
- Applied and adaptive research should be conducted on the genetic conservation, regeneration, processing, grading, marketing and products trading of potential and less known species.
- Training should be given to natural gum experts, tappers, concessionaires and local framers on the different botanical sources, proper methods of tapping, storage, cleaning, processing, grading and marketing.
- Extension services need to be developed to advise farmers/tappers on tapping techniques and other production aspects.
- Viable strategies and continuous action plans should be developed for the development, sustainable utilization and conservation of the respective species and their habitat/forests and all NTFPs of the country to take reliable actions.

There is a better chance of their future sustainability and security and that of the forests in which they are found if such actions are taken before late. NTFPs will continue to be good source of food, traditional herbal medicines and other versatile products, domestic cash-income, foreign earning additional employment for local communities and conservation of biodiversity in Ethiopia.

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Integrategrating Natural Gum and Resin Production with Biodiversity Conservation and Desertification Control and Adapting to Climate Change in Drylands of Ethiopia

Mulugeta Lemenih[1] and Demel Teketay[2]
[1]Wondo Genet College of Forestry, P.O.Box 128, Shashamane, Ethiopia,
E-mail: elerohi@yahoo.com
[2]Ethiopian Agricultural Research Organization, P.O.Box 2003, Addis Abeba, Ethiopia

Summary

Ethiopia's drylands are under increasing human and livestock pressure, an underlying cause for the advancement of desertification and loss of biodiversity. These areas are also prone to the adverse effects of global climatic change. Acknowledging the enormity of the problems facing the drylands, the Ethiopian government has signed several international conventions such as Convention to Combat Desertification (CCD), Convention for Climate Change (CCC), and Biodiversity Convention. Being a party to these international agreements, Ethiopia should bear the responsibility for their implementation. In Ethiopia, the native *Acacia*, *Commiphora* and *Boswellia* species known to provide diverse economic and ecological significances render an opportunity that harmonizes productivity with ecological integrity including combat of desertification, conservation of biodiversity, and mitigation of effects of climate change and adaptation to climate change in the dryland regions of the country. This paper summarized part of the actual and potential benefits of these vegetation resources, and how the benefits can be harnessed to address the multiple development and ecological challenges facing the drylands of Ethiopia.

Introduction

Drylands, which fall within the range of UNEP's definition of desertification, cover about 47% of the landmass at global scale, 66% of Africa (Houerou, 1996) and nearly 75% of Ethiopia (Table 1). This clearly shows the threat of advancing desertification in Ethiopia. These drylands are important as crop and livestock production zones, and as areas with diverse vegetation cover in Ethiopia. For instance, many of the country's major food crops such as wheat, teff, sorghum, maize and millet are cultivated in the dryland zones. Therefore, unless significant adaptation measures are taken to abate the growing desertification, it results in adverse socio-economic and ecological effects to Ethiopia.

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

Bioclimatic zone	Area ($10^3 km^2$)
Hyperarid	53–55
Arid	300–310
Semiarid	207–250
Dry Sub-humid	300
Total	**860 – 915**

Source: Le Houerou (1996) and Tamire (1997)

Besides the looming desertification, drylands in Ethiopia show clear signs of vulnerability to global climatic change. Mean annual precipitation has gradually declined in the last two decades. Frequent drought, fodder and crop failure, and famine are becoming common phenomena in the dryland regions of Ethiopia.

Cognizant of the severity of dryland problems, the Ethiopian Government has signed a number of international conventions such as Convention to Combat Desertification (CCD), Convention on Climate Change (CCC) and Convention on Biodiversity (CBD). CCD aims at combating desertification and mitigating the adverse effects of drought. CCC has its focus on preventing the causes of climate change (i.e. reduction of green house gas emissions), promoting efforts for carbon (C) sequestration and mitigating the adverse effects of climate change. Technically, combat measures to all or some of the conventions are similar or at least complementary each other particularly at local level (Erikson, 2002). Thus, actions to all or some of the conventions could be coordinated. In fact, the CCD indicates that harmonized efforts that contribute to achieving the objectives of the agreements are highly encouraged (Article 8). Furthermore, since implementation of mitigation measures will affect local welfare, control measures that will enhance the social and economic viability of dryland households are promoted. Only measures which combine productivity with conservation could trigger local people for participation and, thus, become sustainable. The conventions also stress that measures should target local (indigenous) resource use (Erikson, 2002), and the goals of measures taken must be sustainable in the long-run (Tamire, 1997).

The socio-economic conditions in Ethiopia's drylands, coupled with the diverse strongly interwoven ecological conservation goals to be addressed, appeal for mitigation measures capable of providing multiple outcomes that can address aspects of productivity and ecological integrity simultaneously. This paper presented the opportunities that the native *Acacia, Commiphora* and *Boswellia* species, which predominate the dryland vegetation formations of Ethiopia, render to address the multi-dimensional problems facing the drylands of Ethiopia. The actual and potential economic benefits and ecological integrity roles, including the qualities these plant species possess to address the issues of desertification control, biodiversity conservation and climatic change mitigation while safeguarding local livelihood in dryland regions of Ethiopia were presented follwing a briefly discussion on the cause and effect of desertification and vulnerability of the drylands to climate change in Ethiopia.

Causes and effects of desertification

Causes of desertification

Desertification is defined as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities" (UNESCO, 1979; UNEP, 1992; UNCED, 1992). The term land includes whole ecosystems comprising soil and water resources, land surface, vegetation, animals and crops. Degradation signifies the reduction of resource potential by one or a combination of processes like water and wind erosion and sedimentation, long-term reduction in amount and diversity of natural vegetation and animals, salinization (Lal *et al.,* 1999). According to Kelly (1999), the two primary characteristics of desertification are the degradation of soil and the degradation of biological diversity (flora and fauna) due to human-induced causes that ultimately introduce desert-like conditions.

Three of the major human-induced causes of desertification in Ethiopia are overgrazing wood collection, and conversion to permanent cultivation. Few aspects of desertification that were not addressed in previous reports, particularly impact of improper land uses in the drylands on soil organic matter (SOM) and its environmental implications were presented herein.

Removal of perennial plant cover in dryland zones causes reduction of SOM, induces soil erosion by water and wind, causes soil crusting by splashing effects of raindrop, and salinization by evaporation. Particularly, vegetation clearance followed by repeated tillage that also involves burning and harvesting of crop residue causes substantial reduction in SOM contents (Mulugeta and Fisseha, 2004; Mulugeta, 2004). For instance, a study along a topo or climo sequence around the Central Ethiopian Rift Valley area showed that deforestation followed by subsequent cultivation causes soil carbon (C) losses of 94 and 1,748 kg ha^{-1} yr^{-1} from semiarid and dry sub-humid ecoclimatic zones, respectively (Mulugeta and Fisseha, 2004). Another study in the same area showed that cleared forestlands can be used for sustainable farming only for 25 years under the present level of management (Mulugeta, 2004). Subsequent cultivation for over 25 years causes severe soil degradation that hampers crop production. Moreover, deforestation followed by subsequent cultivation of any intensity has been shown to degrade and alter soil seedbanks of natural forests—a phenomenon that arrests the potential for future secondary forest regeneration (Demel, 1996 and Mulugeta Lemenih, 2004).

Reduction in SOM in turn reduces soil aggregate stability and thus causes fragile soil structure that is prone to degradation. Unstable soil and poorly developed structure results in soil compaction, low porosity, low permeability to water and low water holding capacity. The low permeability in turn results in increased edaphic aridity and hence reduced productivity. The reduction in SOM and a fragile structure lead to soil surface crusting by raindrop splash, which increases surface runoff. Furthermore, decreasing SOM also leads to low biological activity from micro-, meso- and macro-flora and fauna, particularly symbionts. The decline in organic matter also reduces the turnover of geobiogene elements like N, P, K, S, Ca, Na, Mg, Fe, Cu, Zn, and Co—causing reduced fertility (Le Houerou, 1996). The ultimate consequences of all these processes are degradation of carrying capacity, decline of regeneration capability, loss of biodiversity, depletion of water availability due to destruction of catchments and aquifers and, finally, abandonment of the area as a desertified land. These and other signs of desertification, such as accelerated soil erosion by wind and water, increasing salinization of soils of drylands, reduction of soil moisture retention, increase of surface runoff, variability of stream flows, decline of species diversity and plant biomass, and reduction of overall productivity in dryland ecosystems (Tewolde Birhan, 1989; EFAP, 1994, and Tamire, 1997), are audacious across the drylands of Ethiopia.

Effects of desertification

Degradation of biodiversity

Wide geo-climatic variations have induced great floral and faunal diversity in Ethiopia. Ethiopia has been recognized to host the fifth largest floral diversity in tropical Africa (Sayer *et al.,* 1992; Shibru and Martha, 1998; Eshetu, 2001); has the richest avifauna in mainland Africa (Demel, 2000) and is one of the eight mega centres of crop diversity (Shibru and Martha, 1998). Ethiopia has been particularly regarded as one of the most important countries in Africa with respect to endemism of plant and animal species (EFAP, 1994). Unfortunately, these renowned ecosystems and their biological resources are vanishing rapidly (Tewolde

Birhan, 1989, 1990; Ensermu *et al.,* 1992; Reusing, 1998; Tadesse and Demel, 2001; Tadesse *et al.,* 2001, 2002).

Major loss in biodiversity in the dryland zones of Ethiopia is occurring through the destruction of habitat owing to extensive deforestation and conversion of forests to agricultural lands (Mulugeta, 2004). However, loss of biodiversity has also been taking place in a more subtle style, manifesting itself in a progressive fragmentation and subsequent isolation of forest communities. Moreover, intense land use due to high human and livestock pressure on cleared forestlands, apart from its direct impact on biodiversity, considerably depletes resources needed for secondary forest succession (e.g. soil seed banks, soil fertility and other habitat qualities), leading to further loss of biodiversity (Mulugeta, 2004). In Ethiopia, the effect of continuous cultivation on several aspects of the regeneration capacity of deforested sites, such as soil fertility, soil seed reserves and seed dispersal, has been identified to retard or even potentially arrest secondary forest succession (Mulugeta and Demel, 2004a; Mulugeta, 2004).

Vulnerability and adaptation to climate change in drylands

On top of the increasing vulnerability to desertification, climate change adds further stresses to the deteriorating dryland ecosystems in Ethiopia. Although the contribution of Africa to the emission of "greenhouse gases (GHGs)" is negligible at global scale, ironically, effect of climate change in Africa appears to be the most serious not only because of increasing aridity and other climatic anomalies, but also due to the widespread poverty that limits fast and significant adaptation capability. Furthermore, the fact that farming is predominantly rainfed in most African countries significantly predisposes the continent to the impacts of potential climate change.

Since three to four decades, drought has been severe and increasingly frequent in Sub-Saharan Africa (SSA) in general and in Ethiopia in particular. The erraticness and decline in amount of rainfall are increasing from time to time. There are many accounts of the increasing climatic problems prevailing in the drylands of SSA. Some relate the phenomenon to natural variation caused by the El-Niño-Southern Oscillation while others relate it to global climatic change and progressing desertification. Although, El Niňo effect is well-known as natural climate variability, there is a possibility that global warming may lead to stronger and more frequent El Niňos than ever before (World Bank, 1998).

According to IPCC (2001), land areas may warm by as much as 1.6 °C over the Sahara and semi-arid parts of Africa by 2050. Equatorial Africa might get about 1.4 °C warmer. Projected rainfall changes by the most general circulation models (GCM)—the most common models used to predict climate impact—are relatively modest, at least in relation to present day rainfall variability. However, there is projected estimate that rainfall will decline by about 10% by 2050 over the Horn of Africa. Potential evapotranspiration over the continent is roughly projected to increase by 5–10 % by 2050 (IPCC, 2001). Consequently, it is projected that climate change in arid areas of Africa will increase by about 10 % in the 21st century (IPCC, 2001).

The consequences of such changes are immense. A sustained increase in mean ambient temperatures beyond 1 °C would cause significant changes in forest and rangeland cover, species distribution, species composition and biome (IPCC, 1997). Arid to semi-arid sub-regions and grassland areas of eastern and southern Africa, as well as areas currently under threat from land degradation and desertification are particularly vulnerable (IPCC, 1997).

Minimizing & reversing desertification, biodiversity loss and climate change

Since desertification and its consequences on biodiversity and other ecosystem processes are primarily human-induced, modification of human landuse practices for better land management is part of the solution. The ultimate solutions to combat desertification and control loss of biodiversity require (i) protection and improvement of productivity of land; (ii) protection, development and sustainable utilization of natural vegetation; and (iii) vegetation restoration on degraded sites (Keller, 1999; Lal *et al*., 1999; and Mulugeta and Demel, 2003).

Furthermore, adaptation to climate change is the standard climate policy issue for African countries. Adaptation refers to "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001). The adaptation policy advocates the need and action for options that would make many productive sectors more resilient to today's conditions and thus would help in adapting to future climate changes. Obviously, options to adapt to climate change revolve around forest and forestry, and some of these measures include control of deforestation, improved rangeland management, expansion of protected areas and sustainable management of forests.

Given the rich dryland vegetation resources with known actual and potential economic and ecological benefits in Ethiopia (Wubalem *et al*., 2003; Mulugeta and Demel, 2003, 2004b; Mulugeta *et al.,* 2004), there is an opportunity to be exploited for the reversal of desertification, conservation of biodiversity and adaptation of dryland ecosystems to potential global climate change as outlined in the following section.

Gum- and resin-bearing vegetation resources as potential solutions to environmental protection, biodiversity loss and climate change in Ethiopia

Occurrence and economic importance

Occurrence and geographic distribution: Ethiopia is one of the few tropical countries well endowed with diverse plant species that yield economically valuable gum and aromatic resins such as gum acacia, frankincense and myrrh (Wubalem *et al.,* 2003; Mulugeta and Demel, 2003, 2004b; Mulugeta *et al.,* 2004). Gum acacia is a product of *Acacia sengal* and *Acacia seyal. A. sengal* produces gum arabic and *A. seyal* produces gum talha, both of which are native to Ethiopia. Sources of frankincense are trees and shrubs of the genus Boswellia. In Ethiopia, there are six species of such trees and shrubs most of which yield incense that have commercial value. Myrrh is produced by species in the genus Commiphora. There are a number of species and sub-species recorded to belong to this genus from Ethiopia, including *C. myyrha,* the species known to provide true myrrh ('heerabol') and *C. guidottii* known to produce scented myrrh.

The gum-and resin-bearing trees are characteristically plants of the low-lying semi-arid to arid lands of Ethiopia. They grow in altitudes of 200–2000 m. These hot and dry regions are also areas most prone to desertification and threats of climate change. Indeed, the vegetation of these regions has various values. In most of the dryland vegetations of Ethiopia, *Acacia, Commiphora* and *Boswellia* species are the dominant species (Kuchar, 1995). They virtually occur allover the low–lying dry zones in the West, South, North and East and in the Blue Nile Gorges, predominantly in Afar, Amhara, Beneshangul-Gumuz, Gambella, Oromia and Tigray Regional States (Table 2). The spatial estimates in Table 2, though modest, indicate that Ethiopia has enormous potential of producing these economically valuable commodities sustainably.

Table 2. Estimated area coverage of gum- and aromatic resin–bearing species in Ethiopia

Region	Genus	Area (ha)
Afar	Commiphora & Acacia	65,000
Amhara	Boswellia,Commiphora, Acacia & Sterculia	680,000
Benshangul-Gumuz	Boswellia, Acacia & Sterculia	100,000
Gambella	Commiphora, Acacia & Sterculia	420,000
Oromia	Boswellia, Commiphora, Acacia & Sterculia	430,000
SNNP	Boswellia, Sterculia & Acacia	70,000
Somalia	Boswellia, Sterculia, Commiphora & Acacia	150,000
Tigray	Boswellia, Sterculia, Commiphora & Acacia	940,000
Total		**2,855,000**

Source: Wubalem *et al.* (2003)

The wide geographic and ecological amplitudes of Acacia, Boswellia and Commiphora give rise to great population diversity of their species. The *Acacia, Boswellia* and *Commiphora* species are very tolerant to extreme aridity, and can thrive under adverse conditions. Their importance stems not only from their ecological ranges but also from the diversity of their useful products. The plants provide many economical products and ecological services, which include gum and aromatic resins, nutritious animal fodder (both pods and browse), N-fixation and soil improvement, protection against wind and water erosion, provision of gum and other emergency food (famine-food) and gum and resins for traditional medicinal purposes. Their wood is essential source of fuel while their timber is valued for construction in arid and semi-arid areas. The greatest local and national economic values of *Acacia, Boswellia* and *Commipora* species lie in the production of gums, aromatic resins and tannins, which are used in several national and international commercial industries.

Current economic contribution: In terms of commercial importance and livelihood support, gum and resin producing trees and shrubs in the drylands of Ethiopia occupy a central position at local and national scales. Nationally, gum arabic, frankincense and myrrh are the most valued products. They are among the few export articles from which Ethiopia earns foreign currency. The direct national economic contribution of the dryland vegetation resources of Ethiopia in generating foreign currency far outweighs that of the forest resources in the humid and sub-humid areas (Mulugeta and Demel, 2003). For instance, in the period 1996–2000, the total exported gum was about 2,715 metric tone, which generated over 29 million Birr (about 3,625,000.00 USD) of foreign currency (Pol, 2002). In the year 2001, the Natural Gum Processing and Marketing Enterprise (NGPME) of Ethiopia alone supplied about 1,459 t natural gum and generated about 11,670,544.00 Birr (about 1.4 million USD) from export and domestic markets. At present, Ethiopia and Somalia are major producers and exporters of frankincense and myrrh in the world (fao, 1995). At local household level, gum and resin are collected and sold to generate income. Direct collection, in most cases, and hired labor by forest concessionaries play substantial role as sources of income to households.

In most lowland areas, collection and sale of gum arabic, frankincense and myrrh are among risk aversion strategies used by pastoral households to cope with climatic anomalies (Farah, 1994). A survey conducted in the southeastern lowlands of Ethiopia estimated that collection and sale of oleo-gum resins provide an average income of 80.00 USD per household per year (Mulugeta *et al.,* 2004). This income was estimated to cover one-third of the annual subsistence of a pastoral household, and the contribution from oleo-gum resins was three times greater than the contribution from arable crops in the area. Similarly, a study made in Tigray revealed that tapping of frankincense provides considerable employment opportunity for the local people (Tilahun, 1997). About 1300 individuals are hired annually as daily laborers in tapping of frankincense in North Gonder Zone of the Amhara Region (Abeje, 2002). These economic incentives have many implications in the overall socio-economic conditions of households living in arid and semi-arid lowlands. Economic benefit from the extraction of oleo-gum resins diversifies their economy and, potentially minimizes risks associated with frequent crop and fodder failures as a result of the recurring droughts. Particularly, in the dry lands where the economy of pastoralists and agro-pastoralists is not able to produce enough food, collection of gum and resins may play a great role in supplementing income for the households' livelihood. The importance of forest income usually lies more in its timing than in its magnitude. One advantage associated with the gum and resins collection in this regard is their availability only during dry seasons when forage and grains are scarce (Mulugeta *et al.,* 2004) and, thus, their use as alternative source of income for dry seasons.

Today, the local, national, regional and international market demand for these products is considerable. In addition, growing health consciousness, that is increasingly changing global trends to natural products, is likely to increase demands for these products in the future. In fact, international demand had declined in the past. Some of the major factors that down-played the international demand in the past were lack of supply, poor quality control along all the steps from picking to shipping; and impurity of assortments (Anderson, 1993; FAO, 1995). Therefore, improvements are needed in the production and marketing processes through training of farmers and producers and through investment on the management of the resources.

Possibilities for promoting the economic significance of gum and resin: Gum arabic, frankincense and myrrh are gaining national, regional and international emphases. These gum and resin products have wide applications in several multibillion industries such as pharmaceuticals; food processing, flavor, liqueur and beverage industries; cosmetics and perfume industries (Mulugeta and Demel, 2003, 2004b). Frankincense and myrrh are also widely used in traditional medicines of several countries for treatments of a wide variety of ailments from embalming to cancer, leprosy, bronchitis, diarrhea, dysentery, typhoid, mouth ulcers, inflammatory complaints, viral hepatitis, female disorders, infections, wounds, coughs, tumor, and others (Mulugeta and Demel, 2003, 2004b). They also have several local applications in medicinal, hygienic and insecticide areas that could be developed through research.

Generally, there are still great potentials, which could be developed through research, in pharmaceutical, fragrance and flavor, food technology, epoxy plastics and coating industries to produce other products using these renewable dryland resources (Stiles, 1988). Capitalizing on the information already available and strengthening researches on other potential products, more economic values can be generated from these vegetation resources, which could otherwise be rated as useless thorny bushes. Another important endeavor that should be promoted is the development of value-added processing. Rather than shipping the raw gum and resin, essential oils can be extracted. Oils obtained from crude resins by steam distillation are normally used for flavoring and fragrance applications. As an alternative to the production of essential oils, frankincense and myrrh can be extracted with organic solvents to furnish either a resinoid or an absolute (FAO, 1995). Introducing value-added processing can offer high gains of foreign currency while creating additional local employment opportunities. In general, the promotion of these well-known species for dryland development would help to conserve their diversity, to control desertification, and to sequester carbon, while at the same time providing income that supports livelihood of the local poor, and contributes to the national income.

Ecological significance of gum- and resin-bearing plants in Ethiopia

Besides their aforementioned substantial economic significances, several species of *Acacia, Boswellia* and *Commiphora* could be managed to concurrently provide multiple ecological services that will enable Ethiopia to successfully comply with the international conventions it has ratified. The vegetation resources could (i) help to fight against desertification and soil erosion by water and wind; (ii) contribute to the conservation and enhancement of biodiversity; (iii) improve soil fertility; and (iv) provide opportunity for C-sequestration.

Potential for desertification control: Many techniques of controlling desertification dominantly involve redressing degraded areas with vegetation and preventing or controling soil erosion by wind. Since desertification is derived by factors related to rural economy, its control needs to be related to the development of the rural economy in order to form an eco-economic model that can be applied for control. The *Acacia, Boswellia* and *Commiphora* species, which are naturally well adapted to arid and semi-arid areas, provide opportunity to integrate economics with desertification control. These plants have proved 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 fact that gum and resin collection is non-destructive makes the vegetation provide constant ground cover, which prevents soil erosion and controls the expansion of desertification. Therefore, by managing the dryland vegetations for sustainable economic benefits, their ecological services such as controlling desertification could also be realized.

Potential for biodiversity conservation: There are different production systems by which *Acacia, Commiphora and Boswellia* species can assist biodiversity conservation. Integration with farming in different forms of agroforestry production systems is one possibility. Agroforestry, as one of integrated approaches to biodiversity conservation, is now receiving considerable attention. In fact, Ethiopian farmers have long developed various traditional agroforestry systems as coping mechanisms against the dwindling forest resources and their products. Traditional agroforestry practices such as parkland, homestead and farm boundary tree management have been developed and practiced for centuries in the country. These practices have obviously rendered safe refuges for several indigenous tree species, many of them endangered from the natural stands. Agroforestry approach is also acknowledged as important strategy for controlling desertification and conserving biodiversity, particularly in dryland regions. This form of land use can allow biodiversity conservation even under high population density in dryland zones (Le Houerou, 1996). Many species of *Acacia, Boswellia* and *Commiphora* possess necessary qualities to be integrated in agroforestry. For instance, in the most widespread crop cultivation system in the drylands of Ethiopia, which involves parkland agroforestry, several native *Acacia* species are integrated into the farming system for protection of crops and workers from the sun, and for supply of fuelwood, fodder or fruits. Studies like Chadhokar (1989), Poschen, (1986), Dechassa (1989), Abebe (1998) and Tadesse *et al.,* (2000) have demonstrated the potentials of these parkland trees to enhance crop production and ameliorate soil fertility.Furthermore, in the arid and semiarid regions where livestock resources are the principal capital and main source of household livelihood, the various species of *Acacia, Boswellia* and *Commiphora* are major sources of fodder. The plant families Burseraceae and Fabaceae are known for their nutritious fodder, and virtually all species in the family Burseraceae provide plant parts, which are palatable to livestock (Farah, 1994; Kuchar, 1995; Mulugeta *et al.,* 2004). Species in the genus Acacia are also known for their ability of N-fixation and soil improvement. The foliage and pods are valuable fodder used by goats, sheep, camels, donkeys and cattle. Compared with annual grasses, these perennial woody resources supply more fodder during prolonged drought spells; this makes them more useful in dryland regions. According to Mulugeta *et al*. (2004), the major local demand on the vegetation resources in the southeastern lowlands of Ethiopia is for use as rangelands. In principle, properly managed grazing is even well known for inducing biological diversity (Guevara *et al*., 1997; Bakker and Berendse, 1999). Therefore, integration of the acacia, boswellia and commiphora woodlands into the farming systems of dryland regions of the country will enable the conservation of biological diversity in this ecosystem, while also ensuring economic and other ecological services.

Potential for carbon sequestration: Emission of greenhouse gases in Ethiopia is at present negligible as compared to that of the developed countries (Assress, 1995). Landuse change, which involves deforestation and conversion of forests into farmlands, is the principal source of CO_2 emission in Ethiopia. This change accounts for nearly 81% of the 16,297 Gg annual emission of CO_2 in the country (Assress, 1995).

As a signatory of the CCC, Ethiopia has to collaborate in the ongoing efforts for C-sequestration by making use of various sink potentials. Drylands are probably the most difficult environments to achieve large amounts of C-sequestration, especially in the form of organic carbon. Inadequate rainfall limits the production and storage of high biomass (primary productivity), resulting in sparse distribution and low stature of the vegetation. In addition, poorly developed shallow soils are common in dryland regions. Furthermore, the high temperature prevalent in the dryland environment implies that C turnover is rapid and, thus, its significant storage in the soil will be difficult. The aforementioned facts reflect that C-sequestration attempts may not be easy and convenient in drylands. In fact, the United Nations Framework Convention on Climate Change and its Kyoto Protocol, which set legally binding limits on carbondioxide and other greenhouse gases, recognises the importance of forests in mitigating climate change. In drylands, the most viable approach to achieve significant C-sequestration is by means of productive vegetation management. This could provide large opportunities for C-sequestration both in the soil and biome, while reducing other factors such as dust and aerosols, which have direct bearing upon climate change. *Acacia*, *Boswellia* and *Commiphora* species that grow very well in the dryland environments of Ethiopia are capable of providing good opportunities for C-sequestration. The vegetation could sequester carbon both in biomass and soil by enriching the soil with organic matter from above- and below-ground organic matter inputs. These plants (i) act as windbreaks and, thus, reduce loss of soil C by wind, (ii) intercept rain drops by their widely spreading canopies, and (iii) reduce soil erosion effectively by their root systems, thereby stabilizing soils and protecting soil carbon. The predominance of N-fixing *Acacia* species in the dryland vegetation would mean high soil fertility and high potential for high soil C sequestration. N-fixing vegetation has been shown to provide greater potential of soil C-sequestration than non N–fixing vegetation (Resh *et al.*, 2002; Mulugeta and Fisseha, 2004). In principle, the carbon stored in the process of conservation and restoration of the vegetation in drylands can be traded in Ethiopia's to provide financial incentives to the rural poor in drylands as a strategy for adaptation.

Conclusion and recommendation

As engendered by the pervasive misconception, which might have conceivably emerged from the misleading phrase "drylands", the resourceful dryland areas in Ethiopia, and probably elsewhere in the world, have been rated as less productive, and thus less attractive for development than other "high-potential" highland areas (Mulugeta *et al*., 2004). Nevertheless, drylands in Ethiopia possess resources having wide actual and potential economic and environmental benefits. These resources could be tapped to (i) make sustainable development and create opportunities for adaptation of the dryland rural communities to the potential impacts, which might arise due to climate change; (ii) combat desertification; (iii) conserve biodiversity; and (iv) make dryland ecosystems contribute to C-sequestration both in the aboveground biomass and soils, thereby contributing to the mitigation of climate change and its likely impacts. In fact, by managing the vegetation resources for economic purpose, their services as sinks of C could also be traded according to the provisions set out in international conventions and the Kyoto Protocol. With the alarming expansion of desertification at global scale, these economically valuable plant species adapted to extreme climatic conditions may provide the genetic resource base that could assist in combating desertification and in sustainable economic use of dryland ecosystems in the future.

Failure to recognize the wealth of these local resources in Ethiopia, and many other tropical countries, had led to, and continues to result in, their alarming deforestation for, mainly the expansion of arable lands, which in turn, is leading to the rapid erosion of their genetic diversity. Therefore, we recommend that urgent policy and legislation interventions are required to: (i) reduce or halt deforestation of these extremely valuable resources; (ii) conserve, develop and promote the sustainable utilization of the irreplaceable genetic diversity housed in these dryland vegetation resources for the benefits of the present and future generations; and (iii) exploit these resources to combat the likely, unforeseen adverse impacts of desertification and climate change on the welfare of plants, animals, micro-organisms and, above all, humans.

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Population Decline of *Boswellia papyrifera* and Associated Species in Dry Forests of Northern Ethiopia and Rehabilitation Efforts

Kindeya Gebrehiwot[1], Bart Muys[2], Mitiku Haile[1] and Ralph Mitloehner[3]
[1]Mekelle University, Department of Land Resources Management and Environmental Protection, P.O.Box- 231, Mekelle, Ethiopia
[2]Laboratory for Forest, Nature and Landscape Research, Katholieke Universiteit Leuven, Vital Decostraat 102, B-3000 Belgium
[3]Institute of Silviculture, Section II: Tropical Silviculture, Buesgenweg 1, 37077 Goettingen, Germany

Abstract

Boswellia papyrifera is an important multipurpose tree species in Ethiopia best known for its non-timber forest product, frankincense. Nowadays, the species is declining at an alarming rate due to agricultural expansion, overgrazing, fire, poor incense harvesting practices, shifting cultivation, termite and other infestations. Recently, closed areas have been established to facilitate the rehabilitation of degraded sites and regeneration of important species such as *B. papyrifera*. Such efforts appear successful, but have not been quantified so far. This study attempted to analyse the population trend of *B. papyrifera* and associated dominant species in the dry forests of northern Ethiopia. Efforts were also made to assess the impacts of recently closed areas on the vegetation composition in general and the dominant species in particular. It was found that, though there is significant rehabilitation of degraded sites due to recent closures, the regeneration of dominant species and importantly *B. papyrifera* was not satisfactory. Hence, more concerted efforts are needed to revive the genetic resources that provide non-timber forest products in dry forests of Ethiopia.

Introduction

Dry forests in northern Ethiopia provide timber, fuelwood, non-timber forest products (NTFPs) like leaves, fruits and roots used as food, medicine, dye and several other needs. Species in these forests also play key roles in maintaining genetic diversity, protecting soils and providing niches for other organisms (Kindeya, 1995). Besides, many tree species in the drylands hold potential for yielding economically valuable products like oleo-gum resins (Mulugeta *et al*., 2003). Dry forests, therefore, support a larger human population than do humid forests (Gerhardt and Hytteborn, 1992). This has resulted in intensive human interventions such as letting fire, grazing and use of forestland to obtain fuel or fodder, which have subsequently transformed the dryland forests to different land forms.

Boswellia papyrifera (Del.) Hochst provides multiple economic and ecological benefits in Ethiopia and other dry areas of Africa (Ogbazghi, 2001). The species is well known for its valuable frankincense (Kindeya *et al*., 2003). Despite these importances, or perhaps because of them, the species is facing serious threats (TFAP, 1996; Ogbazghi, 2001). Presently, the natural stock of *B. papyrifera* is declining due to extensive farming, overgrazing, fire, poor incense harvesting practices, shifting cultivation, termite, and infestations with other insects (Ibid). If the trend is not reversed, therefore, the various advantages related to increased fuelwood, construction material, bee keeping, fodder, local employment opportunities, export earnings, medicinal values and the potential roles the species can play in rehabilitating degraded lands cannot be met.

Some efforts are now underway to rehabilitate degraded boswellia forests in northern Ethiopia through using closed areas[2]. However, scientific information on population trend of the species is lacking. Such knowledge, when available, helps to understand the status of future forest composition and needs for conservation of genetic resources. In areas where documented history of forest stand is not available (Condit *et al.,* 1998), distributions of tree stem diameter were used to infer into past disturbances, regeneration patterns and successional trends in tree populations (Lamprecht, 1989; Swaine, 1998). This approach was used also in this study to assess, quantify and understand the population decline of *B. papyrifera* and associated species, and also to evaluate the recent rehabilitation efforts through using closed areas and implications for the conservation of genetic resources.

Materials and methods

The study area

The study was carried out in the dry forests of Tigray Region in northern Ethiopia between 13°14' and 13°42' N, and 38° 38' and 39° 02' E in four sites around a village called 'Jijike', where *B. papyrifera* occurs. The sites differ in management, aspect and proximity to the main settlement Jijike. The first two sites (hereafter denoted as Site I and Site II) have been closed for livestock (closed areas[1]) since 1994 while open-grazing was practiced in the other two sites (hereafter denoted as Site III and Site IV). In all sites, cutting trees was prohibited. The sites are similar in biophysical conditions and are found in the same administrative district

[1] The use of the term "closed areas" throughout this study refers to the management intervention of setting degraded lands aside with the exclusion of human and livestock interference in order to promote natural regeneration (Kindeya, 2003).

(Kindeya, 2003). Limestone, schist and mixtures of these are the dominant parent materials found in the study sites. The dominant soil types are cambic Arenosols, chromic Cambisols, and Leptosols (Goris, 2002). The land is flat and surrounded by mountains with rivers having different drainage patters. The altitude varies from 1400 m to 1650m. Mean annual rainfall amounts 657 mm, mean annual temperature to 22.3 °C, and aridity index 20.3. Nine months are categorized as dry months (Kindeya, 2003). White (1983) categorized the vegetation around the study area as "Ethiopian undifferentiated woodland" under the Sudanian Regional Centre of Endemism.

Data collection and analysis

In each site, 16 permanent plots were identified through the randomization selection procedure. Each plot had three compartments, i.e., A, B and C (Lamprecht, 1989). In Compartment A (50 m × 50 m=2500 m^2) (Kent and Coker, 1992), all trees with diameter at breast height (DBH) $\geq$ 10 cm were recorded. In Compartment B (20 m × 20 m=400 m^2), all small trees and shrubs with < 10 cm DBH and > 1.3 m height were registered. In Compartment C (10 m x 20 m=200 m^2) saplings with $\geq$ 0.3 cm DBH and $\leq$ 1.3 m height were recorded. In all plots, a slope correction factor was applied for ground distance measurements (van Laar and Akça, 1997; Lamprecht, 1989). All plots were given identification numbers and their location was recorded. Distance from the closest major town, altitude, aspect, average slope, geology, soil condition, geographic location (using the Garmin 12 XL GPS) and date of field work were recorded. The trees recorded in compartments A, B and C were denoted as 'trees', 'small trees and shrubs' and 'saplings'.

Differences in abundance (Nha^{-1}) among sites in the three compartments were evaluated using ANOVA (Fowler *et al*, 1998). Mean values were ranked using Tukey's test, whenever significant differences revealed between variables (Ibid). All data were tested for normal distribution using Chi-square goodness of fit. In order to characterize the diameter distributions of tree species in uneven aged forests like forests in the present study area, several inverse functions are available (van Laar and Akça, 1997). Based on the coefficient of determination (R^2), the negative exponential function better fitted this diameter distribution. The stem diameter size distribution of all the tree species in the four sites as a whole was first analyzed. Then, the diameter size distributions of each dominant species (*B. papyrifera*, *Acacia etbaica. Lannea fruticosa* and *Terminalia brownii*) were computed. These distributions were fitted to the negative exponential and the logarithmic inverse J-shaped functions, which were calculated as:

$$f_1 x = e^{\left[a \text{ x } e^{(-b \text{ x } D)}\right]}$$
$$f_2 x = a \text{ x } e^{(-b \text{ x } D)}$$

where:

f1x=the logarithmic inverse J-shaped function
f2x=the negative exponential function
a, b=model parameters
D=diameter in cm
e=base of the natural logarithm, approximately 2.718

While fitting the functions, respective coefficients of determination (R^2) were calculated. The R^2 was the highest for the negative exponential function, $f_2(x)$, showing it as the best fitted function. Further analyses were, therefore, based on this inverse function.

Results and discussion

Effect of area enclosure on abundance

Closed sites I and II had generally significantly ($P< 0.01$) higher abundances as compared to the open-grazed sites (Table 1). The result suggests that recent efforts to reverse the environmental and biodiversity deterioration through area enclosure in the dry deciduous forests of Tigray Region had positive impacts on environmental rehabilitation. These positive impacts could be categorized into two. First, the restricting of access to human beings and prohibition of grazing by livestock, enabled to maintain trees with $\geq$ 10 cm DBH. The abundance of tree species in these areas was higher than in the open-grazed areas. These trees will contribute to the vegetation recovery of these degraded sites. Such increased vegetation recovery will provide important services such as control of soil erosion which is reported to be high in the study area (TFAP, 1996) and conservation of moisture. Furthermore, this will play a role in watershed management (MUC, 1996). More importantly, these trees will serve as sources of seed for continued natural regeneration. For instance, dominant species like *B. papyrifera* are observed to regenerate readily after seed dispersal (Kindeya, 2003), which might mean that there had not been enough seeds stored in the soil before. Recent studies on acacia woodlands (Eriksson *et al.,* 2003) and montane dry evergreen forest (Valckx, 2002) of Ethiopia revealed that the soil seedbank contains very few seeds from trees. Therefore, maintaining mature trees is crucial to sustain supply of seeds for natural regeneration until alternative methods are found through silvicultural studies.

Second, because of the exclusion of livestock, which would have fed on and trampled the seeds and seedlings, the density of naturally regenerated seedlings of the whole stand was enhanced. These seedlings included a number of important species such as *Combretum hartmannianum*, *Ozoroa insignis*, *Stereospermum kunthianum*, *Acacia seyal*, *Acacia etbaica*, *Terminalia brownii*, *Lannea fruticosa*, *Dichrostachys cinerea*, *Maytenus senegalensis*, *Maerua angolensis* and *Dodonea angustifolia*. Moreover, mortality of naturally regenerated seedlings of *B. papyrifera* was also significantly reduced in the closed areas (Kindeya, 2003).

These positive results indicate that protecting regenerated seedlings should be an immediate task for species rehabilitation in these forests of northern Ethiopia. However, this does not presuppose that livestock damage is the only factor interfering with natural regeneration. Insect infestation, foraging by wildlife and intensive tapping are also reported to disrupt the natural regeneration process of *B. papyrifera* (Tilahun, 1997; Ogbazghi, 2001). Such positive developments agree with the findings and views of Pohjonen (1989), Kebrom (1998), Getachew (2000), and Tesfaye (2000). It is possible to change, rehabilitate, conserve the genetic resources and develop the degraded areas in Ethiopia protecting them in one way or another like by area enclosures and designation of protected sites from human and livestock interferences. Some authors like Ewel (1980) and Josse and Balslev (1994) argue that heavily disturbed dry forest sites deserve conservation, because they quickly return to their original pre-disturbance vegetation as compared to other tropical forests, and thus can serve as preserves for species or as sources of timber and non-timber forest products for the future. Therefore, the conservation of the genetic resources of the dry forests can be rewarding.

Table 1. abundance of trees, small trees and shrubs, and saplings in the four sites (Mean ± SE)

Site	Abundance (Number per hectar)		
	Trees	**Small trees and shrubs**	**Saplings**
I	311 ± 27 (a)	586 ± 60 (a)	850 ± 103 (a)
II	383 ± 39 (a)	592 ± 75 (a)	458 ± 50 (b)
III	280 ± 22 (b)	470 ± 51 (b)	414 ± 52 (b)

IV	139 ± 8 (c)	378 ± 64 (b)	366 ± 42 (b)

Note: Means followed by different letters are significantly ($P<0.05$) different from each other based on Tukey HSD test.

Stand diameter distribution

The model parameters and R^2 values of the diameter size distribution of the four sites were computed. Diameter size distribution for tree, sapling, and seedling per hectare in the four sites followed the inverse J-shaped function (negative exponential function) with $R^2 > 0.75$ (Table 2). The lower the R^2 of the negative exponential function, the flatter the diameter distribution becomes. In contrast, the higher the R^2, the more J-shaped the diameter distribution becomes. In this study, the coefficient of determination was higher for the closed areas (Sites I and II) as compared to the open areas (Sites III and IV). A diameter size class distribution that drops exponentially with increasing DBH (shown with high R^2) as seen in the closed sites is characteristic of species with good rejuvenation (Swaine, 1998). Such a distribution is often referred to as an inverse J-shaped distribution.

Table 2. Negative exponential functions and coefficients of determination (R^2) of the stem diameter distribution in the four sites

Site	Exponential function	R^2
I	$f(x) = 1114.8 * e^{(-0.356298 * DBH)}$	0.97
II	$f(x) = 545.9 * e^{(-0.217399 * DBH)}$	0.95
III	$f(x) = 355 * e^{(-0.1537686 * DBH)}$	0.87
IV	$f(x) = 262.1 * e^{(-0.140871 * DBH)}$	0.76

Note: *f(x)* = estimated diameter in cm, *e*=base of the natural logarithm, approximately 2.718; DBH=tree diameter in cm at 1.3 m height.

There were more individuals in the lower (<5 cm diameter) classes in Sites I and II than in Sites III and IV (Figures 1a–d). This means that there was more regeneration and recruitment in Sites I and II than in Sites III and IV. Swaine (1998) showed that a flat diameter size distribution, represented by relatively lower R^2 values in this study for Sites III and IV, is an effect of declining population sizes. This can be the case in Sites III and IV where tree species were exposed to browsing and grazing. Flat distribution curves indicate lack of recruitment and perhaps changes in species composition (Hall and Bawa, 1993). Although Condit *et al.* (1998) argued that this can also be caused by other factors like rapid growth in small size classes and high overall survival rates, Swaine (1998) showed that these other factors had little role in species composition in West Africa. In general, recent efforts through the use of closed areas in the dry forests have brought about positive impacts on vegetation replenishment.

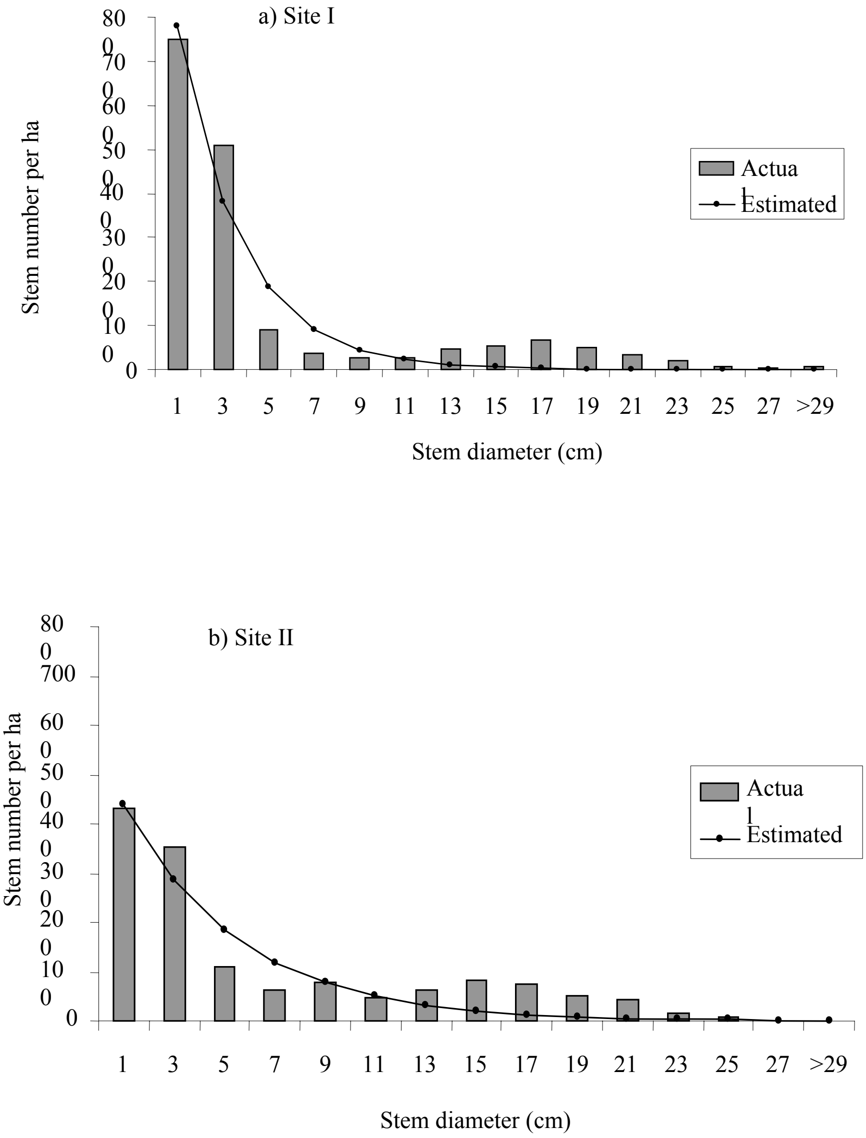
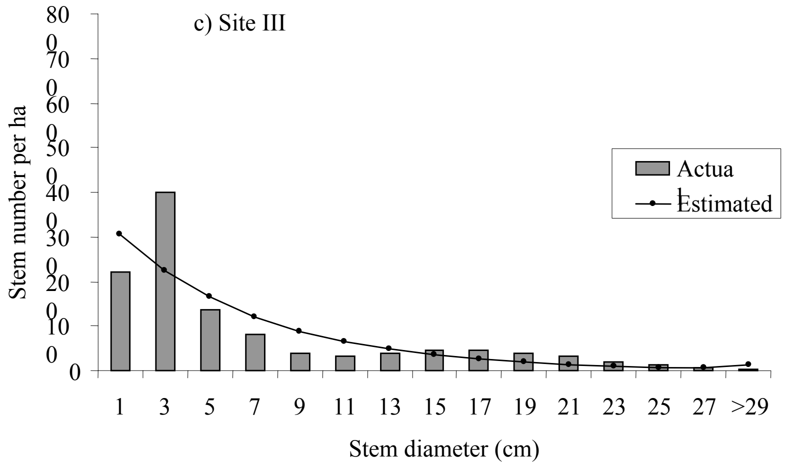
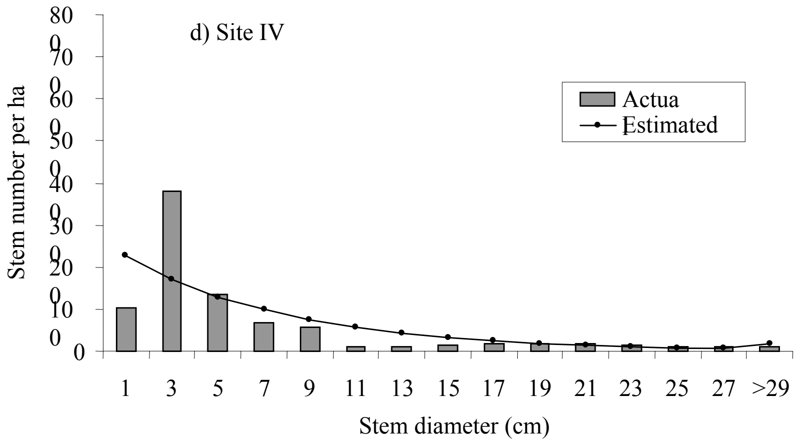


Figure 1a & b. Comparison of actual (bars) and estimated (line) diameter size distribution of the whole stand in Sites I and II.





Figures 1c & d. Comparison of actual bars and estimated line diameter size distribution of the whole stand in Sites III and IV.

Distributions of stem diameter size of dominant tree species

In order to obtain an insight into the population status and regeneration patterns of tree species and to set priorities for rehabilitation and gentic conservation, the diameter size distributions of the dominant tree species that is *B. papyrifera*, *A. etbaica*, *L. fruticosa* and *T. brownie,* known both for their timber and non-timber products (Kindeya, 2003), were analyzed and the model parameters and respective R^2 values were calculated.

Boswellia papyrifera: The R^2 of the exponential function of *B. papyrifera* was very low in all sites (Table 3). There was discontinuity in diameter size distribution of small and saplings (Figure 2), reflecting the effect of past disturbances which created regeneration gaps. There was a higher abundance of stem diameter of between 11 and 23 cm in trees from Sites I and II than in Sites III and IV.

Table 3. The negative exponential function and coefficient of determinations (R^2) for the diameter

distributions of *B. papyrifera*, *A. etbaica*, *L. fruticosa* and *T. brownii* in the four sites

Site	Species	Negative exponential function	R^2
I	*B. papyrifera*	$f(x) = 14.71 * e^{(-0.002 * DBH)}$	0.02
	A. etbaica	$f(x) = 785.24 * e^{(-0.41 * DBH)}$	0.99
	T. brownii	$f(x) = 35.22 * e^{(-0.45 * DBH)}$	0.94
	L. fruticosa	$f(x) = 1.29 * e^{(-0.04 * DBH)}$	0.35
II	*B. papyrifera*	$f(x) = 18.99 * e^{(-0.004 * DBH)}$	0.04
	A. etbaica	$f(x) = 322.92 * e^{(-0.24 * DBH)}$	0.98
	L. fruticosa	$f(x) = 0.76 * e^{(-0.01 * DBH)}$	0.08
	T. brownii	$f(x) = 5.36 * e^{(-0.212 * DBH)}$	0.83
III	*B. papyrifera*	$f(x) = 13.7 * e^{(-0.015 * DBH)}$	0.19
	A. etbaica	$f(x) = 191.98 * e^{(-0.17 * DBH)}$	0.82
	T. brownii	$f(x) = 0.17 * e^{(-0.048 * DBH)}$	0.43
	L. fruticosa	$f(x) = 0.64 * e^{(-0.01 * DBH)}$	0.07
IV	B. papyrifera	$f(x) = 5.20 * e^{(-0.002 * DBH)}$	0.03
	A. etbaica	$f(x) = 5.89 * e^{(-0.013 * DBH)}$	0.98

Note: *F (x)* = estimated diameter in cm, e=base of the natural logalism, approximately 2.718; DBH = tree diameter in cm at 1.3 m height

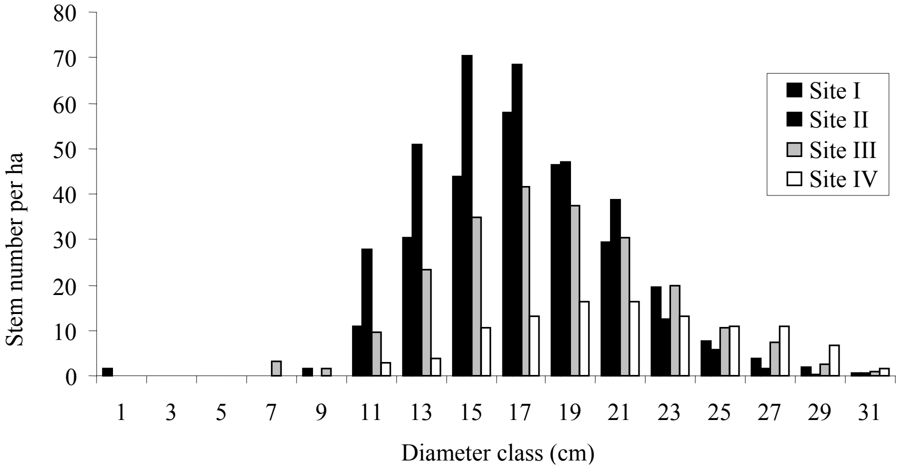


Figure 2. Distribution of Stem diameter size of *B. papyrifera* in the four sites.

Abundance of *B. papyrifera* in lower classes (<10 cm in diameter) in the closed areas was low (Figure 2). Only a few juveniles were seen, and this is a warning that the population is declining. Similar situations prevail in many dominant tree species in African forests (Swaine *et al.,* 1990; Condit *et al.,* 1998). The incongruence between overstorey and understorey forest stands is both an indicator of change and a major concern for conservation (Foster *et al.,* 1996).

Acacia etbaica: The diameter distribution of *A. etbaica* was different from those of the other species (Tables 2 and 3; Figures 2–5). *A. etbaica* had the highest number of individuals (up to 500 stems per hectare in Site I) in the lower diameter classes, especially in less than 10 cm diameter class (Figure 3). Moreover, there was a continuous representation of *A. etbaica* trees in all diameter classes, which shows the continuity of natural regeneration and recruitment into higher classes. There were more saplings of *A. etbaica* in Sites I and II than in Sites III and IV. This indicates the positive effect of area enclosure on the regeneration of this species. The presence of natural regeneration, even in Sites III and IV, indicates that the species is resilient and more resistant to the prevailing livestock grazing than the other species.

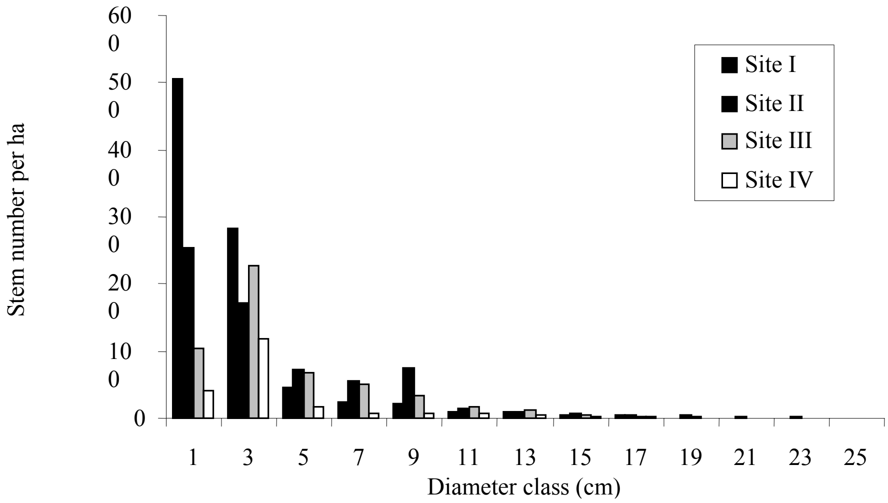


Figure 3. Stem diameter size distribution of *A, etbaica* in the four sites

Terminalia brownii: The overall abundance of *T. brownii* per diameter class in all the sites was very low (Figure 4) when compared with the abundance of *A. etbaica* and *B. papyrifera*. It was also reported by Wilson (1977) that *T. brownii* had low population density of 11 plants per hectar in central Tigray. Moreover, there was a discontinuity in the diameter distribution of *T. brownii*, especially between 3 and 11 cm diameter.Relatively, there were some young *T. brownii* trees in Sites I and II, but no *T. brownii* individuals in the lower diameter classes in Site III (> 13 cm DBH). Absence of juveniles suggests population decline of the species (Condit *et al.,* 1998).

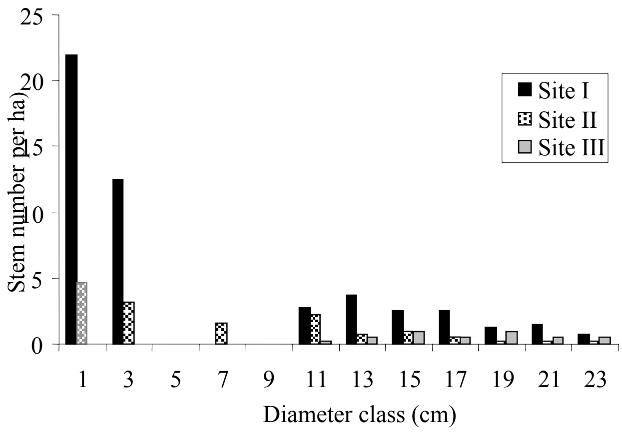


Figure 4. Stem diameter size distribution of *Terminalia brownii* in the three sites.

Lannea fruticosa: The R^2 values of *L fruticosa* were quite low (R^2=0.07–0.35 (Tble 3). There was a very low abundance of *L.fruticosa* as compared to *B.papyrifera, A.etbaica* and *T.brownii* in all sites (Figure 5). Besides, there was discontinuity in the diameter distribution

(Figure 5). In the lower diameter classes, there were more *L. fruticosa* trees in Sites I and II than in Site III. This shows the positive impacts of closure in replenishing the declining population of the species.

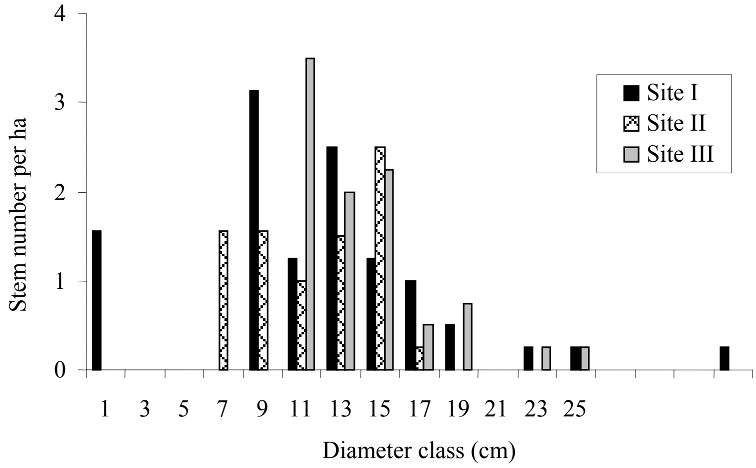


Figure 5. Distribution of stem diameter size of *L. fruticosa* in the three sites

Conclusion

In the dry deciduous forests of the Tigray Region, *B. papyrifera* plays important economical and ecological roles (Tilahun, 1997; Wubalem *et al.,* 2002). Thus, sustainability of the resource base *B. papyrifera* is essential for ensuring sustainability of its uses. This is especially true in Ethiopia where local communities are entirely dependent on their local ecosystems for satisfying all their resource needs. To maintain the supply of important tree products such as frankincense, traditional medicine, fodder and environmental services from *B.papyrifera*, tackling the problems that contribute towards the decline of the population of the species is necessary. The prevailing deterioration, in spite of some attempts to reverse it, is partly due to lack of knowledge about the existing resource base and the required management conditions. Therefore, efforts have to concentrate primarily on identifying and understanding the underlying causes, which lead to deforestation of the dryland forests where *B. papyrifera* grows. These will help to formulate interventions to eliminate these factors of degradation, to rehabilitate and manage these forests in general and economically important species, such as *B. papyrifera*, in particular.

Results of the stem diameter distribution showed that the populations of *B. papyrifera* in the dry forests in Tigray are in decline. The density of *B. papyrifera* trees with DBH >10 cm ranged from 254 to 325 trees per hectare in the closed areas (Sites I and II) and from 109 to 219 trees per hectare in the openly grazed areas (Sites III and IV). Very few small trees (2 per hectare) and saplings (25 per hectare) of *B. papyrifera* were recorded both in closed and open areas. These results show that closed areas were able to maintain more tree individuals of *B. papyrifera* with > 10 cm DBH. However, the low density of small trees (<10 cm DBH but >1.3 m height) and saplings (<10 cm diameter, and $\geq$ 0.3 and $\leq$ 1.3 m height) of *B. papyrifera* highlights the prevailing gaps created due to past disturbance. Other studies in the Tigray Region (e.g. TFAP, 1996; MUC, 1996) described similar trends of population decline. Therefore, concerted efforts are necessary to save the genetic resources of these important species through better land management practices that can sustain the species and subsequently contribute to the economy of the Region.

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Potential of Ethiopian Bamboo Forests in Biodiversity Conservation, Environment Improvement and Socio-Economic Development

Kassahun Embaye
Institute of Biodiversity Conservation, P. O. Box 30726, Addis Ababa, Ethiopia

Summary

Bamboo is one of the world's greatest renewable resources that yield a multitude of high economic value products and services to human kind, and plays a vital role in ecological stability and biodiversity conservation. It interacts with the environment in many ways at fast rate, and thereby creates and maintains a productive, healthy and sustainable biological system. Bamboo is the fastest growing perennial grass with a tree stature that could provide food, forage and culm (woody stem) every year in large quantities for household and industrial use. Bamboo grows to tree size within three months and its culm attains sufficient strength for most structural uses within three years. These virtues of bamboo have never been appreciated and consequently the plant is little used in Ethiopia. Countries in Southeast Asia are adequately harnessing the potential of their bamboo resources. China earns billions of dollars annually from bamboo product exports; and its internal consumption is many folds higher than its exports. Ethiopia, as the most endowed country in bamboo resources in Africa, with 7 % of the worlds bamboo forest cover, needs to strive to efficiently utilize the resource. The unique bamboo resources of Ethiopia are however, disappearing at an accelerating rate before their potentials are fully appreciated. These resources should therefore be conserved, expanded and used on sustainable basis to support the county's economy. This requires a well thought out strategy that can be implemented under the existing situation. This paper contrasted bamboo forests of Ethiopia against those of the whole of Africa and the world and described their growth behavior and their potential for socio-economic and environmental improvements. It also proposed a strategy for their conservation, expansion, sustainable management and utilization by drawing on the experience of Southeast Asian countries.

Introduction

Ethiopia's capacity to conserve and use its rich biological resources contributes to its future development on sustainable basis. It has wide biodiversity. Most of the species are indigenous and some of them are endemic, but almost all of the forest resources still await activation. Bamboo is one of the currently latent resources under limited use despite its high potential to improve the socio-economics of the localities where it grows and where it could be successfully expanded. Furthermore, the spin-off effect of bamboo development and utilization could be of national and global significance.

Bamboos are perennial woody grasses which belong to the Poaceae (Gramineae) family and Bambuseae subfamily (Ohrnberger, 1999). Thus, they have more or less similar morphology and physiology to other grasses. However, since most of them attain tree size at maturity, they are called tree-grasses (Kelecha, 1980). Some species like the giant bamboo grow to over 30 m height and 30 cm diameter. The average size of the indigenous bamboo species of Ethiopia is 6–8 m height and 4–8 cm diameter although much taller and larger bamboo populations are found in some localities, like the highland bamboo forest at Masha, southern Ethiopia and the lowland bamboo forest at Mandura, southwestern Ethiopia.

Ethiopia has two indigenous bamboo species: the African Alpine Bamboo (*Yushane alpine* K.Shumann Lin, synonym *Arundinaria alpina* K. S Chumann) and the monotypic genus lowland bamboo (*Oxytenanthera abyssinica* A. Richard) Munro. These species are also found in some African countries but nowhere outside Africa. Therefore, they are indigenous to Ethiopia and endemic to Africa, confined to some localities in the sub-Saharan region. There are about 1500 bamboo species in the world (Ohrnberger, 1999) growing on about 14 million hectare of land (Jiping, 1987). About 80 % of these species are found in tropical and sub-tropical Asia (Sharma, 1980). Africa has only 43 species occurring on about 1.5 million hectare of land (Kigomo, 1988). About 40 of these are distributed mainly in Madagascar while the remaining are found in mainland Africa. Ethiopia has about one million hectare of highland and lowland bamboos (Luso Consult, 1997). The lowland bamboos cover much larger area (850, 000 ha) than the highland bamboos. About 67 % of the African bamboo resource and more than 7 % of the world total is found in Ethiopia. Even if the world coverage could be double of the reported figure, the proportion found in Ethiopia is still substantial even at global scale. However, Luso Consult (a firm contracted by GTZ) reported the Ethiopian bamboo forest coverage in 1997 that the bamboo forest area has probably shrunk substantially mainly due to agricultural expansion. For example, the lowland bamboo forest of Metekel in Southwest Ethiopia, between Gilgel Beles and Mandura, flowered and died in 1998. All the biomass decomposed on the site for lack of market and a considerable portion of that area is now under crop cultivation. It is saddening to see this uniquely accumulated biological resource, which was a product of long evolution period, being wasted, while its potential in construction, industry, energy, food and feed was there almost unexplored but continuously growing, and could have helped alleviate current pressure on the meager timber resources of the country.

Bamboo characteristics and its potential uses

The aerial part of a bamboo plant contains the main stem called culm, branches and leaves while the underground part constitutes the rhizome and root system. The culm is the most versatile in use and is economically valuable part of the plant. The culm of the highland bamboo is hollow, while that of the lowland bamboo is solid at maturity.

The rhizome is the food store of the plant system, which also serves as a structural foundation on which the plants depend for their mechanical anchorage, growth, vigor and spacing (Liese, 1985). The thin and fibrous roots that spring from the rhizome nodes absorb water and nutrients (Wimbush, 1945). Rhizomes are structured as a leptomorph, giving rise to single-stemmed culms adequately spaced from each other or as a pachymorph, developing into groups of clustered culms–clumps (Liese, 1995). There are also some species with rhizomes between these two distinct structures. The Ethiopian lowland bamboo is a pachymorph while the highland bamboo is a leptomorph in fully developed forests.

Bamboo is the fastest growing perennial plant. Once the rhizome and root system is well established, new bamboo shoots attain full growth within 2–3 months (Liese, 1995). Maximum height of 24 m and diameter of 20 cm have been measured in the highland bamboos of Masha, Southwest Ethiopia, which are mature, strong and ready for utilization after 2–3 years (Virtucio, 1990). Bamboo flowers towards the end of its lifetime and dies soon after, only to restart growth again from germinating seeds. For this reason, Ethiopians in bamboo growing areas consider bamboo flowering as a “lethal disease” and the emergence of seedlings from germinating seeds as “resurrection”.

Bamboo provides a wide range of goods and services more than any other plant does. It is a source of food, fodder, furniture and building materials, industrial inputs, medicine and fuel. It also plays a vital role in environmental amelioration, bio-diversity preservation, soil conservation and waste purification (Kelecha, 1980; Getahun, 1992; Ayre-Smith, 1963; Liese, 1995).

Tropical Asian countries have accumulated experience on bamboo utilization, which is worth emulating. In Nepal, bamboo is used in more than 180 ways (Poudyal, 1991). More than 300 machine-intensive bamboo-processing factories have been established from 1985 to 1992 in Peninsular Malaysia (Abdul Latif *et al,* 1992). Bamboo is widely used in large quantities for pulp and paper production in India (Adkoli, 1991), China (Yang-Yuming and Zhang-Hongjian, 1994), Indonesia (Widijaja, 1980) and other Asian countries. Bamboo pulp is of high grade, better than wood pulp in many aspects and the chemical recovery problem due to the high content of silicon is now solved by de-silification (Oye, 1980). In Burma, it is extensively used as a roofing material (Sein-win, 1982). China produces good quality activated carbon of high economic value from bamboo (Hirai *et al,* 1992). Excellent quality particleboards that meet Type 1 British standard requirements are also produced from bamboo (Teck *et al,* 1991). China earns about a billion US dollars annually from the export of bamboo products.

Bamboos are also widely used in Asia at household and cottage industry levels to produce mats, scaffoldings, ladders, sticks, hand tools, brushes, pipes, funs, umbrellas, toys, sport equipment, musical instruments, spears, arrows, rafts, fishing rods, caps, baskets, flower pots and many other items (Ohrnberger, 1999, Oye, 1980, Poudyal, 1991, Mohmod and Liese, 1995). In this way, the rural people meet a wide range of their needs and supplement their income. They are also preferred shade materials in plant nurseries and are used as props to support the growth of agricultural crops like banana, tomatoes and flowers.

Bamboo shoots are among the most important staple food items in Asia. Their nutritional value is comparable to those of many commercial vegetables (Suwannapinut and Thaiutsa, 1990). It is also cultivated for export to earn multi millions of US dollars every year from bamboo shoot sale; for example, China and Taiwan each get more than ten million dollars from shoot exports.

Bamboo is the most preferable plant for rehabilitating degraded areas. It grows fast and produces many vegetative shoots every year, thereby protecting the soil surface from harmful effects of the sun, rain and wind. The rhizomes and roots grow in all directions forming a complex network up to more than one-meter depth under the ground surface that effectively holds the soil particles together, and thereby preventing soil erosion and promoting water percolation. Litter-fall conditions the soil and improves its qualities. In this way, it conserves all the living things in the food chain spectrum (Chritanty *et al,* 1996). Bamboo effectively restored the vegetative cover of denuded lands in Philippines (Bumarlong and Yagi, 1994). Every year, bamboo population increases by 5–10 shoots per clump (Bumarlong and Yagi, 1994).

Bamboos are also planted as ornamentals owing to their graceful figure, attractive foliage and easy-to-shape clump (Tewari and Bindhi, 1979). The high growth rate of bamboo is associated with high water and nutrient consumption. This makes it suitable for vegetation filter, a biological means of waste purification whereby most of the pollutants in the waste are used for biomass production in the plant growth process. Increased biomass production means enhanced carbon sequestration and oxygen release, and hence improved environmental cleaning. All these qualities make bamboo an ideal plant for urban planting as a hedge and buffer near water bodies and surrounding waste deposits. In addition, it is established for production to supply bio-fuel and raw materials for construction and furniture industries.

Present use of bamboo in Ethiopia

Bamboos are the most freely and readily available resources for the communities living within and around the natural bamboo forests of Ethiopia. However, despite the availability of the resource in large quantities and at low cost, its uses have been backward, mainly limited to hut construction, fencing, and to a lesser extent, production of handcraft, furniture, containers for water transport and storage, baskets, walking sticks, agricultural tools, beehives, household utensils and various art-facts (Kelecha, 1980; Getahun, 1992). Ignorance on the properties, processes and potential applications of bamboo so far impeded its enhanced utilization. For example, the low level of utilization of bamboo culm in Ethiopia is due to the susceptibility of bamboo culms to deterioration by biological and physical agents. The service life of bamboo products is believed to be very short. Although various technologies are now available to extend the durability of bamboo and to use it for various valuable applications, the population is unaware of these technologies. Bamboo is still considered as a perishable material, and hence useless. This pernicious misunderstanding, together with the remoteness of bamboo forests and the high cost of transportation to cities, has led to the neglect of bamboo forests. For example, thousands of tones of bamboo biomass decomposed on site in 1998, when the whole bamboo forest in the area flowered and died; because no one was prepared to use the resource on a large scale.

Bamboo shoots are also consumed in Ethiopia by the rural people living near the bamboo forests, though less popular. Boiled rhizomes are also eaten in these areas. There are reports indicating that 'enset' (*Ensete ventricosum)* helped the Ethiopian people to ease the effects of drought and famine. Also bamboo could be used for the same purpose, to supplement the food requirement of the Ethiopian people. A panel held under the theme "Drought in Ethiopia" on 21 August 1999 in Addis Ababa recommended, among other things, drought-resistant crops and income-generating activities to resist and minimize the effects of recurring drought (Walta Information Center News, 21 August 99). Bamboo, being a multipurpose species and drought-resistant, particularly the lowland one, is suitable for achieving these objectives.

At present, there is no large-scale industry in Ethiopia that converts bamboo to various marketable products. Its potential for industrial use has yet to be popularized, for acceptance both by potential investors and growers. Practical demonstration is the most effective way to convince people. Therefore, it is urgently needed to direct research and development towards this end. Viable market for potential bamboo owners has to be created, by promoting bamboo-based investment, underpinned by the existing natural bamboo forest. Expansion and proper management of both plantation and natural bamboo forests will follow soon, driven by market forces without any imposition. However, workable incentives and appropriate support, in the form of extension services, will be needed to accelerate the process. All links in bamboo production, management, processing, manufacturing, end-product distribution and utilization chain, through well functioning market, have to be established, strengthened and maintained, emphasizing again on the urgency of research and development on bamboo in Ethiopia.

Strategy for bamboo forest conservation, expansion, sustainable management and utilization

Economic potential resources should be developed in developing countries like Ethiopia that are faced with serious economic problems, and the various social problems that result from it.

There is, however, no simple solution as to how best to do it. Resource development is a complex issue that requires advances in all fronts, and committed and innovative stakeholders. Expression of desire for development is not enough. Expressed intents must be translated into reality to bring about the desired resource development. This should be done using appropriate bamboo development approaches that bring maximum economic return while enhancing environmental improvement and biodiversity conservation. This is possible but requires a thoroughly thought-out strategy that provides incentives to sustainably protect, manage, expand and use the resource.

Any bamboo resource utilization initiative has to be based on the remaining natural bamboo forests as there are no bamboo plantations in Ethiopia yet. It is, thus, crucial to look into the ownership or user-right of the remaining natural bamboo forests. Part of the remaining natural bamboo forests should be preserved as *in situ* conservation sites to ensure continued survival of the bamboo for the future generation without interference. This also requires future studies on the natural course of development in the absence of human-induced disturbances. The relevant offices of the agricultural bureau of the regional states could handle the natural bamboo forests set aside for preservation in collaboration with the Institute of Biodiversity Conservation (IBC). The rest could be distributed to individuals or groups of innovative entrepreneurs who commit themselves to manage and use the natural bamboo forests sustainably, according to an agreed management plan. Systematic and organized harvesting, based on a management plan, could dramatically improve the growing stock quality and bolster perpetual yield increment by reducing mortality and creating space for new recruits to emerge and grow. Portions of the natural bamboo forests could also be given to farmers living in and around the forests for communal management and use based on the same premises.

A properly designed incentive structure that operates through market mechanism, grant system, tax concessions, tenure security and technical backup is required to promote bamboo development and utilization endeavors. The grant system has worked well in the developed world to promote specific activities like tree planting and management on selected areas based on an overall development plan. It could also be adopted and adapted in its appropriate form, with an in-built mechanism to monitor and evaluate its effectiveness. Financial resources required to sustain a grant system could be considered as a revolving fund as it can be recovered in a form of sales tax on bamboo products and value added items of bamboo origin. This is a feasible intervention where international aid agencies and development partners could play a meaningful role with fruitful results. Overhead costs and corruption are likely to be low since the resources will be given directly to bamboo growers (farmers) and to bamboo product processors (industries) to be used for the intended purposes based on agreed terms and conditions. The development momentum will sustain itself when aid agencies and development partners withdraw their support as far as there is perceivable demand for the bamboo products by the markets purposefully created and stimulated for this purpose. It is worth reiterating that market forces are the ultimate determinants of development. Steady expansion of markets for bamboo growers, by promoting investment in bamboo-based industries, is vital. Likewise, bamboo-based industries should also see expanding markets for their produce. Once a securely growing market is established and a grant system is put in place, protection and expansion of bamboo as useful crop will perpetuate. Knowledge about the propagation, management and utilization of bamboo will accelerate the rate of development.

China's experience in bamboo development and utilization

China is a country worth emulating in bamboo production and development. Bamboo and rattan account for more than 70 % of some counties in Southeast China, which means that almost all the population in those counties depends on bamboo and rattan cultivation, management, harvesting, processing, manufacturing, distribution and marketing. The success is attributed to the integrated approach they have used in bamboo production, processing and marketing systems. This was done through establishing a Steering Unit composed of members from different pertinent ministries, companies and other stakeholders in all bamboo growing counties. The task of the Unit has been awareness creation on the economic potential of bamboo and bringing together pertinent government ministries, farmers (producers) and companies and would-be companies to work together and support each other for mutual benefit.

The government plays a facilitator and promoter role through policy and strategy arrangements and incentive structures as well as information exchange. The incentive structure includes financial support for emerging bamboo-based companies with good intention and workable plan in their initial phase, tax concessions and provision of land and buildings (if available) free of charge for some years. The government also supports farmers by providing land for planting, supply of bamboo seedlings and by assuring them that their produce will be sold at least at pre-set minimum price. The government also promotes information flow so that industries produce based on market demands and farmers grow and harvest bamboo based on company requirements. The industries buy bamboo culms or shoots or both, mostly after these are semi-processed by farmers, in central village markets once a week after thorough quality inspection. The government also provides technical support both for farmers and industries based on a thematic research by research centers and higher learning institutions.

The government collects tax after the whole scheme is well established and the companies have passed the economic take-off. The success in China is a staggering one. Demand for bamboo raw material and its corresponding price is always higher than it was in the preceding year despite the ever-expanding bamboo plantations. Market for bamboo products is always outpacing supply as a result of new designs and applications. In this way, the whole system of bamboo cultivation, processing and marketing is growing in China at an unprecedented rate. The Chinese strategy of bamboo cultivation and utilization should be studied in relation to the objective realities in Ethiopia and a workable strategy and procedure need to be established to harness the potentials of bamboo by promoting bamboo-based economic institutions.

Conclusion

Bamboo is one of the most versatile resources with very high economic and environmental potential. Ethiopia has this resource in abundance, but is in a latent state. The responsibility of actualizing this potential rests on both the public and the government. We need to communicate adequately in order to create awareness among farmers and potential investors on the potential value of bamboo, and what that means in terms of socio-economic development and environmental improvement. We need also to demonstrate how to translate the potentials of bamboo into actual uses. This requires a leading body and an integrated approach of planning to manage, expand, harvest, process and market bamboo resources with due consideration for biodiversity conservation, at least at pilot level, which could serve as a springboard for a variety of national and regional high-impact initiatives on bamboo development and utilization. The government could then give it the priority it deserves if convinced by the demonstration on the excelling socio-economic and environmental role of bamboo.

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Utilization and Agricultural Significance of Essential- and Fatty-Oil-Bearing Trees and Shrubs in Ethiopia

Getinet Alemaw
Ethiopian Agricultural Research Organization, Essential Oils Research Centre
P. O. Box 3395 Addis Abeba Ethiopia

Summary

Essential oils are volatile compounds extracted from seeds, flowers, leaves, stems and roots of aromatic plants. These high value but small volume commodities are suitable for export. The aromatic plants that yield essential oils vary from perennial trees such as *Eucalyptus citriodora* to annual plants. Essential oils are used in the preparation of food products, beverages, pharmaceuticals, personal care and household products. Fatty oils are largely triglycocides obtained by pressing seeds. These products are largely used in food, cosmetics, paint, and lubricant industries. There are various processes of extraction of essential oils and fatty acids from plants as well as a recount of the essential oils from the major essential oil and fatty acid producing trees and shrubs of Ethiopia.

Introduction

Essential oils are complex mixtures of odorous and steam-volatile compounds which are deposited by plants in the subcutitcular space of glandular hairs, in cell organelles, in idioblasts, in excretory cavities and canals, and exceptionally in heartwoods. These oils are volatile materials, which can be extracted from odorous plant parts such as flowers, herbs, woods, fruits, roots and leaves using water and stem distillation, solvent extraction and maceration. Essential oils have traditionally been used in the preparation of food products, beverages, pharmaceuticals, personal care and household products. Consumer demand for natural flavorings and fragrances continues to grow despite the increasing market share of synthetic products which offer advantages, such as lower production costs, stable price and constant supply. However, not all essential oils can be replaced by synthetic products; organic products are considered healthier by consumers, particularly in EU and Japan. In addition, some essential oils cannot be synthesized for economic and technical reasons. The production of essential oils is very important for:

- they are good sources of raw material for local industries that can create jobs
- they are lucrative export commodities
- they are usually produced organically and not mostly costly as they do not use pesticides, herbicides or fertilizers
- most essential-oil-source perennials protect the soil from erosion and the spent remaining after distillation is used as mulch to enrich the soil
- the stem left after the harvest of leaves of trees such as *Eucalyptus globulus* and *Eucalyptus citriodora* can be used as fire wood or construction

- they can be produced using established technology and have international market
- their volume is small and hence incur low transportation costs and
- there are eager entrepreneurs willing to be engaged in the business of essential oil production and marketing.

As Nicolas (1995) indicated, the market for selected essential oils reached well over one Billion USD in 1990. The major producers of these oils are developing countries. The major consumers are Australia, Canada, EU, Hong Kong, Japan and USA. The entire need for the essential oils from Ethiopia comes from abroad and there exists a wide opportunity both for local and export markets (Essential Oils Research Center, 2004). According to Ethiopian Customs Authority (1995), the country imports over 60 million Birr worth of essential oils and their products.

Some companies are being established around Addis Ababa for essential oils production and export. Ethiopia is currently engaged in research on the extraction of essential oils from various plants. This work is mainly carried out by the Essential Oils Research Center of Wondo Genet, which currently has more than 200 essential-oil-bearing and medicinal plants. The extraction activities at the Center are, however, on a pilot scale that they are not fully known by the industry and the farming community. Essential-oil-bearing plants vary from giant *E. citriodora* and *P. africanum* to Japanese mint. Currently, castor, pyrethrum, artemisia, geranium, *E. citriodora*, *E. globulus*, L*emon grass, Citronella grass, Palma rosa* and *Java citronella* are being studied at the centre.

Processing of essential oils

Broadly, there are four methods of extracting essential oils from raw materials. These are (1) steam or water distillation, (2) cold pressing, (3) solvent extraction and (4) extraction with liquid gasses.

Steam distillation is by far the most widely used method of essential-oil extraction. However, essential oils that have high solubility in water and susceptibility to damage by heat cannot be steam distilled. For steam distillation to be feasible, the oil must be steam volatile. Most essential oils are steam volatile, and are practically insoluble in water.

Steam distillation involves passing steam through closely packed plant material placed in tank. Emerging vapors containing the volatile essential oils are led to a condenser for condensation. Condensed water is separated from the immiscible oil in a special vessel called oil separator. Steam may be obtained from an external boiler or produced within the tank by boiling water. Crude essential oil obtained from the separator may be dried, filtered or centrifuged to improve its appearance and keep quality.

Water distillation is different from steam distillation in that in water distillation, the plant material is almost entirely covered with water in the still which is placed on the furnace. Water is made to boil and the essential oil is carried over to condenser with the stem which is formed. This method, sometimes referred to as hydro-distillation, is the oldest and simplest process known for obtaining essential oils from plants.

Delicate essential oils from flowers such as jasmine and tuberrose are obtained by extracting the flowers with volatile solvents. The essential oils are sensitive to heat and are present in a very small quantity that it is hard to obtain them.

Extraction of essential oils using liqufied gasses such as carbon dioxide is a recent development. The process essentially involves circulation of liqufied gas near its critical point through a high pressure extraction vessel. The solute is separated from the solvent gas by a change of pressure or complete vaporization. The gas is recompressed for reuse.

Essential-oil-bearing trees and shrubs

Eucalyptus citriodora Hook

The genus Eucalyptus was discovered in the costal plains of Australia by Joseph Banks during Captain James Cook's voyage to the Pacific (Graffiti, 1972.). Although the genus is native to Australia, several of its important species are now naturalized in the tropics. Some of the species produce quality timber and some possess paper-pulping quality while others are known for their industrial, medicinal and perfumery grade oils. The use of *E. citriodora* as a source of perfumery oil has been known since its discovery in 1882. The essential oil content of the leaves varies between 0.5 and 4 % although races containing up to 7 % essential oil are known (Pratap 1977).

E. citriodora was introduced at Wondo Genet in the early 1960s for essential oil production. The plant has been under production since then and today it occupies 40 ha of land. *E.citriodora* is propagated entirely by seeds. The seeds are very small; 1000 seeds weighting only about 4 gm. Healthy seeds are usually planted on seed bed and transferred to polyethylene bags containing sand, forest soil and top soil in a ratio 1:1:1. The seeds usually germinate in about eight days and are ready for transplanting to field in 4 months. The seedlings are then transplanted to well prepared field usually in June or July. Commercial cultivation of the tree for essential oil content is not known outside Wondo Genet.

In India, the tree has maximum biomass and reaches for harvest in three years. It has been known that a hectare of three years old *E.citriodora* plantation yields 250 L essential oil under irrigated condition and 200 L under rain fed. Preliminary results at Wondo Genet showed that biomass of *E. citriodora* reached 30 tha^{-1} with essential oil content of about 4% depending on the season. The oil is colorless, has very pleasant smell containing citronellol and citronerllal, on which price and acceptability of the oil depend.

The oil is used for perfumery and as a source of citronellal for the manufacture of citronellol and hydroxy citronellal and menthol. It is an effective substitute for Java citronella oil and is also used in soap and cosmetics industries. The wood is good firewood and is known in paper industry.

Eucalyptus globulus Labill

Eucalyptus globules is one of the dominant plantation species in Ethiopian forestry (AACAEPB, 2000). According to EFAP (1994), it accounts over 58% of the total industrial plantations. It is favored by local highland people especially because of its excellent growth performance and unpalatability of the juvenile leaves to cattle browse. *E. globules* is commercially exploited as fuel and for construction poles in Ethiopia. The leaves are used as a source of traditional medicine. However, countries like India, Spain, Portugal and Brazil use it for industrial applications of its essential oil.

The essential oil, distilled from fresh leaves and terminal shoots, is colorless or pale yellow liquid with aromatic camphoraceous odor and pungent taste. Based on its chemical composition, the essential oil derived from *E.globules* is categorized as medicinal oil that contains about 70–85 % cineol or eucalyptol. The oil is used as antiseptic deodorant expectorant in mosquito and vermin repellent preparation as well as an ingredient in aerosol. The vapors of essential oils are inhaled to relieve cough in chronic bronchitis and asthma. Industrially, the oil is used in the refinement of mineral oils by floatation and also for the manufacture of thymol and menthol.

Eucalyptus oils are classified as cineolic; mainly fom *E.globulus*, *E.sideroxylon* and *E.elacophora;* and perfumery oils from *E.citriodora*, *E.statgeriana* and *E.macarhurl*. Chemical composition of 12 *Eucalyptus* species grown at Wondo Genet showed that 1, 8-cineole was the major constituent in *E.globulus, E.dalnympleana, E.deanelnitens, E.teretisornis, E.urophylla* and *E viminali*. Pinene was the major constituent in *E.dalnympleana*, *E.deanelnitens*, *E.tereticornis*, *E.urophylla, E.viminali, E.globulus, E.delegatensis, E.grandis, E.nitens, E.saligna* and *E.citriodora* had citonellal and citronellol as major constituents. Therefore, 1, 8-cineole, pinene, citronellal, and citronellol are the major constituents in the Ethiopian eucalyptus oils (Table 1). However, oil content and composition is known to vary according to growth stage and growing environment of the trees. The oil from *E.citriodora* is used as a fragrance ingredient in soaps, perfumes, cologne, bath oil, air fresheners, disinfectants and other household products; and as starting material for the isolation of citronellal (Ermias *et al*. 2000, Pratap 1977).

Table 1. Essential oil composition of twelve eucalyptus species grown at Wondo Genet

Species	1	2	3	4	5	6	7	8	9	10	11	12
Content %W/W	1.1	1.0	0.6	1.1	0.6	1.1	0.6	1.4	0.6	0.6	0.4	0.8
1,8-cenole	26.2		17.0	14.5	8.3	71.0	16.9	51.4		31.1	52.1	80.6
4-terpineol	3.1		1.8						1.3	1.9	0.7	
Anethole				1.5								
Camphene			2.0									
Camphor		5.0										
caryophyllene oxide	1.6				1.3	1.3		3.2				2.9
cinnnam aldehyde	2.2			2.5								
Citronellal		70.1		7.0			1.5		3.0			
Citronellol		5.4					2.5					8.7
citronellyl acetate	4.7					2.5						8.7
Cryptone	12.4			12.4					2.6			1.0
eugenyl acetate							3.8					
Graniol										1.3		
Limonene				16.7								
p-cymene	18.5			26.4	13.9		1.3		8.5	17.3		
Pulegone				3.3								
Terpeniol		10.0			5.6	1.3	6.8	9.4		1.7	3.3	
α-pinene	1.4	19.4	32.7	1.3	36.9	19.0	49.5	25.4	49.8	29.9	13.5	6.8
β-pinene											7.4	
α-terpinene					19.9					0.9		
γ-terpinene									19.5			

1=*E.camaldulensis*, 2=*E.citriodora*, 3= *E. dalrympleana*, 4=*E.deanei*, 5=*E.delegatensis*, 6=*E.globulus*, 7=*E.grandis,* 8=*E.mitens*, 9=*E.saligna*, 10=*E. tereticornis*, 11=*E.urophylla,* and 12=*E.viminalia*

Source: Ermias *et al*. (2000)

The volatile oil from *Eucalyptus globulus* is mainly cineole which has a major application in pharmaceutical industry. Cineole is known as medical eucalyptus oil and constitutes 70-80 % of volatile oil in *E.globulus.* Pharmaceutical applications include its use in the manufacture of various types of lotions, pestille and syrup for the treatment of cough, colds and chest and skin complaints. Volatile oil content, oil yield, as well as biomass yield vary according to species, location, year and season. Annual biomass yield reaches 30 t ha^{-1} with annual oil yield of 150–300 kg ha$^{-1;}$ i.e, 3 % from 1.5 × 1.5 m spaced plantation.

Rosmarinus officinalis L.

*Rosmarinus officinalis L.*belongs to Labiatae family. It is a typical shrub of the Mediterranean origin. Its small and narrow aromatic leaves are used as fragrant seasoning herb. The plant has a very good potential to use as herb spice simply used fresh or dried or distilled for its essential oil. Rosemary oil is used in the preparation of cosmetics, soups, perfumes, deodorants and hair tonics. The plant is usually propagated by cutting and rooting can be influenced by using various factors.

Rosemary is a well know and valued herb native to southern Europe. It has been known since long to improve and strengthen memory. The plant has a long-standing reputation as a tonic, invigorating herb, and imparting a zest for life. It is raised from cuttings and seeds and prefers warm, moderately dry climate and sheltered site. Rosemary oil contains borneol, camphor and cineole. It also contains flavonoids, tannins, rosmarinic acid and rosmaricine. Rosemaricine is stimulant and mild analgesic. Rosemary has anti-inflammatory effect mainly due to rosmarinic acid and flavonoids.

Thymus specie

Thymus grows wild in the afro-alpine vegetation parts of Ethiopia. *T. schimperi,* which grows in the afroalpine regions of Gojjam, Shewa, Bale, and Tigray, and *T. serrulatus* which grows only in Tigray and Gonder are endemic. Thymus is perennial herb woody at the base, and has greenish purple young branches. Leaves are ellipitic, ovate to cordate. The plant is endemic to Ethiopia, occurring in open grassland, on bare rocks, slops and tops of mountains, and sometimes growing in ditches in Afro mountain and alpine regions, ranging 2550–37509 m, in Bale, Gojjam, Gonder, Tigray and Shoewa. The chemical composition of thymus oil from Bale, Debre Sina and Mezezo was analyzed by Nigist and Berhanu (1995). The major chemicals were thymol and carvacrol (Table 2). Samples from Bale and Mezezo had the highest tymol content.

The essential oil obtained from the leaves using stem distillation is used in the manufacture of soaps, cologne and lotions, condiments, seasonings, bakery and liquors. The oil has antifungal, antiseptic and vermifuge purposes.

Table 2. Chemical composition of oils of *T. scemperi* and *T. serrulatus* from Bale, Debre Sina, Mezezo, Mekele amd Michew

Chemical	*T. scemperi*			*T. serrulatus*	
	Bale	**Debre Sina**	**Mezezo**	**Mekele**	**Michew**
Pinene	1.13	1.08	2.36	1.39	3.43
3-carene	1.11	1.55	0.73	0.70	2.06
p-cymene	15.43	15.44	20.07	12.54	9.66
Terpinene	9.14	10.49	8.69	4.85	11.33
Linalool	4.38	2.92	3.37	8.78	3.16
Thymol	43.33	21.10	42.78	14.29	24.78
Carvacrol	15.75	38.21	13.17	50.06	22.83

Source: Nigist and Birhanu, 1995

Fatty-oil-bearing trees

Balanites aegyptiaca (L.) Delile (Bedena)

Bedena is an important dryland tree distributed 35 °N to 19 °S and 16 °W to 49 °E from the costal plains of Mauritania to cost of Somalia (John and Daniel, 1991). It grows from 380 m below sea level in the Dead Sea to as high as in the Tchad. The tree grows in areas with 200–800 mm annual rainfall and 20–30 °C mean annual temperature. In Ethiopia, the tree is widely distributed throughout the Rift Valley and semi arid areas such as Dire Dawa, Arba Minch, Zeway and Rift Valley lakes. Although bedena is a staple food of the local people, it is disappearing very fast due to illegal charcoal production.

Bedena is propagated from seed by raising seedlings or by direct planting of seeds. Seeds can be collected from fruits processed for other purposes or collected directly from trees. The stones are separated by soaking in water for several hours and stirring vigorously to remove the pulp. Seed germination is improved by intestinal scarification and boiling for 7–10 hours or by soaking for 12–18 hours in hot water. Germination may take 1–4 weeks.

Bedena kernels contain edible oil and protein containing 20–30 % protein and 30–60 % oil (John and Daniel, 1991). The nutritional composition of the oil is comparable with most vegetable oils. It contains same oil content as sesame and peanut and more than soybean and cotton. It contains less crude fiber than soybean, sesame, cotton and sunflower and about the same amount as peanut. The kernel can also be processed into peanut-butter-like product.

Simmondsia chinensis (Link) Schneider (JoJoba)

Jojoba is a perennial tree that was practically unknown until 1975 (Benzioni and Forti 1989). Since then, it has generated worldwide interest as an oilseed crop due to its unique oil content in the plant kingdom. Jojoba grows in widely different environments from the tropics to the temperate zones. It is tolerant to salinity and moisture stress. Its ability to stand severe moisture stress gives flexibility to adjust irrigation and its salinity tolerance gives the possibility to utilize marginal water and soils.

The seed contains up to 50 % liquid wax which is classified as oil. Unlike other vegetable oils, it contains not triglyceride fat but wax composed, almost entirely, of esters of straight long chain unsaturated fatty acid and alcohols. The oil is extracted by pressing and is largely in cosmetics industry and over 300 different products are available in the USA market alone. Jojoba has been introduced to the former Keffa province during the Derg government without significant economic contribution. The writer learned that the plants still exist in Bebeka and Tepi Coffee Plantations.

Elaeis gineensis) Jacq (Palm)

Of all the oil seeds, palm yields the most up to 5–7 t ha^{-1} (Jacoson *et al,* 1989). The production of palm oil is always increasing. Palm oil has become the most important oil crop in the world market. It originated in humid warm tropical Africa within 15º N and S of the equator. Important characteristic of palm oil is its life span. The first plants introduced to Indonesia are now 160 years old and are still reproducing. The oil palm produces male and female inflorescence and the ratio is influenced by genotype, environment and their interaction. After fertilization, the female flowers produce fruits that weight 15–20 kg per tree. The life span and the area occupied by the tree are the most important constraints in the improvement. However, the ease of cross-and self-pollination, abundance of pollen, the number of fruits produced on every tree and individual plant observations are advantageous.

The fruit is a sessile drupe which varies in shape and weights 3–30 gm. At maturity, the fruit turns reddish orange and then red and consists of the pulp, the shell and the kernel. The pulp or mesocarp is yellowish and rich in oil, containing about 40–60 %. The shell or endocarp consists of black sclerenchyma. Two alleles determine the presence or absence of color of the shell and define the fruit form to be *dura* (thick shell) or *pisifera* (shell-less) or *tenera* ((thin-shelled). The dried kernel yields about 50 % oil. The oil paunch provides 20–24 % palm oil and 2–3 % palm kernel oil. Palm oil has normally 50:50 ratio of saturated and unsaturated fatty acids. Thus, it consisted of a liquid fraction that is clear at 5 to 7 ºC and a fraction which is solid at that temperature. Because of its tendency to cloud at low temperature, the edibility of palm oil tends to be restricted to hardened fats such as shortenings, vanaspati, margarines and frying oils. Recently, many countries, particularly Malaysia and Brazil, have shown interest to use it as fuel.Palm grows very well in the costal plains of Somalia, Kenya, Zanzibar and Mozambique. As the crop is most productive, the warmer humid areas can benefit from palm plantations. Palm has been introduced in the former provinces of Keffa and Illubabor although there is no significant economic benefit from the palm plantations, due to economic liberalization.

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Potential of *Trilepisium Madagascariense* DC for Non-Timber Uses in Southwest Ethiopia and the Need for Its Genetic Conservation

Mohammed Adilo[1], Feyera Senbeta[2], Abebe Yadessa[1] and Tadesse Woldemariam [2]
[1]Ethiopian Agricultural Research Organization, Forestry Research Center, P.O.Box 30708, Addis Ababa, Ethiopia
[2]Center for Development Research (ZEF), University of Bonn, Walter-Flex-Str.3.53113, Bonn

Summary

Throughout human history, plants have been playing significant roles in socioeconomic systems as sources of food, fuelwood, construction material, medicine, dyes, poisons, shelter, fibers, products for use in religious and cultural ceremonies, and in their ecological and aesthetic values. *T. madagascariense* is one of the economically and ecologically important indigenous tree species occurring in transitional montane rainforests of Southwest Ethiopia. This paper highlighted the importance of *T. madagascariense* as source of NTFPs and of enhancing its use and conservation. *T. madagascariense* has several uses: its fruit is edible, bark is reported to treat stomach ulcer, rheumatism, and anaemia; roots are used as a remedy for impotence; the latex is used for making birdlime. However, deforestation is threatening the transitional montane rainforest of Ethiopia, including the population of *T. madagascariense*. Therefore, there is a need to develop *in situ* and/or *ex situ* conservation strategies, while using the tree species and its forest habitat in a sustainable way.

Introduction

The choice for appropriate tree crops is a good option to supplement food, feed and income and to thereby contribute to sustainable agricultural production and land management. Enormous potential exists for developing perennial plants that can provide staple food and feed comparable to yields from cereals, legumes and vegetables and that at the same time enhance ecological functions and services. Wild plants make an important contribution to the life of local communities in Ethiopia and elsewhere in developing countries. They play a significant role in various agricultural systems as a source of wild foods, fuelwood, construction materials, medicine, dyes, poisons, shelter, fibers, products for use in religious and cultural ceremonies, and aesthetic and ecological values. *T. madagascariense* is among the multipurpose wild tree species. *T.madagascariense* is the only species representing the genus Trilepisium in Ethiopia. The species provides non-timber uses in many African countries (Agbovie *et al*., 2002; Ruffo *et al.*, 2002). The potential uses of the species for food and medicine suggest the need for its genetic conservation and domestication. This paper highlighted the importance of *T. madagascariense* as source of NTFPs and of enhancing its uses and conservation in Ethiopia.

Botanical description

T. madagascariense grows to 30 m height and 60 cm diameter. It has buttressed trunk and stems and leaves produce milky white latex. Young branches are glabrous. Leaves are papery and usually turn brown when dried; they ovate, obovate, or lanceolate; are 3–10 X 1.5–5 cm; they have cuneate to truncate base, entire margin, usually long acuminate apex; are mostly glabrous on both sides and have lateral nerves anatomizing near the leaf margin. The petiole is 3–10 mm long; stipules are 2–12 mm long. The inflorescence reaches 5 mm in diameter. Stamens are numerous and grow to 10 mm long. A single female flower has 1.5–3 mm long perianth, up to 9 mm long style and up to 8 mm long stigmatic branches. Fruiting receptacle ovoid, often slightly curved, 0.8 –1.5 cm long (Hedberg and Edwards, 1989).

Ecology and geographical distribution

The species grows in the transitional montane rainforest of Ethiopia at altitudes of 900–1600 m and annual rainfall of 1600–2200 mm (Friis, 1992; Hedberg and Edwards, 1989). Its geographical distribution in Ethiopia includes the southwestern part of Northwest Highlands as far as northern Wellega (about 10^0 N) and the extreme southwestern highlands (about 6^0 N) specifically in Gambella Region; Bench-Maji Zone of Southern Nations, Nationalities and Peoples Region; and Illubabor and East Wellega Zones of Oromia Region. Outside Ethiopia, it is reported that the species occurs in tropical, southern and western Africa (Figure 1)

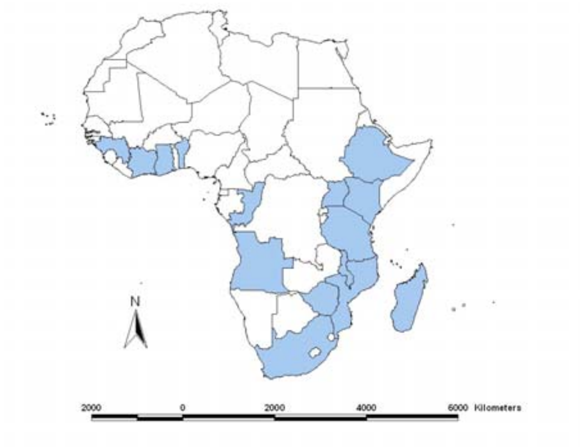

Figure 1. Distribution of *T.madagascarienses* in Africa (shaded areas)

Socioeconomic importance

Despite its wide distribution, information on the biology, ecology, environment, and socio-economic importance of *T.madagascarienses* is scanty in Ethiopia. However, several reports from indicate that the plant has versatile socioeconomic and ecological importance. The wood is used for firewood, building poles, tool handles and the spoons and fruit are edible. Its bark can be used to treat stomach ulcer, rheumatism and anaemia (Agbovie *et al*., 2002). In Tanzania, for instance, ripe fruits are eaten by children. The roots are pounded, soaked in cold water and the infusion is mixed with porridge made of finger millet flour and the porridge is drunk as a remedy for impotence; the latex is used for making birdlime (Ruffo *et al*. 2002). In Southwest Ethiopia, during drought and chronic food shortage, many families of the Mejnegir, Diz, Surma, Shako, Menit and Bench people are completely dependent on *T. madagascariemse* fruit for their food supply (personal observation). Particularly they collect the fruit, boil it with water and then roast the fruit and eat it. However, systematic extraction and marketing of the fruit has not been explored in Ethiopia.

With the ongoing habitat loss and destruction, sustainable utilization of the species can only be possible through domestication or incorporation into other farming systems. In this regard, it is important to support villagers to develop their own micro enterprises for cultivating, selling and processing products of the species. Training in business management practices would help to ensure gains in the commercialization of these products.

Because of its large and spreading leaves, the species plays an important role in protecting the soil from erosion. It also serves as shadetree for coffee. *T. madagascariense* can serve as major sub-strata for many epiphytic species, thereby increasing biodiversity.

The need for genetic conservation

Habitat loss and deforestation are proceeding at an unprecedented rate all over the transitional montane rainforests and destroying the forest ecosystem in general and *T. madagascariensis* genetic resources in particular. The inadequate utilization of forest products, conversion of forest lands into other types of land uses, cultivation of tea and coffee plantations and other activities are devastating the forest ecosystems (Tadesse, 2003; Kumelachew and Taye, 2003). As a result, natural habitats of *T. madagascariense* and many other species are being fragmented. This would result in genetic erosion of the wild species. Thus, strenuous efforts must be made to conserve the genetic base of such important tree species by providing the widest conservation options for primary transitional montane rainforests. Particularly, montane rainforest ecosystems are being degraded because of their favorable location for human living and for their conducive environment in supporting coffee and other agricultural production systems. These all processes will definitely affect the population and genetic diversity of *T. madagascariense* and other valuable species. Efforts made so far for conserving the forest genetic resources have been largely surpassed by the speed of deterioration. These problems and potential uses of the species call for urgent planned and scientific conservation strategy to conserve this economically and ecologically important species *in-situ* or *ex-situ* or both.

The need for domestication of the species

Despite the importance of the species, the risk of deforestation is increasing (e.g. the annual rate of deforestation is 150,000–200,000 ha in Ethiopia). However, there still is considerable potential for domestication and breeding of *T.madagascariense* without expensive inputs because *T.madagascariense* exists in a better balance with other components of forest ecosystem in some parts of Ethiopia (Tadesse, 2003). Although domestication does not necessarily assure conservation and sustainable use of the species, it increases intra-specific diversity (Leakey *et al*., 2003). Thus initiating research projects on domestication of indigenous fruit trees, which can contribute to poverty reduction and livelihood improvement (Poulton and Poole, 2001) and diversifying farming systems (Gockowski *et al*., 2001) are vital.

In most societies, the use of wild plants is part of traditional or indigenous knowledge and practices developed and accumulated over generations. A few of such plants may be managed in their natural habitat; for some species, seeds, saplings, cuttings or other parts of the plants are collected for propagation in fields or home gardens. Selection of plant species for domestication or management is based on their overall usefulness, availability of propagating material and convenience of growing it. Therefore, domestication and improvement of the genetic bases of *T. madagascariense* deserve proper attention.

Valuation of non-timber forest products

The economic value of keeping transitional montane rainforests of Ethiopia is often overlooked. Transitional montane rainforests are sources of useful fruits, medicines spices, coffee, firewood, building materials and ecological functions and services. Particularly, in many parts of Southwest Ethiopia, households are highly dependent on harvesting coffee, spices and other products from such forests for their daily existence and livelihood. However, the value of transitional montane rainforest goods and services to local populations is usually ignored in the economic analyses upon which development decisions are based owing to the fact that these societies often operate with little involvement in the cash economy.

In several areas, population density and natural resource depletion are such that agriculture cannot possibly remain the only source of income (RESAL, 2000). The poorest agricultural region strongly depends on non-farm income (partially provided by commercialization of NTFPs) not because of high absolute levels, but because of low agricultural income (Pol, 2002).

Careful use of NTFPs can have considerable potential for the communities and for the forest, too. The economic benefits from the genetic resources of the forest have also been left out of the cost-benefit analyses of development projects affecting rainforest areas although the extinction of a single plant species with genes that could be used in an agricultural crop may well represent a loss of billions of dollars (Myers, 1985; Wilson, 1988). In real sense the value of NTFPs often far exceeds the value of timber in montane rainforests.

Prospects

Conservation of biological diversity in general and *T.madagascariense* in particular requires a shift in thinking at all levels. This should involve a commitment to increasing levels of human and financial support, acquisitions of comprehensive and reliable information on the biology, silviculture, ecology, and socioeconomics of the species to fully integrate it into all levels of decision-making and farming. The most effective way to conserve particularly genetic diversity is in-situ conservation; which respects the ecosystem interactions within and between wildlife populations as well as between different species. Also ex-situ conservation and domestication of the species are worthy for the sustainable utilization and conservation of *T.madagascariense*.

Conclusion

Multipurpose wild tree species like *T. madasagascariense* occur in specific biogeographical regions and habitats. However, biodiversity loss due to habitat destruction, overharvesting, and inappropriate and often accidental, introduction of exotic plants and animals is increasing at an alarming rate—threatening the genetic diversity of wild species in general and *T. madasagascariense* population in particular. Therefore, sustainable utilization and integrating the species into different farming and agroforestry systems is necessary to consereve such species.

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Natural gum Producing Trees of Ethiopia: Distribution, Types and Chemistry of Gum

Sisay Feleke
Foresry Research Centert, P.O.Box 2322, Addis Ababa, Ethiopia,
E-mail: fpurc@telecom.net.et, sisayfeleke@yahoo.co.uk

Summary

The gums produced by trees of Boswellia, Commiphora and Acacia spp are the major forest products referred as non-timber forest product. These non-timber forest products are chemically different from each other and even within the same product depending on collection time, storage, and geographical location. The products derived from these species have been used in different areas since the ancient time. Utilizing these resources with proper conservation, management and sustainable harvesting will contribute to poverty reduction in the country in particular and in Africa in general.

Introduction

Forest genetic resources are economically important to local communities in many ways like food, fuel, and medicine. In Ethiopia, these resources are normally collected from natural stands, and some of the species in those stands are adapted to the dry areas of the country and to the continent as well. Extraction of these and other forest products is aggravating the country's deforestation problem, leading to degradation and loss of the genetic resources. This finally results in poor economic benefit for the rural community who depend on such products as added income source.

The Boswellia and Commiphora genera belong to the Burseraceae family, while the Acacia genus belongs to Leguminosae. The centers of diversity of the Boswellia and Commiphora genera are located in Northeast Africa within the arid dryland areas with 75 % endemic species (Hedberg and Eduards 1989).

There are about 1000 acacia species, around 130 of which are found in Africa. About tenth of the acacia species, including the major gum producing spp. *Acacia senegal* var *senegal* and *Acacia senegal* var *kerensis,* are found in warm areas of the country with altitudinal range of 600–700 m, whereas, the *Acacia seyal* var *seyal* and *Acacia seyal* var *fistula* are found in northern and eastern Ethiopia, and they extend to Egypt in North Africa. The *A. seyal* species grow in 500–2000 m (Ibid).

Ethiopia produces and exports natural gum from different indigenous species of *Acacia*, *Boswellia* and *Commiphora* found in different agro-climatic zones (Azene *et al*., 1993; Hedberg and Eduards, 1989).

Distribution

Boswellia is one of the 17 genera in the family Burseraceae, the family distributed throughout tropical and sub-tropical regions, particularly in arid areas notably in northeastern Africa (Khalid 1983). It extends from Ivory Coast to the Horn of Africa and Southwards to the northern Madagascar. It is also found in the Middle East as well as India. In Ethiopia, there are two genera of Boswellia with 58 species in total. The center of geographical diversity of the genus is located in the northeast tropical Africa within dry lowland areas where more than 75% of its species are endemic (Vollesen, 1989). In Ethiopia, there are *B. papyrifera, B. pirota, B. neglecta, B. rivea, B. microphylla* and *B. ogadensis.* According to Hedberg and Eduards (1989), *B. sacra* are assumed to occur in eastern Hararghe. Of this *Boswellia* spp., only gum of *B. papyrifera* is collected from natural woodlands by wounding the tree bark intentionally. *B. pirottae* is a rare species found in Tekeze, Abay (Nile) Gorge and Gibe River system in northern Ethiopia; *B. rivae* is distributed in southern Ethiopia (Sidamo, Bale) and Harage; *B. neglecta* and *B. ogadensis* grow within altitude of 300–400 m (Ibid).

The Commiphora genus includes 150–200 species widespread in the drier parts of tropical Africa, Madagascar, and from Arabia to India. The genus is dominant in the dry bushlands of northeast Africa, and a large number of species are endemic to this area. In Ethiopia, the genus has about 50 species including *C. myrrha*, which produces myrrh gum (Ibid). The Commiphora species are found in southern and southeastern Ethiopia (Sidamo, Bale, Hararghe, and Gamo Gofa) and predominantly grow in areas which are 250–400 m high. The species are characterized by production of good-scented resins as small hardened exudates distributed randomly over the bark in large quantities. Frankincense is the resin obtained from trees of the Boswellia genus and myrrh is the resin from trees of the Commiphora genus.

There are about six species of *Boswellia* that produce frankincense. *B. saca* produces frankincense internationally known as Somali type olibanum. Ethiopia, Sudan and India rank as important incense producing countries. Ethiopia and Sudan produce frankincense, which is internationally referred to as Eritrean type, which is derived from *B. papyrifera*.

B. papyrifera (Del.) Hochst and *B. neglecta* (Moore.) are the main commercially important tree species in the genus. Other commercially important species are *B. carteri (syn B. sacra), B. frereana, B. microphylla* and *B. rivae* but they have limited distribution, confined mostly in the Horn of Africa and Yemen. *B. papyrifera* has a natural distribution in the Horn of Africa (Ethiopia, Eritrea and Sudan); *B. neglecta* is widespread in the drylands of eastern Ethiopia, Kenya, Somalia, Tanzania and Uganda.

The *Acacia* spp. that produce gum are distributed in northern parts of the sub-Saharan countries (Niger, Nigeria, Chad, Mali, Sudan, Ethiopia, Kenya, and Somalia). The major gum Arabic producing *Acacia* species are *A. senegal* and *A. seyal*. Other *Acacia* spp produce gum of inferior quality.

The *Commiphora* spp are widely distributed over the eastern Africa, Arabian Peninsula and northern India, comprising over 150 species in general (Hedberg and Eduards 1989). The gums of *commiphora* spp are known as myrrh, produced by *Commiphora myrrha* which is found only in Ethiopia, Somalia, Arabia and Northeast Kenya. The exudates of the *Commiphora* spp have various traditional applications to cure various types of animal and human diseases

The gum of all of the species of *Commiphora*, *Acacia* and *Boswellia* except for *B. papyrifera* in Ethiopia and *B. serrata* in India, are collected only when the natural ooze comes out from the bark wounded by mechanical injury or insect attack of the wood in the case of *Acacia* spp.

Chemical composition

Quality of gum is influenced by botanical origin and post-harvest treatment. Gum from different species has intrinsically different characteristics. Even within the same species, different varieties produce gum with different physico-chemical characteristics. Recognizing these differences in the species or varieties is important in producing gum for desired end use. Gum quality is also affected by pre-and post-harvest treatment. Tapping, for example, gives a more consistent and better formed gum than do natural ooze, wind breakage of parts, and wounds by insect borers and other factors.

The gum from *Boswellia* and *Commiphora* spp. has characteristic essential oils that can be obtained by hydro-distillation. The composition of these oils may have intra-and inter-variation in collection time, storage and other factors (Aman *et al*. 1999). Storage of the gum for a long period or storage condition may cause accumulation of the major component n-octyl acetate (Aman *et al*. 1999). Treas and Evans (1978) and Abdel *et al.* (1987) reported that olibanum from *B. carteria* contains 60–70 % resin and 3–8 % volatile oil. Myrrh contains 25–40 % resin and 7–17 % volatile oil. Karamalla (1997) found that oleo gum resins from *B. papyrifera, C. africana* and *C. abyssinica* contain respective ethanol amount of 72.1, 72.27 and 95.9 %, and steam-distilled oil of 2.8, trace, and 9.6. Volatile oil yield of 8% was collected from *B. papyrifera* from Northern Ethiopia, Metema (Aman *et al*. 1999). Twenty-five terpene compounds were identified from the oil of *B. papyrifera*: α-pinene, β-pinene camphene, β-phellanderene, myrcene, limonene, n-hexayl acetate, cis-ocimene, trans-ocimene, 1,8-cineol, n-octanol, linalool, endo-borneol, n-octyl acetate, α-terpeneol, nerol, bornyl acetate, p-mentha-6,8-dien-2-one, neryl acetate, α-murrolene, 1(5),6-guaiadiene, 4,7(11)-selinadiene, β-elemene, α-terpeniol, verticellol (*Ibid*). Twenty-seven sesquiterpene hydrocarbons have been identified in the oil of *Boswellia* spp obtained by steam distillation (Yates and Wenninger, 1970) (Table 1). The volatile oil of myrrh has been found to contain terpenes and sesquiterpenes of esters, aldehydes and alcohols; whereas the volatile oil of olibanum has been found to consist of numerous terpenes and sesquiterpene acetate, ketone and alcohol (Aman *et al*. 1999, 2002) (Table 1). The essential oils from the four spp. of *Commiphora* vary in chemical composition and quantity (Table 1), which leads to various areas of application of products from these species.

The average physico-chemical, carbohydrate and amino acid composition values for gum from *A. senegal* and *A. seyal* were consistent with published data and typical of each type of gum irrespective of source country or locality. The specific gravity is from 1.33 to 1.52. They almost invariably form white powder. However, though they possess the same chemical properties, gums from the two species could be distinguished from each other by their specific (angle of) rotation $[\alpha]_{D,}$ which is negative, i.e. laevorotatory which varies in $-43-^{520}$ for *A. senegal* while it is positive, i.e. dextrorotatory which varies from $+40$ to $+60^{0}$ and for *A. seyal*. For the use of gum arabic in pharmaceutical applications, the laevorotatory one is preferable. This calls for producing and marketing the two gums separately if future improvements in quality are to be attained (Gaspar 2003, FAO 1999). In many cases, the gum of acacia were collected from different species and mixed up; this makes the production quality very low.

Table 1. Chemical components of essential oils from *Commiphora* species

Components	*C. sphaerocarpa* (%)	*C. holtziana* (%)	*C.kataf* (%)	*C.myrrha* (%)
αPinene	0.6	-	-	
Myrcene	1.5	-	-	
δ–Elemene	-	-	0.4	2.1
α-Copaene	5.3	1.1	tr	0.2
β-Bourbonene	-	-	0.7	1.2
β-Elemene	6.7	5.0	6.4	8.7
α-Gurjunene	7.0	-	0.5	
trans-Caryophyllene	1.0	-	0.5	1.3
α-Hummulene	0.7	0.4	0.7	0.6
Germacerene D	-	23.0	9.0	3.2
β-Selienene	8.0	7.0	2.0	0.6
α-Selienene	11.0	-	2.4	0.5
α-Guaiene	6.0	-	-	
γ-Cadinene	4.7	-	0.3	1.2
δ-Cadinene	2.1	1.1	1.0	0.4
Germacerene **B**	5.0	7.2	7.1	4.3
β-Eudesmol	-	-	2.0	-
T-Cadinol	7.0	-	-	-
Curzerenone + Furanodienone	13.0	6.1	1.0	-
Germacerone	1.0	2.0	3.0	-
Furanosesqueterpene	3.4	18.0	15.0	-
8,12-epoxygermacra-1,7,10,11-tetraen-6-one	2.0	11.4	22.0	-
Furanoeudesma-1,4-diene	-	-	-	34.0
Furanoeudesma-1,3-diene	-	-	-	12.0
Isofuranogermacrene	-	-	-	2.0
Furanodiene	-	-	-	19.7

Source: Aman *et al*. (2002)

The best quality of gum arabic is colorless, of a shin vitreous fracture, opaque in mass, but transparent in small fragments, hard but pulverable, inodorous, and of a faintly sweetish and viscous taste. The very pale, yellowish-white, yellowish-red, or brownish tears belong to the second quality, and may be rendered colorless by the effect of sunlight, or when treated with chlorine water. It can be stored for a long time in dried form.

Conclusion

Plant gums and resins in Ethiopia bear significant roles and value. The resources are found in hot and dry regions, where they are valuable in various ways. However, the most valued commodities in economic terms are the gums gum arabic, myrrh and frankincense obtained from *A. senegal, A. seyal, B.* spp. and *Commiphora* spp. Virtually, all the gum arabic of commerce comes from Africa, with Sudan accounting for up to 70–90% of the world production. Gum arabic has wide applications in food and pharmaceutical industries; it also has miscellaneous technical applications like for film making, printing, and for sizing in textile industries. In food (foods and drinks) industries, it is used as a thickening, stabilizing, emulsifying and suspending agent. In pharmaceuticals, it is used as a binding agent in tablets and as a suspending and emulsifying agent in creams and lotions. Some of the technical applications are. Myrrh is produced by species in the genus Commiphora. The main source of true myrrh is *C. myrrha* found in Somalia, Ethiopia and Kenya. Myrrh, like resin, is produced by *C. habessinica*, *C. confusa*, *C. africana* and *C. incisa.* Also *C. holtiziana* and *C. pseudopaoli* produce resins commercially referred to as oppoponax, which are used as tick repellant.

Frankincense is produced by species in the genus *Boswellia*. The main source of frankincense from Africa is *B. papyrifera* found in Ethiopia, Sudan and Somalia. *B. neglecta* from East and the Horn of Africa also produce commercial incense. Myrrh and frankincense are used mainly as sources of fragrances and pharmaceuticals. The major producer of frankincense is Ethiopia. Utilizing these resources with proper management and sustainable condition will contribute to poverty reduction in Ethiopia in particular and in Africa in general. Ethiopia has enormous resources with the potential of producing these non-timber forest products, i.e. the natural gum products in the dry arid zones, on a sustainable basis. If proper production mechanisms are developed, the resources will provide reliable supply and contribute to the attainment of food security. Therefore, a co-ordinated strategy is required for conservation and development of these resources.

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Economic Value of Trichilia emetica, Delonix elata, Berchemia discolor and *Warburgia ugandensis* in Ethiopia

Miftah Fekadu and Temesgen Yohannes
Forestry Research Center, Ethiopian Agricultural Research Organisation, P.O.Box 30708, Addis Ababa, Ethiopia E-mail: mfkedir@yahoo.co.uk

Summary

There are many commercially valuable indigenous tree species in Ethiopia, but only few are selected for widespread utilization. Because of the over utilization of well known tree species and the less attention given to under-utilized tree species, remnant high forests of Ethiopia are being lost at alarming rate, timber harvesting being the major factor driving forest loss. Commercialization of the non-wood value of forest trees could contribute to the reduction of the rate of forest loss. *Trichilia emetica, Delonix elata, Berchemia discolor* and *Warburgia ugandensis* are four of the many tree species, which have a lot of non-wood product. To initiate the domestication and further research on these tree species, a review was conducted on the uses of each species. *T. emetica* and *D. elata* are fast growing trees; their fruits are used as supplementary diets of many people in Ethiopia. *T. emetica* fruit is nutritious and is sold in markets; the leaves, bark, roots and the oil serve as medicine. *D. elata* leaves and twigs are used to treat mouth ulcer and the bark is used to treat bilharzia and diarrhea. *B.discolor* fruits are eaten by humans, the leaves and fruits serve as feed to liestock. *W. ugandensis* has dense foliage used as fodder and the tree is used by herbalists to treat parasitic diseases.

Introduction

Today, Ethiopia has less than 2.3 % land under high forest cover (EPA, 2003) and this area is being lost at a rate of 150,000–200,000 ha per year (EFAP, 1994). The loss of forests is attributed to land use changes and associated excessive forest extraction. Few well-known tree species are planted and utilized commercially. Most of the indigenous tree species are not observed in plantation or on farms. Many of the farmers grow trees mainly for wood value and edible fruit. Trees with non-wood products are either unknown or, if known, the products are utilized traditionally and secretly (personal communication). There are 300 or more tree species in Ethiopian high forest, of which, more than 25 are regarded as commercial species and more than 30 as potentially usable for the wood industry (MOA, 1998; EPA, 2003), although silvicultural knowledge lacks about many of these species.

Undeniably, indigenous tree species are economically profitable and ecologically suitable. Because of easy access, the collection cost is reasonably low and related environmental conditions are easy to adapt. As a result, Ethiopia's well-known tree species are endangered because of overexploitation; and the less known are also threatened because of less attention for their conservation. Some of the indigenous trees are at the verge of extinction (personal communication) even without the knowledge of curious farmers of the country. So, domestication of trees or shrubs is the ultimate solution to participatory genetic conservation and use of forests of Ethiopia. The experience of cutting trees to fetch only wood, seems to facilitate the destruction of forests of Ethiopia. Domestication of trees or shrubs for mere conservation in famine prone countries like Ethiopia is unbearable.

So, commercializing non-wood products could alleviate the rate of forest loss, because, the farmer or any tree grower can benefit from non-wood products without cutting the tree, in addition to the wood product that can be harvested when ultimate wood product is in need. Utilization of non-wood product also simulates to the use of dairy livestock, when the livestock serves as milk and beef. This paper addressed the economic value of *Trichilla emetira, Delonix elata, Berchemia discolor*, and *Warburgia ugandesis*, which are forgotten but highly economic indigenous tree species of Ethiopia with respect to wood and non-wood product (timber and non timber value).

These species were selected primarily because their non-wood products had never been studied in Ethiopia, secondly personal observation made during forest inventory in different parts of Ethiopia, where the selected tree species exist, revealed absence of promising regeneration in natural forests, although literature like Ruffo *et al.* (2003), Bein *et al.* (1996), Thirakul (1995) showed that the propagation techniques are simple. Therefore, this paper was a firsthand initiation for the domestication and further research works on these selected tree species, which will have a great role in alleviating the current food and feed problems of Ethiopia. Domestication of these species is important because it is amicable to have these trees around, because it is easy to deal with at home, because they can be improved through cultivation. It is also more economical to produce the product than to collect it from the wild. Therefore, researchers should study the domestication and conservation mechanisms of these species and aware the local people and tree growers to start the domestication and conservation of the genetic base of the tree species. The importance of each tree species in providing food, feed, marketable products, medicinal value, and wood value is remarkable.

Economic value of the four species in Ethiopia

Trichilia emetica (Vahl, 1790)

T.emetica is a fairly fast growing, ever green tree species. It grows to 15–30 m height, its trunk is swollen at the base and it sometimes becomes fluted with age (Thirakul, 1995).

The species is widely planted in urban areas of Zimbabwe for shade (Grundy, 1993). It is propagated by seedlings and wildings. Seeds lose viability quickly and sowing fresh seed gives best results. Seed germination test conducted in Tanzania showed that untreated seeds attained a total germination of 28 % in the laboratory and 33 % in the nursery in about 31 days. The main cause of poor germination was due to the impermeability of the aril to water and gas. Complete removal of the aril before sowing the seeds raised the germination capacity to 88–99 % in the laboratory and 77–93 % in the nursery in about 13 days. Application of gibberelic acid to seeds seed coat of which had been completely removed resulted in complete emergence of all seeds sown (Msanga and Maghembe, 1993). The tree is managed by coppicing and pollarding.

In Ethiopia, this tree species is found in dry and moist kolla zones in Bale, Sidamo and Omo River, with altitudes of 0–1800 m. It requires 600–2300 mm mean annual rainfall and 19–31 ^{o}c mean annual temperature. It grows well in medium texture, free draining and neutral reaction soils and tolerates frost, wind, termite and salty soils. The species belongs to the family Meliaceae. Its vernacular name in Ethiopia is "Mahogani"(Amharic) and "Anona"(Borena - Oromiffa) (Thirakul, 1995; Bein *et al*., 1996).

Seeds are squeezed in water and the resulting tasty fatty suspension is used for cooking (Ruffo *et al.,* 2002). An analysis of the edible portion of *T.emetica* fruit showed that it contains 17 % protein and 3164 µg/g phosphorus, together with other components of fat and carbohydrate (Saka, 1994).

It is suspected that the seed from which oil has been extracted contains poisonous substances, which make it unsuitable for the feeding of cattle (Calvino, 1993).

The seeds of *T.emetica* contain oil concentration as high as most oil-rich dicotyledonous seeds and are potential sources of income for rural people. Seed production from matured trees varies greatly between years, averaging 64.7 kg of fresh seed per tree annually in Harare (Zimbabwe). Fresh seed yields oil amounting approximately 308 mm kg^{-1}, using a simple ram press. The oil produces a good finish on wooden surfaces and would compete successfully with other commercial wood oil (Grundy, 1993). Oils present in the kernel and husk of the seeds of the tree contain high proportion of saturated fatty acids. It is therefore excellent commercial oil for making soap, candles and cosmetics (Henry and Grindley, 1994; Ruffo *et al.*, 2002). Calvino (1993) stated the main experience gained in Portuguese East Africa, which exports a considerable amount of seeds of *T. emetica*. Large-scale plantation cultivation in Italian East Africa, which tolerates long drought periods and adapts itself to a great variety of soils, appears feasible and very desirable in view of the insufficient oil production of the Italian Empire. According to Henry and Grindley (1994) the presence of a bitter principle in these oils has been confirmed and it has been shown that a normal caustic soda refining removes the bitter principle in the 'acid oil', leaving the oil free from objectionable taste.

Leaves, bark, roots and oils serve for medicine (Azene *et al.,* 1993). The oil extracted from the seed kernel is used to treat rheumatism, leprosy and fractures (Ruffo *et al.,* 2002). An infusion of the leaves and the bark is used to treat dysentery, fever, lumbago and bruises. An infusion from the bark is used as an emetic and for treating pneumonia. A decoction of the roots is used to treat intestinal worms, rheumatism, colds, and persistent infertility and to induce labour in pregnant women (Ruffo *et al.*, 2002). The extracts of *T.emetica,* as tested for *Plasmodium falciparum* in Sudan, have antiplasmodial activity (Tahir *et al.,* 1999) and also have growth-inhibiting effects on common plant pathogenic fungi (Lovang and Wildt-Person, 1998).

T.emetica is used for firewood, charcoal, construction, furniture, tool handles, boats and standard plywood (Tack, 1953).

Despite its multitude uses, no domestication trial has been observed so far in Ethiopia. Research is needed on propagation, nutritional analysis and medicinal value of the plant for the domestication and expansion of the tree species in Ethiopia.

Delonix elata (L. Gamble)

Delonix elata is a fast growing deciduous legume tree species that reaches to a height of 5–15 m (Bein *et al.,* 1996). It is widely planted in Indian subcontinent both as an ornamental, avenue tree along high way and for green manure. It ameliorates infertile and saline soils. It is similar in habit to ubiqutose ornamental *Delonix regia (*the flame bouyant*),* but has smaller flowers with yellow petals. The tree species is propagated by seedlings, direct sowing and cutting. The germination capacity of the seeds using nitric acid scarification for seven minutes is 75 % in day 42 and 56, without using nitric acid scarification, the germination is 15 % at day 42 and 35 % at day 56 (Rokhade and Nalawadi, 1989). In Ethiopia, *D. elata* exists in Bale lowlands, Dellomena and Negelle Borena and in other parts of the country often on rocky slopes or streams (Thirakul1995; Hedberg and Edwards, 1989). It is capable of growing on poor soils from 0 to 2200 cm altitude. The tree sp. requires 450–1900 mm average annual rainfall, 18 to 27 ^{o}c temperature, and light to medium texture free draining soils which are neutral in reaction. *D. elata* has naturalized in some parts of India, supposedly having been introduced by Arabs from Ethiopia (Troup and Joshi, 1983). The species belongs to family

Fabaceae and its vernacular name in Ethiopia is “Sukela” (Oromiffa) and “Debi” (Somali) (Thirakul, 1995).

Ruffo *et al*. (2002) stated that the leaves are edible. Tender leaves are collected, chopped, cooked and served with ugali. The seeds are boiled and eaten.

Leaves are used for forage (Ruffo *et al.,* 2002)**.** According to Olsson (1989), leaves of *D. elata* are highly nutritive and palatable to livestock. Crude protein content is 20–25 % of dry matter; it has low lignin content and malvalic acids. Farmers can collect and sell leaves for feed.

The flowers are a good source of nectar for honey bees. The local people can get a good deal of marketable honey.

Leaves and twigs are chewed and swallowed to treat mouth ulcers. The bark is soaked in warm water and the resulting liquid is drunk for several days to treat bilharzia. An infusion from the bark is also used to treat diarrhea. The bark of *D. elata* is used in Indian medicine (Harriham, 1969; Subramania and Ramakrishnan, 1968). The fruit pods are used for medicine and laxative and the fruits for tannin making (Bein *et al.,* 1996). The roots are ground on with little water and the paste is put on an abscess to hasten ripening. A decoction from boiled roots is used as an antidote for a variety of ingested poisons (Ruffo *et al.,* 2002).

Singh (1984) found that the tree is most promising as fire wood source; it has high density, calorific value, carbon percentage and low silica and nitrogen.

Ethiopia can benefit much in domesticating this tree species. Researches on propagation and nutritional and medicinal analysis are highly important.

Berchemia discolor (Klotzsch) Hemsley

Berchemia discolor is a semi-deciduous tree or shrub which grows to 18 m height (Azene *et al.,* 1993; Ruffo *et al.,* 2002). This tree is planted for ornament. It is propagated by seedlings, suckers and coppicing. In natural forests of Ethiopia, *B. discolor* exits in Wello, Shewa, Gemo Gofa, Bale and Hararghae in dry and moist kolla agroclimatic zones on alluvial soils from 550 to 1900 m altitude. This species belongs to family Rhamnaceae and its vernacular name in Ethiopia is "Jejeba" (Amharic and Oromiffa) (Azene *et al.*, 1993; Bein *et al.*, 1996; Thirakul, 1995; Hedberg and Edwards, 1989).

Ripe fruits are usually collected from the tree and eaten raw. They are sweet and very much favoured by children, herdsmen and farmers. Ripe fruits can be soaked in water, squeezed and the juice drunk or used for making porridge (Ruffo *et al.,* 2002). The fruit may also be boiled and eaten with sorghum. Leaves are used as tea (Azene *et al.,* 1993).

Fruits and leaves serve as fodder and flowers as bee forage (Azene *et al.,* 1993; Ruffo *et al.,* 2002). The fruits are sold commercially in local markets because the trees are not easily accessible (Ruffo *et al.,* 2002). The resin and the powdered heartwood and roots can be processed for black dye, which is used by basket makers (Azene *et al.,* 1993).

The roots serve medicinal value (Azene *et al.,* 1993).

The tree is used for fuel wood, pole, lumber (construction and furniture). It is one of the hardest woods in East and Central Africa. The ash from burnt wood is used to produce a substitute for white wash. The ash is mixed with water, the liquid filtered and used as a tenderizer for vegetables (Azene *et al.,* 1993; Ruffo *et al.,* 2002).

Ethiopia has great potential to domesticate and use *B. discolour.* However, research works on seed germination capacity and other propagation techniques are lacking. There is no documented source on specific medicinal use of the species. Therefore, more research is required on nutritional, medicinal, dye and tea values of the trees species.

Warburgia ugandensis (Sprague)

W. ugandensis is an evergreen tree which grows to 35 m height and 120 cm diameter with a dense leafy canopy. It is propagated by cuttings, seedlings, direct sowing and coppicing. Germination rate of seed is around 80 % by washing the fruit and sowing fresh seeds. The tree is managed by coppicing. In Ethiopia, it is widely distributed in moist and wet kolla and weyna dega agro climatic zones within 1300–2200 m altitude. *W. ugandensis* is in family Canellaceae. Its vernacular name in Ethiopia is "Zogdom" (Amharic) and "Beeftii" (Oromiffa) (Azene *et al.,* 1993; Thirakul, 1995).

The leaves, bark, young shoots and fruits can be used in curries and roots are used for soup (Azene *et al.,* 1993; Bein *et al.,* 1996).

The leaves and fruits serve as fodder (Azene *et al.,* 1993; Bein *et al.,* 1996).The ample fruits produced from a single tree can be sold for customers.

The bark, roots and young twigs have medicinal value (Azene *et al.,* 1993). *W. ugandensis* is used by herbalists in Kenya to treat parasitic disease (Kioy *et al.,* 1990). Extracts from *W. ugandensis* are active against bacteria, like *Bacillus subtilis* and *Escherchia coli,* and fungi like *Saccharomyces cerevisiae* and *Pencilium crustosum* (Taiguchi and Kubo, 1993).

The wood is hard, heavy and has fine grain and pleasant odor. It is used for firewood, furniture, turnery, plywood and veneers, and cabinetwork. However, the wood is not durable underground and is not termite-resistant. It has high oil content (Azene *et al.,* 1993; Thirakul, 1995).

Ethiopia has great potential to domesticate this tree species. However, domestication trial has not been conducted so far. Further more, there is research gap on nutritional evaluation of leaves and fruit and medicinal analysis of leaves, fruits, barks and roots.

Conclusion and recommendation

Domestication of indigenous tree species is environmentally suitable and ecologically profitable. Making use of non-timber forest products is the best solution for the survival and sustainable utilization of forests of Ethiopia. Before the expansion of the domestication activity of wild plants, in Ethiopia, research should be conducted on propagation, nutritional evaluation, medicinal analysis and calorific content analysis of the plants. *T. emetica* is a highly economic fast growing tree to be domesticated in Ethiopia. Before domestication, research on the chemical analysis of the different parts is most important. *B. discolour* is an economic tree of highly valued fodder. *W. ugandensis is* a big tree with massive leaf and fruit production; it has great potential in areas where livestock feed is scarce. These tree species are highly economic and their propagation os easy. Therefore, immediate research on nutritional and medicinal values and further propagation techniques should be launched in Ethiopia to increasing the role of forestry in food security and import substitution and in reducing the rate of forest loss of the country.

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Extraction and Physical and Chemical Properties of Seed Kernel Oil of *Moringa stenopetala*

Shiferaw Abebe, Dechesa Jiru and Tedilaye Tamiru
Ethiopian Agricultural Research Organization, Forestry Research Center, P.O.box 30708, Addis Ababa, Ethiopia

Introduction

Moringa stenopetala belongs to Moringacae family, which is represented by a single genus moringa. The genus consists of 14 species including *M. stenopetala*. Northeast tropical Africa is the center of endemism and diversity to the genus. *M. stenopetala* originated in Ethiopia and northern Kenya, specifically southern Rift Valley. *M. stenopetala* spread to northern Kenya from Derashie (Mark, 1998; Dechasa, 1995).

The species grows in the former Kefa, Gamo Gofa, Bale, and Sidamo provinces; Borana and Debub Omo Zones, Konso, Wolaita, Burji, Seisse, Male and Dherashe Special Woreda (Simon, 2002). The Soil and Water Conservation Department of the Ministry of Agriculture planted *M. stenopetala* in Wello, Shewa, Harargie and Sidamo for demonstration. The Forestry Research Center has also planted *M. stenopetala* as an alley cropping trial in Fontenina (Wello), Dhera (Arsi), and as a windbreak trial at Zeway. Awasa College of Agriculture and the International Livestock Research Institute (ILRI) have planted the tree in Zeway. The National Forest Seed Project is distributing *M. stenopetala* seed throughout Ethiopia. The species grows within an altitude range of 390–2200 m (Azene *et al*, 1995; Dechasa, 1995).

Konso farmers commonly use the species as an arable tree inter-crop especially as tree crop multi-storey system. Young leaves of *M. stenopetala* are a staple food in South Ethiopia, especially in Gamo Gofa, where they are eaten cooked as fresh cabbage. Because of this, the number of *M. stenopetala* trees farmers possess on their land is used to determine their social status and it is also a factor considered in decision-making for marriage in Konso (Dechasa, 1995; Simon, 2002).

The seed of *M. stenopetala* is very important for water purification as treatment of water with this seed can remove 90–99 % of bacteria. Women in Sudan use the seeds to purify the turbid water of Blue Nile. All the tree parts—bark, root, fruit, flowers, leaves, seeds and even gum—have medicinal value. In addition, browning seeds from mature pods produce an excellent cooking or lubricating oil, which is very similar to olive oil. The oil preserves well although it turns rancid with age. Indonesian pharmacologists from Gadja Mada University have confirmed the non-toxicity of moringa kernel; up to 50-gram seeds per 100 ml of water had no effect on mice (Jahn, 1986; ECHO, 2003; eBigChina, 2002).

Despite the fact that *M. stenopetala* is native to Ethiopia and its being widely cultivated, its oil is not being utilized in Ethiopia on a wide scale. This study was an attempt to analyze the physical and chemical properties of the oil, to determine the oil content and promote the extraction method and use of the oil in order to enable the *M. stenopetala* growing farmers to either sale the seed to oil extracting factories or to extract the oil for their own consuption. This benefit will stimulate the expansion of *M. stenopetala* planting in the country. Oil processing industries can also extract oil from *M. stenopetala* seed. Ethiopian investors can export different parts of this plant, which can be converted to medicines, lubricants, and other products in different areas of the world (ECHO, 2003; eBigChina, 2003).

Combining crop cultivation with growing perennials like *M. stenopetala* can contribute to attaining food security in Ethiopia. *M. stenopetala* is one of the perennials that can be used as source of edible oil. This tree is very resistant to drought; once it is planted, it never completely fails although amount and distribution of rainfall may be poor.

The main objectives were to determine the oil content of *M. stenopetala* seeds; assess the physical and chemical properties of *M. stenopetala* oil; and to determine the protein content of *M. stenopetala* seed cake.

Methods

Seed of *M. stenopetala* was collected from Arbaminch area, Ethiopia by Forest Seed Section of Forestry Research Center. To determine the oil content of *M. stenopetala* seeds, soxhlet apparatus (extraction chamber) was used. The extracting solvent was ethyl ether. Heat extraction method (Robblen *et al*, 1989) was used to extract the *M. stenopetala* seed oil for identification of chemical and physical properties. The chemical and physical characteristics of *M.stenopetala* seed (kernel) oil were tested using different methods (Table 1).

Table 1. Methods used to test the chemical and physical characteristicsof *M.stenopetala* seed (kernel) oil

Characteristic	Test method
Moisture and volatile matter at 103 0C by mass	ES B.K 8.010
Insoluble impurities % by mass)	ES B.K 8.011
Soap content (% by mass detected)	ES B.K8.012
Density at 20 O_C	ES B.K 8.003

Refractive index at 40 O_C	ES B.K8.004
Clarity at 15 to 20 O_C after 24 hours	visual inspection
Acid value max.mg KOH/g	ES B.K 8.005
Iodine value (Wijs)	ES B.K 8.007
Peroxide value, max. peroxide perkg	ES B.K 8.009

Source: Ethiopian Quality and Standards Authority (1990)

Secondary data were taken for chemical and physical characteristics of other crop oils for comparison. The laboratory work of determining the oil content was done at Kulumsa Agricultural Research Center Laboratory and identification of the physical and chemical properties was conducted at Ethiopian Quality and Standards Authority Laboratory.

Results

Oil content

Average oil content for *M. Stenopetala* kernel samples extracted using ethyl ether was about 32.5% by weight, the maximum being 33.8% and the minimum 31.2%. This result was in the range of the oil content of the common oil crops in Ethiopia but a bit less than the oil content of some oil crops like nigerseed, which has about 40 % oil content, and better than some others.

A trial conducted at Arba Minch Water Technology Institute revealed that seed yield per tree of *M. stenopetala* varies with age and height. At 4–13 years of age, 4500–10000 seeds can be collected from a tree annually, which equals 2.3–5 kg per tree per year (Mayer 1990). On a hectar of land, about 1000 *M. stenopetala* trees can be grown using 3 × 3 m spacing. This means, *M. stenopetala* seed of about 2300–5000 kg or 23–50 qha^{-1} can be obtained per year four years after planting. This also gives about 747–1625 kg litter of edible oil in a hectare of plantation of *M. stenopetala*. Taking the current edible oil price at 10 birr per litter, about 7470–16 250 Birr can be obtained annually per hectare of plantation of *M. stenopetala.* Whereas, annual oil yield of the most widely used oil crops in Ethiopia, noug, is about 600–1000 kg., *M. stenopetala* gives higher yield of both seeds and oil per ha per year. *M. stenopeta* can give about three times more seed and oil yields per ha per year than noug can. *M. stenopeta* gives 2300–5000 kg seed per hectar per year with 32.5% oil content and 747.5–1625.0 kg or L oil yield per hectar per year. Whereas, noug gives 600–1000 kg seed per hectar per year with oil content of 40% and oil yield of 240–400 kg or L oil per hectar per year.

Protein content of cake of *M.Stenopetala* kernel

Four samples of cake of *M.Stenopetala* kernel were tested for percent protein content per weight and mean protein content of 36.22 % was obtained per weight, the maximum protein content per weight was 37.00 % while the minimum was 35.44%. The cake has high protein content of 36.22%. Therefore, it can be good to use as animal feed. In addition, seed cake from which oil has been extracted retains its coagulant properties. Therefore, after the oil is extracted, the cake can be used for water purification. Moreover, the cake is also good organic fertilizer (eBigChina, 2003). Moreover, under *M.stenopetala* plantation, it is possible to grow root crops or cereals as an agro forestry system. The plant is resistant to drought and has environmental protection effect.

Physical & Chemical properties of *M. stenopetala* kernel oil

Amount of moisture and insoluble impurities of *M. stenopetala* kernel oil is higher than the standard given for other oils (Table 1). This can be improved by further purification of the oil. Before separating the oil and the meal, 2–4 % of water can be added to precipitate hydrateable gums. The water and precipitate gums with meal will be separated by continuous centrifuges (rotating the cooking material with floating oil and the meal for a certain period). This parameter is controllable either by purification or by applying better extraction method, like cold pressing. The *M. stenopetala* kernel oil has no soap even though the standard allows up to 0.005 % of soap content, showing that *M. stenopetala* has best quality in soap content (Robblen *et al*, 1989). Density, refractive index and clarity values of *M. Stenopetala* kernel oil were almost the same with the standard (Table 1). Edible oil contains 95 % triglycerides, which are esters obtained from one unit of glycerin with three units of fatty acids. The triglycerides are constitutes which we wish to recover and use as neutral oil in the manufacture of finished products. The non-triglyceride portion contains variable amount of impurities like free fatty acids (FFA) and non-fatty materials, generally classified as 'gums' (Robblen *et al*, 1989). This also holds true for the edible *M. stenopetala* oil.

Table 1.Comparisonn of Physical and Chemical properties of *M. stenopetala* kernel oil with properties of other oils

Contaminants level	***M.stenopetala*** **Kernel oil**	**Niger seed oil**	**Linseed oil**	**Maize oil**	**Cotton seed oil**	**Rape seed oil**
Max moisture and volatile matter (% at 103 ^{O}C by mass)	2.46	0.2	0.2	0.2	0.2	0.2
Ins % by mass (maximum) soluble impurities	0.54	0.05	0.05	0.05	0.05	0.05
Maximum soap content (% by mass)	Nill	0.005	0.005	0.005	0.005	0.005
Physical properties						
Density at 20 O_C	0.925	0.9250-0.9270	0.9120-9330	0.9170-0.9250	0.9250-0.9270	0.9100-0.9200
Refractive index at 40 O_C	1.475516	1.4665-1.4695	1.4715-1.4825	1.4650-1.4680	1.4665-1.4695	1.4650-1.4690
Clarity at 15 to 20 O_C after	No sediment	No sediment	No sediment	No sediment	No sediment	No sediment
Chemical properties						
Acid value max. .mg KOH/g	4.2	0.6	0.6	0.6	0.6	0.6
Iodine value (Wijs) g/100 gm	5.4	128-134	110-143	103-128	99-119	94-100
Max. peroxide value (kg)	0.72	10	10	10	10	10

Source: Ethiopian Quality and Standards Authority, 1990.

The chemical properties of edible oils are very important parameters determining oil quality. Among the chemical characteristics, acid value is most important. It indicates milligram of KOH required to neutralize free fatty acids per gram of oil. Free fatty acids (FFA) are impurities, which highly affect oil quality. The higher the free fatty acids the lesser the quality of the oil will be. However, higher FFA content is good for lubrication. The FFA occurs naturally or is produced during storage or processing. The FFA exists in edible oils as a distinct chemical unit in uncombined state (Robblen *et al*, 1989; Martin, 2000; Chopra and Kamwar, 1999).

The acid value of seed kernel oil of *M. stenenopetala* is higher than the Ethiopian standards given for other edible oils (Table 1). Except edible oils produced by Ameresa, Mojo and Bahir Dar edible oils factories which have FFA neutralizing machine, most of the edible oils manufactured in Ethiopia don't fit this standard. According to the Ethiopian Quality and Standards Authority, rape seed oil with 12 % acid value used to be produced as edible oil because the neutralizing machine was unaffordable for many edible oil factories in Ethiopia (personal communication with a chemist working at Ethiopian Standards Laboratory). Moreover, good crude oils have less than 5 % FFA, with more contents than 10 % regarded as spoiled (Martin, 2003). Therefore, 4.2 % acid value of *M. stenopetala* seed kernel oil, with no neutralization or purification, is very good, and it is manageable with even simple purification methods that can be applied by farmers. Iodine value indicated the tendency of saturation of the oil. The higher the iodine value, the lesser the saturation of the oil will be. The iodine value of *M. stenopetala* is less than most of the standards given, but it is by far higher than iodine value of palm kernel oil, which is 14.5 % (Table 1) (Chopra and Kamwar, 1999),which is an acceptable value.

Quality of edible oils depends directly on quantity of oxygen absorbed. The peroxide value (PV) determines the content of peroxides formed in the oil. High PVs imply low quality oil. The PV of *M. Stenopetala* (0.72) is incredibly less than the Ethiopian standards given for most of the common oils. Therefore, this oil has an excellent quality in terms of this parameter (Mortin, 2000, table, 1). In addition, *M.stenopetala* oil is yellow orange, which is also true for many crude vegetable oils (Rebbelen *et al*, 1989) and its odor is very good, its flavor is the same as nigerseed oil.

Conclusion

Seed kernel oil of *M. stenopetala* is very good edible oil in oil content percent and physical, chemical and other properties. Therefore, it is a very good source of edible oil for many poor farmers living in southern Ethiopia, mainly for the Konso people who are highly dependent on the leaves of *M. stenopetala* as a vegetable, and who have long experience in cultivating this tree. In addition, it can also be planted in drought-pron areas for sustainable oil yield. Demonstration of the extraction of the oil and the various uses of seed kernel oil of *M. stenopetala* to the people of southern Ethiopia, where this species is abundant, is an important step in the promotion of this oil for use by local communities. Frequent advocacy and demonstration is essential to get people accept the oil. Investors and other edible oil processing organizations can produce seed kernel oil of *M. stenopetala* for export and inland consumption. Detail studies of provenances and seed yield per tree or per hectare basis of *M.stenopetala,* further chemical composition analysis and oil content determination of the oil need to be undertaken as quality and quantity of the oil and seed yield per tree per year may vary depending on soil type, provenance, and other factors.

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Genetic Conservation Status of Some Woody Medicinal Plants in Southwest Moist Montane Forests of Ethiopia

Getachew Berhan and Taye Bekele
Institute of Biodiversity Conservation, P. O. Box 30726, Addis Ababa, Ethiopia

Abstract

Southwest Moist Montane Forests of Ethiopia harbor many plant species of medicinal values which are threatened by different factors. Conservation status of nine commonly known medicinal plants: *Hagenia abyssinica, Prunus africana, Schefflera abyssinica, Croton macrostachyus, Myrsine africana, Myrsine melanophleos, Syzygium guineense, Allophylus abyssinicus* and *Brucea antidysetrica* was assessed in Boginda, Bonga, Masha-Anderacha and Yayu moist montane forests of Southwest Ethiopia. A systematic transect line sampling technique was employed with a sampling size of 10 X 50 m (500 m^2) for floristic composition and structural performance assessment, and 2 X 20 m (40 m^2) for regeneration assessment for each 50 m altitudinal drop. *H. abyssinica* was encountered only in Bonga forest and analysis of its population structure showed poor reproduction and poor recruitment. *S. abyssinica* was found in all the study areas but with no reproduction and poor recruitment. The population structure of *P. africana* in all the study areas showed U-shape distribution—indicating the selective cutting and removal of middle-sized individuals. *C. macrostachyus*, *A. abyssinicus* and *S. guineense* were encountered in all the assessed four forests with relatively good reproduction. *M. melanophleos* was found only in Bonga forest with good reproduction and poor recruitment. *B. antidysetrica* was found in all the four forests with relatively good reproduction in Boginda forest. *M. africana* was found only in Yayu forest. In general, the result on the density, frequency distribution and regeneration status of the nine medicinal plants in all the four forests showed that the natural recruitment process is not sufficient for the existence of these species and there should be some management intervention to maintain their genetic resources.

Introduction

Ethiopian forests are repositories and gene pools for several domesticated and wild important plants, wild animals and microbes. There are about 92 high forests in Ethiopia, 56 of which are from the Dry Evergreen Montane Forests, 30 from the Moist Montane Forests, 5 from the Transitional Dry-Moist Evergreen Montane Forests and 1 from the Lowland Semi-Evergreen Forests (Reusing, 1998; Zerihun, 1999; Edwards *et al.,* 1999). These forests are currently threatened by pressure from investors who are converting the Moist Montane Forests into other land use systems such as coffee and tea plantations. Large proportions of Bonga and Masha-Anderacha forests were cleared without any biodiversity assessment in the areas. The role of investment in economic development is undeniable but it should be done without harming the environment and should be accompanied by appropriate Environment Impact Assessment before and after intervention (Taye *et al*, 2002).

With the loss of forestland, many plant species are threatened and becoming extinct. One of the victims of such land use changes are medicinal plants although most Ethiopians depend on traditional medicine due to limitedness of health facilities. The major sources of traditional medicine are wild plant species found in the remnant forest areas of the country. The main objective of this study was to present the conservation status of highly valuable and commonly used woody medicinal plant species *Hagenia abyssinica, Prunus africana, Schefflera abyssinica, Croton macrostachyus, Myrsine africana, Myrsine melanophleos, Syzygium guineense, Allophylus abyssinicus* and *Brucea antidysetrica* in Boginda, Bonga, Masha-Anderacha and Yayu Southwest Moist Montane Forests of Ethiopia and to commend appropriate genetic conservation measures in the natural habitats (*in situ*) and outside the natural habitats (*ex situ*). Inventory of the woody plants of forests was carried out from December 1999 to June 2000. These species have various therapeutic values with different use and preparation methods (Annex 1).

Materials and mthods

Study area

Boginda and Bonga forests are found in Kefa Zone; Masha-Anderacha forest in Shaka Zone of Southern Nations, Nationalities and Peoples Region, and Yayu forest in Illubabor Zone of Oromya Region. area coverage is 7500 ha for Boginda, 161,424 ha for Bonga, 160,000 ha for Masha-Anderacha and 135,300 ha for Yayu forests (Taye *et al,* 2002). Mean temperature and rainfall patterns in each forest vary (Table 1).

Table 1. Mean temperatures, rainfall and traditional agro climatic zones of the four forests.

Forest	**Mean temperature (^{0}C)**			**Mean annual rainfall (mm)**	**Traditional agro-climatic zone**
	Minimum	**maximum**	**Mean**		
Boginda	9.75–12.13	25.26–29.08	18.5–20.4^{0}C	>1500	Wet Weinadega
Bonga	17.4–18.4	19.4–20.5	18.1–19.4	1710–1892	Wet Kolla to wet Dega
Masha-Anderacha	9.8–11.1	20–23.2	14.3–15	2215	Wet Kolla to wet Dega
Yayu	11.5–13.8	23.2–28.8	15–20	1800–2000	Wet Kolla to wet Weinadega

Source: Adapted from Woody Species Inventory Reports of Forest genetic Resources Conservation Project

Data collection

A systematic transect line sampling technique that involved quadrates of 10 X 50 m at every 50 m drop in altitude was employed to assess floristic composition and structural performance of the forests. Within each quadrate, two sub-quadrates each 2 X 20 m were laid at both ends of the main quadrate along the transect line to enumerate regeneration by species. The diameter and height of all tree and shrub species that were beyond 2.5 cm in diameter were measured for the 10 X 50m quadrates. Diameter at breast height (DBH) was measured over bark using a Caliper. Heights of all tree or shrub species were measured by Suunto clinometer and height was estimated where it was difficult to measure. Individuals with < 2.5 cm DBH and < 30 cm height were considered as seedlings while those with DBH < 2.5 cm and height between 30 cm and 2 m were recorded as saplings.

Geographic location of each quadrate and the beginning of each quadrate were determined using Garmin GPS 48. The altitude of each quadrate was recorded using an Alpin-el altimeter and the aspect (exposure) by using a compass.

Data analysis

The structural (density and frequency) analyses of the medicinal plants were summarized by Access Software. The following formulae were used to enumerate density and frequency

$$DA = \frac{DT}{S}$$

where *DA*= Density of all tree or shrub species
DT= Total number of stems of all tree or shrub species
S= Sample size per hectare

$$DI = \frac{Nts}{S}$$

where *DI*= Density of each tree or shrub
Nts= Total number of stems encountered for a given tree or shrub
S= Sample size (ha)

$$F = \frac{Nq}{Tq} \times 100$$

where ***F*** *= Frequency of individual species*
Nq *= Number of quadrates in which a species was recorded*
Tq *= Total number of quadrates*

Results and dscussion

Population structure, density, frequency and regeneration were used in the determination of the conservation status of each species.

Population structure

The species population structure is the stems per hectar coverage of individuals in a predetermined diameter class. Based on 5 cm intervals, nine diameter classes were formed: 1=2.6–7.5, 2=7.6–12.5, 3=12.6–17.5, 4=17.6–22.5, 5=22.6–27.5, 6=27.6–32.5, 7=32.6–37.5, 8=37.6–42.5, and 9=>42.5. Population structure analyses of the eight commonly known medicinal plants were done for all the forests in which they were encountered. The patterns of species population structure that emerge can be interpreted as an indication of variation in population dynamics in the forest (Tamrat, 1994).

H. abyssinica was encountered in Bonga forest. This species was missing in smaller diameter classes. It had no reproduction and had poor recruitment. The frequency pattern showed that individuals are frequent only in the highest diameter classes (Table 2) and they are very big and old individuals, which are no longer reproducing or regenerating. This indicates that regeneration of the species in the area is at high risk and needs special consideration to sustain the genetic material. The population structure of *S. abyssinica* in Bonga forest had J-shape distribution where the density was very low in the lowest diameter classes (Table 3), indicating the poor reproduction of the species in the area. In Boginda, Masha-Anderacha and

Yayu forests, the species was found with poor reproduction and recruitment, indicating that there should be genetic conservation activity in these forests to save the species. The structure of *C. macrostachyus* showed reverse J-shape distribution in the four forests (Table 4), indicating good reproduction but poor recruitment. The species was found with relatively good recruitment in Boginda and Maha-Anderacha forests. In many documents, it was indicated that this species is an indicator of forest disturbance and these forests might have been in serious exploitation in the past. *M. melanophleos* was encountered only in Bonga forest in 2375–3000 m altitudes. This species had inverted J-shape distribution pattern (Table 5), indicating the predominance of small size individuals. It had good regeneration but bad recruitment and if the appropriate management is applied, the species can recruit itself in the future.

The structure of *S. guineense* in Bonga forest showed a U-shape pattern; per hectare coverage of stems was high in the lowest and highest DBH classes but very low in the intermediate classes (Table 6). This pattern indicates selective cutting and removal of medium size individuals of this species. In Boginda forest, the species had an inverted J-shape pattern whereas, in Masha-Anderacha, it had J-shape. This means, the species was in good reproduction but poor recruitment in Boginda forest and had poor reproduction and poor recruitment in Masha-Anderacha that special attention should be given for its genetic conservation. In Yayu forest, *S. guineense* was encountered in the first, second and ninth diameter classes with very low stems per hectare coverage. The result showed that the provenance of this species in this area is at high risk of extinction.

A. abyssinicus had a reverse J-shape (good reproduction and poor recruitment) (Table 7) in Bonga and Boginda forests and poor reproduction and poor recruitment in Masha-Anderacha and Yayu forests. *B. antidysentrica* was encountered only in first diameter class in Bonga forest and in the first and second diameter classes in Boginda forest (Table 8). In Masha-Anderacha and Yayu forests, it had low stems per hectare. Even though the species was not expected to reach bigger diameter classes, the provenance in Masha-Anderacha and Yayu forests need immediate genetic conservation effort. The structure of *P. africana* showed a U-shape pattern in all the study areas (Table 9), indicating selective cutting and removal of medium size individuals, probably for timber production. It was noted that there is serious genetic erosion of this species in all the study areas. The population structure of *M. africana* was not assessed because of its shrubby nature.

Table 2. Population structure of *H.abyssinica* in Bonga forest

	Diameter class (cm)								
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bonga	0			0.6		2.7	0.6	1.5	4.5

Table 3. Population structure of *S.abyssinica* in Bonga, Boginda, Masha-Anderacha and Yayu

Site	Diameter class (cm)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bonga	0.3	0.3			0.3	0.3	0.6	0.6	5.07
Boginda	1.38		0.69		2.76				2.76
Masha-anderacha	0	0.21		0.21	0.21				0.83
Yayu	0.55	0.55							1.1

Table 4. Population structure of *C. macrostachyus* in Bonga, Boginda, Masha-Anderacha and Yayu

Sites	Diameter class (cm)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bonga	2.99	1.19	1.49	1.49	0.9	1.19	0.6		1.19

Boginda	12.41	5.52	2.76	1.38	3.45	3.45	0.69	2.76	2.76
Masha-anderacha	3.12	0.83	1.88	0.83	0.42	0.83	0.42	0.63	2.29
Yayu	14.25	10.96	6.85	4.66	2.47	1.92	1.37	0.82	0.27

Table 5. Population structure of *M.melanophleos* in Bonga forest

Site	**Diameter class (cm)**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bonga	12.54	10.45	1.79	4.18	3.88	2.69	1.49	0.30	1.79

Table 6. Population structure of *S. guineense* in Bonga, Boginda, Masha-Anderacha and Yayu

Site	**Diameter class (cm)**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Bonga	30.45	4.48	2.09	1.19	2.69	3.28	1.79	2.69	11.34
Boginda	15.86	5.52	2.07	1.38	3.45	6.21	3.45	2.07	2.76
Masha-anderacha	3.33	4.17	3.96	0.83	1.46	1.25	2.08	1.67	13.96
Yayu	1.1	1.1							0.55

Table 7. Population structure of *A. abyssinicus* in Bonga, Boginda, Masha-Anderacha and Yayu

Site	Diameter class (cm)								
	1	2	3	4	5	6	7	8	9
Bonga	10.75	7.16	0.6	0.3	0.6	1.19			0.9
Boginda-anderacha	13.1	6.9	3.45	2.07	2.07	2.76	0.69		
Masha	3.96	2.50	1.25	0.63	0.42	0.21	0.42	0.63	1.46
Yayu	1.92	1.37	0.27	0.55	0.55		0.27		

Table 8. Population structure of *B.antidysentrica* in Bonga, Boginda, Masha-Anderacha and Yayu

Site	Diameter class (cm)								
	1	2	3	4	5	6	7	8	9
Bonga	2.69								
Boginda-anderacha	13.79	3.45							
Masha	0.83	0.62	0.21						
Yayu	0.55		0.27						

Table 9. Population structure of *P. africana* in Bonga, Boginda, Masha-Anderacha and Yayu

Site	Diameter class (cm)								
	1	2	3	4	5	6	7	8	9
Bonga	7.16	0.3		0.3				0.9	0.9
Boginda-anderacha	2.07	0.69						0.69	2.76
Masha	1.67	0.21	0.21			0.21		0.21	1.87
Yayu	11.78	2.74	1.1	0.55				0.27	2.19

Density and frequency

The woody species densities of all the species encountered were 1232 stems per hectare in Bonga, 1565 stems per hectare in Boginda, 1712 stems per hectare in Masha-Anderacha and 2087 stems per hectare in Yayu forests (Taye *et al,* 2002). The contribution of the selected medicinal plants in these forests was very minimal (Table 10).

A. abyssinicus, B. antidysenterica and *C. macrostachyus* had high densities and frequency distribution in Bonga forest. This may indicate that Bonga forest is a suitable and appropriate site for the *in-situ* conservation of these species. *A. abyssinicus* in Boginda forest was found in almost 50% of all the quadrates laid for woody plant inventory in the area.

Table 10. Density and frequency distribution of medicinal plants in four forests

Species	Boginda		Bonga		Masha-Anderacha		Yayu	
	Density	Frequency	Density	Frequency	Density	Frequency	Density	Frequency
Allophylus abyssinicus	31.03	48.28	21.49	35.82	11.46	21.88	4.93	12.33
Brucea antidysenterica	17.24	17.24	2.69	8.96	1.67	5.21	0.82	4.11
Croton macrostachyus	35.17	51.72	11.04	19.40	11.25	25.00	43.56	61.64
Hagenia abyssinica	0.00	0.00	9.85	14.93	0.00	0.00	0.00	0.00
Myrsine africana	0.00	0.00	0.00	0.00	0.00	0.00	5.48	4.11
Myrsine melanophloeos	0.00	0.00	39.10	16.42	0.00	0.00	0.00	0.00
Prunus africana	6.21	13.79	9.55	14.93	4.38	6.25	18.63	13.70
Schefflera abyssinica	7.59	17.24	7.46	17.91	1.46	6.25	2.19	9.59
Syzygium guineense	42.76	31.03	60.00	35.82	32.71	38.54	2.74	2.74

Regeneration status

Relative abundance, distribution and growth of seedlings, saplings or both in the understorey of forests are important in determining species sustainability. However, abundance of seedlings, saplings or both is by no means an indicator of the definitive establishment of young individuals. This is because, for many indigenous tree or shrub species, the seedlings, saplings or both are often not easy to establish since the microhabitat in which regeneration occurs might not be a suitable environment for establishment or they could be easily browsed by animals. But there is a general assumption that species that have good seedling and sapling recruitment have more chance of continuity than those which have bad recruitment. Therefore, evaluating the regeneration status of each species is decisive to know the conservation status of the species in the forest.

Assessment of regeneration of the target species in Bonga, Boginda, Masha-Anderacha and Yayu forests revealed that soft-stemmed and short-lived shrub and liana species such as *Dracaena afromontana, Dracaena steudneri* and *Landolphia buchananii* dominate the area (Taye *et al,* 2002), indicating forest disturbance (Grubb *et. al.,* 1963). Forest disturbance can inevitably cause irreversible genetic erosion, which may result in loss of the species.

Total regeneration densities were 2119 seedlings and 3537 saplings per hectare in Bonga, 5888 seedlings and 7319 saplings per hectare in Boginda, 2277 seedlings and 2719 saplings per hectare in Masha-Anderacha, and 2986 seedlings and 3832 saplings per hectare in Yayu forests (Taye *et al,* 2002). In Boginda forest A. abyssinicus had the highest seedling density (193.45) and the highest total density (103.55) followed by *B.antidysenterica* which had seedling density of 68.97 and total density of 129.31 (Table 11). *B. antidysenterica* also had high sapling density of 60.34. In Bonga forest, *M.melanophleous* had the highest seedling density of 134.33, sapling density of 201.49 and total density of 335.82. In Masha-Anderacha forest, *P.africana* had the highest seedling density of 41.67, sapling density of 20.83 and total density of 62.50. *P.africana* also had the highest densities in Yayu forest. The result suggests that the contribution of the nine medicinal plants to overall regeneration density in all forests is very low.

S. abyssinica was recorded as matured stand in all the study sites but it was totally missing in the regeneration assessment. This might suggest that regeneration from seedlings or saplings would be unlikely once matured individuals disappeared and this species is either under threat of local extinction or may prefer coppices or sprouts as survival strategy.

Seedling and sapling density of *H. abyssinica* was also found to be very low. In general, the regeneration of the medicinal plants in the four forests was very low, indicating the need for management intervention to the continuity of these species.

Table 11. Seedling and sapling densities of medicinal plants in four forests

Species name	Boginda forest			Bonga forest			Masha-Anderacha forest			Yayu forest		
	Seedling	Sapling	Total	Seedling	Sapling	Total	Seedling	Sapling	Total	Seedling	Sapling	Total
Hagenia abyssinica	0.00	0.00	0.00	7.46	3.73	11.19	0.00	0.00	0.00	0.00	0.00	0.00
Schefflera abyssinica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croton macrostachyus	0.00	51.72	51.72	7.46	0.00	7.46	15.63	5.21	20.84	6.85	3.42	10.27
Myrsine africana	0.00	0.00	0.00	0.00	14.93	14.93	0.00	0.00	0.00	0.00	0.00	0.00
Myrsine melanophleos	0.00	0.00	0.00	134.33	201.49	335.82	0.00	0.00	0.00	0.00	0.00	0.00
Prunus africana	0.00	0.00	0.00	70.9	119.4	190.3	41.67	20.83	62.50	20.55	17.12	37.67
Allophylus abyssinicus	103.45	43.10	146.55	67.16	70.9	138.06	28.65	2.60	31.25	0.00	6.85	6.85
Brucea antidysenterica	68.97	60.34	129.31	18.66	18.66	37.31	5.21	7.81	13.02	0.00	0.00	0.00
Syzygium guineense	17.24	17.24	34.48	22.39	44.78	67.16	33.85	0.00	33.85	0.00	0.00	0.00

Conclusion and recommendation

Medicinal plant species that are a source of traditional medicine, on which most Ethiopians depend, are disappearing due to the accelerating deforestation in the country. The results of this study, conducted on the conservation status of nine medicinal plant species in four moist montane forests in Southwest Ethiopia, revealed that all of them are at high risk of genetic erosion. This may indicate that these species (and perhaps many others which have not yet been assessed for their potential medicinal and other uses) may disappear unless necessary genetic conservation measures are taken. Therefore, appropriate genetic conservation measures have to be taken to save the genetic resources of these species.

There are two commonly known strategies for the conservation of forest plant genetic resources: *in situ and ex situ* conservation. *In situ* conservation refers to the conservation of forest genetic resources within the natural ecosystem in which they occur. *Ex situ* conservation implies the conservation of reproductive material in different environments outside its natural site of occurrence. The *in situ* conservation can be realized using different techniques and the most widely employed *in situ* conservation measures are conservation of natural stands, natural regeneration and seeding and planting *in situ.* Also the *ex situ* conservation can be realized using different implementation techniques and the most appropriate for Ethiopian condition are planting *ex situ* and storage of seed.

For actual implementation of genetic conservation measures of medicinal plants, ecological demands and breeding systems of the species have to be known. However, at this time, there is limited information available to recommend the appropriate conservation measures and there should be further research on this aspect. Even though there is limited information on the ecological requirements and mating systems of the species, the following recommendations (Table 12) were drawn based on the existing information

Table 12. Recommended genetic conservation measures for the medicinal plant species

Species name	Conservation measure	
	In-situ	***Ex-situ***
Allophylus abyssinicus	planting	planting
Brucea antidysenterica	planting	planting storage of seed
Croton macrostachyus	natural regeneration planting	planting storage of seed
Hagenia abyssinica	natural regeneration planting	planting storage of seed
Myrsine africana	planting	planting storage of seed
Myrsine melanophloeos	natural regeneration planting	planting
Prunus africana	natural regeneration planting	planting
Schefflera abyssinica	planting	planting
Syzygium guineense	natural regeneration planting	planting

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Annex

Annex 1. The use and method of preparation of medicinal plants

Species	Parts used	Method of preparation and medical uses
Hagenia abyssinica	Root	Roots are cooked with meat and the soup is drunk for treating many illnesses
	Female inflorescence	Dried and pounded female inflorescence is used as anti- intestinal worms, especially tapeworm.
Prunus africana	Bark	The bark is pounded into paste and added to cold water, and the liquid drunk as a remedy for diarrhea and stomachache.
	Leave	Fresh leaves are crushed and inhaled to reduce fever and leaf infusion drunk to improve appetite.
	Bark	The liquid extraction from the bark is used in the treatment of benign prostatic hyperplasia and prostate gland hypertrophy. Pounded bark mixed with water produces a red color solution used as a remedy for stomachache and the bark extract is also reported to be used as purgative for cattle.
Schefflera abyssinica	Gum	Gum obtained from the tree is a cure for coughs and lung problems, especially bronchitis.
Croton macrostachyus	Leaves	Leaves are boiled and the decoction is drunk for treating coughs. Juice from fresh leaf is applied on fresh wound to hasten blood clotting.
	Bark and root	Barks peeled from the stems and roots are boiled in water and newly born babies bathed in the mixture as a remedy against skin rashes. The root decoction is used as an anthelmentic for tapeworm and as a purgative. Juice from boiled root is drunk for treating malaria and venereal diseases.
Myrsine africana	Fruit	The fruits are used to remove roundworm and tapeworm and as a remedy for chest pains and stiff joints. To treat worms, 2–3 handfuls of ripe fruits are eaten. For chest pain and stiff joints, ripe fruits are ground into fine powder. A spoonful of this powder is taken either in milk or cold water.
Myrsine melanophleos	Fruit	Used as an anthelmentic for tape worm when 3–5 berries are eaten. An infusion of ground berries is mixed with milk and drunk as a purgative and anthelmentic.
Syzygium guineense	Seed	The seeds pounded together with finger millet are cooked and drunk as a medicated gruel to remove intestinal worms.
Allophylus abyssinica	Root	Roots ground and mixed with a little salt and lemon water are eaten in small quantity for treating coughs and rheumatism. Roots crushed and mixed with salt are also used against ringworm.
Brucea antidysetrica	Leaf	Powdered leaves mixed with butter are used against dermal diseases and wound. Leaves and roots are cooked with meat against stomachache, indigestion and as a remedy for asthma.
	Root	Boiled root decoction is used for abdominal pain and dysentery.

***Source**:* Getachew and Shiferaw (2003) and Fichtl and Admasu (1994)

Non-wood Forest Products: Potentials and Constraints in Bale, Southeast Ethiopia

Motuma Didita[1] and Abebe Yadessa[2]
[1]Sinana Agricultural Research Center, P.O. Box 208, Bale-Robe, Ethiopia, E-mail: motumadidita@yahoo.com
[2]Ethiopian Agricultural Research Organization, Forestry Research Center, P.O. Box 30708, Addis Ababa, Ethiopia, E-mail: abebeyadessa@yahoo.com.

Summary

Forests in Bale area constitute valuable resources other than timber. Mid and high altitude areas of Bale are important sources of honey, coffee, bamboo, medicinal plants and wild spices. Lowland areas are good sources of extractives (incense and gum myrrh), honey, medicinal plants and both cultivated and wild fruits. The contribution of these non-wood forest products to food security is significant and seems a promising option for improving rural livelihoods in Bale. However, not all non-wood forest products are well utilized to their full potential mainly due to inaccessibility of the resources, lack of market, and poor infrastructure. So far, little attention has been given to non-wood forest products despite their potential as domestic use and export commodities. This trend should be changed in the light of the current Market-oriented Agricultural Development Strategy of the country and research should focus on this area in the future. The aim of this paper was thus to give an account of the major non-wood forest products found in Bale, Southeast Ethiopia and assess their potential and constraints in contributing towards improving the livelihood of the farming communities in the area and to indicate future research needs. The paper is based on observations made during field tours and on review of literature. It highlights the major non-wood forest products: extractives (incense and gum myrrh), honey, wild spices (*Thymus* and *Ocicum* species), forest coffee, wild fruits, traditional medicines, bamboos, eco-tourism, etc. obtained from forests in Bale.

Introduction

Forests shelter many valuable NTFPs resources in addition to timber. In many places, NWFPs have played significant roles in providing food, medicine and household items since long time. They, thus, can have the crucial advantages of familiarity and local value (Pol, 2002). Rural households are often dependent on forest products for food, fodder, fuel, fibre, fertilizer, gums, resins and tannin. Thus, in recent years, there has been increasing interest in forests as a source of local rural employment and income, particularly through non-farm activities. This interest has been reinforced by the fact that utilising NWFPs causes less ecological destruction than does harvesting timber, and is therefore a sounder bases for sustainable forest management (FAO, 1989; Leykun, 2001; Pol, 2002).
Income earned from forest-based activities like NWFPs contributes to food security in many ways like the availability of cash for food purchase, especially during hardship periods. Therefore, the concept of diversification and its incorporation into the food security programs

have provided great scope for trees and tree-related systems to be considered as an asset to fight food insecurity and poverty among the local communities.

This paper attempted to give an account of the major non-wood forest products found in Bale Zone of Southeast Ethiopia (Figure 1), and assess their potentials and constraints in contributing towards improving the livelihood of the farming community in the area. It is based on observations made during field tours and on review of literature.

Bale is one of the largest zones in Oromya Regional State extending 5°22'– 8°08' N and 38°41'– 40°44' E. Robe is the Zonal capital, 460 km Southeast of Addis Ababa. It has diversified landforms, agro-climatic zones, and soil and vegetation types. About 30 % of the Zone is covered with forests. Wheat, barely, maize, teff, sorghum, horse beans and field peas are the major crops grown in the Zone, where also enset, coffee and chat are grown. Bale is endowed with numerous perennial and seasonal rivers and springs.

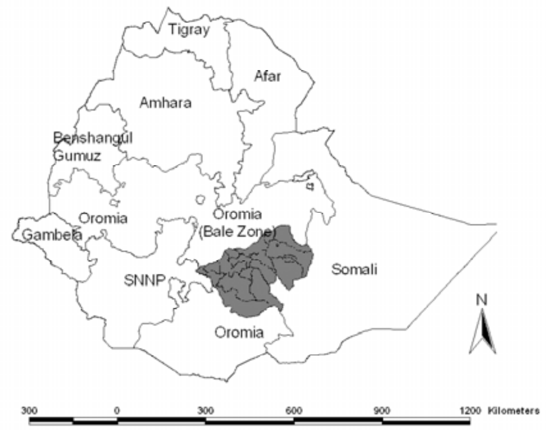

Figure 1. Location of Bale Zone

Non-wood forest products

Extractives (frankincense and gum myrrh)

Frankincense and gum myrrh are resinous plant exudates obtained from certain species of the tropical genera Boswelia and Commiphora, which belong to the family Bureseraceae (Mulugeta and Demel, 2003). In lowland areas of Bale including Mada Walabu, Rayitu, Goro and Gindhir districts, there are tree and shrub species with potential for tapping of incense and gum myrrh. The major species include *Boswelia microphyla*, *Commiphora myrrh* and *Commiphora ogadensis*. The products are harvested from woodlands, bushlands or shrublands and sold at local markets, especially in Rayitu, Mada Walabu and Gindhir districts. The extreme lowlands of Bale bordering Borana, Somalia and Harari are potential ground for extraction of incense (frankincense) and gum myrrh (Paulos *et al*, 1999; Motuma, 2004). Today, Ethiopia and Somalia are the major producers and exporters of these products in the world market (Mulugeta and Demel, 2003). Despite the significant contribution of incense and gum myrrh for improving the livelihood of the local community, the national market and for export, deforestation, market inaccessibility and poor tapping methods are damaging the plant and threatening the sustainable utilization of the products in the Zone.

Honey

There is high floral and faunal diversity in Bale, ranging from Acacia-Commiphora woodland to the Afro-alpine ecosystem. High floral diversity is one of the opportunities for honey production and it has been an encouraging natural endowment for the long-standing traditional bee-keeping activity, which it is one of the sources of livelihood for the local communities and developed over years to meet household honey consumption or sale requirements. Milk and honey were the stable foods for ancestors of people in Bale Zone as elders reported (B&M Development consultants, 2003a). The most widely used tree and shrub species for bee-keeping in lowland areas of Bale include *Acacia mellifera, A bussei, A. sieberiana, Croton macrostachyus*, *Cordia africana*, *Felicium decipiens* and *Commiphora ogadensi*. The types of tree and shrub species visited by bees determine the quality of honey produced, and this can help distinguish highland honey from lowland honey.

Results from the survey conducted in six sample peasant associations (PAs) in the Zone revealed that each household owns on average seven beehives and harvests about 6.15 kg of honey per beehive. Average honey produced per household per year was about 43 kg, of which about 18 kg was sold (Table 1). Therefore, honey production significantly contributes to improving household income in this area. Honey is harvested one to two times a year in the highlands and two to three times in the lowlands (B&M Development Consultants, 2003b; Paulos *et al.,* 1999).

However, honey production is declining because of the decline in bee population which is affected by tobacco production and the use of herbicides and other agro-chemicals in the area. The disappearance of bee forage as a result of deforestation is another in the lowlands.

Table 1. Traditional beehives owned and honey yield in six PAs in and around Bale Mountains National Park (BMNP) and Mena-Angetu National Forest Priority Area (MA-NFPA)

PA	Beehives owned (no)	Average harvest (kg per beehive)	Total production (kg per year)	% of households who owned beehives
Rira	23	10.57	243.1	3.6
Kumbi	10	5.40	54.0	14.9
Shawe	4	5.27	21.1	73.3
Hawo	12	4.06	48.7	45.0
Hora Soba	1	7.65	7.7	48.2
Gojera	0	0	0	62.3
Sample mean	7	6.15	43.1	41.2

Source: B&M Development Consultants, 2003a &b

Wild spices

In addition to the major spice crops cultivated throughout the lowlands of Bale, there are some wild spices both in lowlands and highlands with more coverage in highlands including the peaks of Bale Mountains National Park (BMNP). *Thymus* and *Ocicum* species are among the commonest wild spices growing in Bale.

T. cerulatus, which has similar species locally called *'tosign'*, is one of the dominant species of wild spices growing throughout the BMNP with more abundance around the Head Quarter of BMNP. It is harvested mainly as a main source of cash in high altitudes. This particular species is usually used for flavoring food items and for traditional medicine. Its dried leaves are sold at local and national markets.

Ocicum spp. such as *O. suave* (locally called 'urgo'), *O. lamifolium* (locally called 'kusaye') and *O. basilium* (locally called 'kefo') grow throughout Mena-Angetu and Mada Walabu districts, mainly in forest, grazing and crop lands. It was observed that the species diversity of such spices is complex in morphology, flower, aroma and other characteristics (Derege, unpublished). The species are used for several purposes including medicinal values, traditional food processing (butter, oil) and as botanicals. There are *Ocicum* spp. known for their botanical uses for killing insect pests in local residences. Flowers, stems and leaves are usually used to sweep the roofs and floors of houses. The aroma defused from these plant parts is highly repellent to the insect pests. These extractives can also be used in clearing unwanted odours away from homes.

Despite their multiple uses, diversity and abundance of these spice crops are being threatened due to the underlying problems of deforestation and over grazing.

Forest coffee

The Bale Mountains are endowed with rich flora and fauna of indigenous species owing to their biophysical setting and land feature. The Harenna Forest, covering the southern slopes of the mountains, is known for its value as source of timber, NTFPs and for maintaining important watershed and habitat for biodiversity conservation. The forest is home for wild Arabica coffee populations (Mesfin and Lisanework, 1996). Wild coffee was harvested from Harenna forest starting from 1977 (Yonas, unpublished). Formerly, the market was limited and only few farmers realized the economic opportunity of coffee. With increasing immigrants from different parts of the country, coffee production began to be expanded and gained attention among settlers as a result of the robust coffee prices of the 1990s, whereby it finally attained a market boom in recent years. Thus, farmers began to engage in coffee planting as an adaptive strategy that supports survival in times of crop failure and to generate cash income. It has been one of the most important cash crops that play a great role in the life of the local communities living in and around the Harenna forest.

Currently, there is a massive clearing of the forest to open way for coffee plantations, with the current total area under coffee plantation estimated at 12,980 ha (B & M Development Consultants, 2003b). Coffee production from the Harenna forest was 134 t in year 1995, 100 t in 1996, 1974 t in 1997, 1058 t in 1998, 1533 tones in 1999, and 3965 tones in year 2003 (B & M Development Consultants, 2003b). Wild coffee is considered as one of the most important NWFPs that can be harvested without seriously harming the natural forest. However, the present mode of coffee platting is negatively affecting both the coffee diversity and the natural forest. The current outbreak of die-back of coffee trees as a result of coffee wilt disease is a notable example of this event.

Wild fruits

Food from forests and other tree systems constitutes an important portion of food supply in Bale. In many villages and small towns, the contribution of forests and trees to food supply is essential for food security, as it provides a number of important dietary elements that the normal agricultural produce doesn't adequately provide (Pol, 2002). There are both cultivated and wild fruits in most lowland districts of Bale. Farmers grow major tropical and sub-tropical fruits such as *Mangifera indica*, banana, *Carica papaya*, *Persia americana*, *Citrus lemon*, *Citrus sinensis* and minor fruits. They are widely grown in Mena-Angetu, Mada-Walabu, Gindhir, Agarfa and Gassera districts. In addition, various wild fruits are widely harvested for local consumption. The major ones include *Tamarindus indica*, *Grewia bicolar* and *Opuntia ficus-indica*.

T.indica was found growing in Wada-Walabu, Mena-Angetu and Rayitu districts of Bale. Tamarind is popular for its fruits and juice called 'tamarin'. In addition to its local consumption in the area (in its fruits), it is supplied to markets in the nearby Somalia Region. Nationally, *T. indica* has a wide growing range in Ethiopia (0–1700 m) (Gebre Kidan, 2003).

Nevertheless, it is not regarded as a very important resource and hence, the stock is dwindling owing to the uncontrolled cutting of trees for local construction and other minor purposes. Usually, the farming communities in most parts of the country value *T. indica* only as a source of dry season fodder. This trend needs to be changed through promotion of domestication of the species and processing and diversifying its products for local, national, and international markets.

O. ficus-indica is one of the perennial crops with edible fruits growing in Bale Zone used as a hunger-breaking plant for humans and animals. It is an exotic species introduced to Dire Shekana Hussen from where it was brought to the highland areas. *O. ficus-indica* is now widely spread in Agarfa, Sinana-Dinsho, Gassera and Gindhir districts where it was initially introduced as a live fence, but now its fruits are consumed by the communities. It also serves as a source of income and as supplemental feed for animals. Currently, its production is spreading over farmlands owing to its ease of propagation and adaptation to less fertile and dryland areas.

Farmers witness that *O. ficus-indica* improves milk yield of cows during lactation and the fruit cover is used as feed in animal fattening. The species is also used to treat venereal diseases like syphilis, urinary tract infection and gastritis. It is a source of income for households particularly women and children who have no control over the income from livestock and crops. *O. ficus-indica* can give marketable products 3–4 years after planting (Assefa *et al*, unpublished) and, it is possible to harvest fruits for about 4–5 months. A single stem can give 10–50 fruits depending on soil and weather conditions. It was estimated that an average household could gain 240 birr (about US $ 30) additional net income per month for five months in a year from the sale of *O. ficus-indica* fruits.

Despite the multiple merits of *O. ficus-indica,* there are a lot of threats for the plant to get its way into commercial crop. These include lack of market outlet, lack of processing technologies for diversification of its products and poor management system.

Medicinal plants

The world Health Organization (WHO) estimated that 80 % of the population of developing countries rely on traditional medicine, mostly herbal drugs, for their primary health care needs (Mulatu *et al*, 2001). In Ethiopia, the importance of traditional medicine in general and medicinal plants in particular is well recognized and it is officially acknowledged by government authorities that as much as 75–80 % of the population depend on traditional medicine. Reports indicate that more than 35 000 plant species are being used around the world for medicinal purposes. Forests, particularly tropical forests, represent vast resources of medicinal plants most of which are untapped. Besides their uses as wood sources and for environmental protection, more than 60 % of all medicinal plant species are trees (Gebrekidan, 2003). Plant diversity remains indispensably important for human well-being in providing a significant number of traditional and modern remedies required in health care. However, it needs great concern to realize that the annual extinction rate of plant species is estimated to be about 3000. This could imply that loss of these plants in traditional medicine in developing countries and the loss of potential drugs against incurable conditions such as cancer, influenza and AIDS (Mulatu *et al*, 2001).

Mulatu *et al.* (2001) indicated that there are a lot of medicinal plants in the area belonging to herbs, climbers, shrubs and trees in habit. They are found in different ecosystems including forestland, woodland, grazing land, home garden and farmland, with more frequency in forestland and woodland ecosystems. Different parts of the plants are used for treating different diseases (Table 2).

Table 2. Major species used as herbal medicine in and around the Bale Mountains National Park

Species	Habit	Part used	Medicinal use

Warburgia ugadensis	Tree	Bark	Malaria
Harrisonia abyssinica	Herb	Root	Hepatitis
Silene microselen	Herb	Root	Evil eye
Carissa edulis	Shrub	Root	Evil eye, epilepsy
Hagenia abyssinica	Tree	Flower	Tape worm
Withania somnifera	Shrub	Root	Evil eye
Croton macrostachyus	Tree	Root	Gonorrhea
Olea europea sub.spp. cuspidate	Tree	Bark	Renal problems
Echinops kebericho	Herb	Root	Abdominal problem
Aloe spps.	Herb	Leaf	Hepatitis
Clematis longicauda	Climber	Whole plant	Diarrhea
Rumex abyssinica	Herb	Root	Diarrhea
Rumex nepalensis	Herb	Root	Hepatitis
Jathropa curcas	Shrub	Fruit	Evil eye, abdominal problem

Source: Mulatu *et al.,* 2001

Assefa *et al.* (unpublished) indicated that there are various plant species used for medicinal purposes. These species include *Commiphora ogadensis*, *Commiphora myrrh*, *Boswelia microphyla*, *Aschynomene elaphroxylon*, *Acacia mellifera* and *Tamaridus indica*. Although there are numerous commonly used medicinal plants along with the traditional medicinal skills, the present rate of destructive harvesting and the ever increasing demand for these herbal drugs is likely to threaten the diversity of the species and their sustainable utilization.

Bamboo (*Arundinaria alpina* K. Schum.)

Bamboos are fast growing and high yielding perennial woody grasses (Kassahun, 1999; Pol, 2002) which belong to the Poaceae (Gramineae) family and Bambuseae subfamily. Bamboo has considerable potential for socio-economic development and environmental protection in many parts of Ethiopia. On the southern slopes of the Bale Mountains Massif, there is dense stand of highland bamboo, *A. alpina*. This species is widely used in Bale mainly for fencing residential houses, construction, and for making household furniture. It is commonly used for household consumption and as a source of income.

Eco-tourism

Eco-tourism is one of the latest sources of income in the forestry sector (Mukiibi, 2001). Besides the role of forests in fulfilling wood requirements for various purposes and environmental protection, they serve as natural tourist attraction—contributing a lot in revenue generation. The BMNP and MA-NFPA are excellent sites that have great potential to attract many tourists because of their exceptional scenic beauties including the landscape, the unique flora and fauna as well as the endemism they are endowed with. The BMWB site has generated average annual revenue of 69966 Birr from local and foreign tourists from 1993 to 2001 (Table 3).

Table 3. Revenue generated from tourists by the BMNP, 1993–2001

Year	Visitors' category and amount of revenue generated (Birr)		
	Ethiopian visitors	Foreign visitors	Total revenue

1993	109	565	37301.00
1994	207	623	49726.00
1995	47	464	31659.00
1996	130	806	57891.00
1997	195	1011	67418.00
1998	164	880	58919.00
1999	203	751	62807.00
2000	207	797	57411.00
2001	151	787	206565.00
Average	**157**	**743**	**69966.00**

Source: B& M Development Consultants, 2003c.

On average, 743 foreigners and 157 Ethiopians visited the Park every year during 1993–2001. Foreigners constituted about 82.6 % of the visitors while Ethiopians were only about 17.4 %. The flow of tourists and the revenue generated from tourist visits was generally low because of the poor level of infrastructure and facilities. This area needs attention for the future to exploit the existing potential.

Conclusion and recommendation

This study demonstrated the contribution of non-wood forest products to improving the livelihoods of the rural community in Ethiopia, as it was reported by several studies (Pol, 2002; Leykun, 2001; Kassahun, 1999). The various ecosystems found in Bale, including the Bale Mountains, are endowed with rich floral and faunal diversity. As a result, they are home for different non-wood forest products apart from their significance as a source of timber, and maintenance of important watersheds and habitat for biodiversity conservation. The mid and high altitude areas are sources of honey, coffee, bamboo, medicinal plants and wild spices while lowland forests are important sources of extractives (incense and gum myrrh), honey, medicinal plants and both cultivated and wild fruits. The contribution of the products for household consumption and cash generation highly varies from area to area depending on access to the resources and market, infrastructure and socio-economic status of the community. It is probably due mainly to this that the potential of the resources is untapped. Farmers are less aware about the multiple uses of non-wood forest products. Moreover, little attention is given to non-wood forest products despite their potential as export commodities that can supplement or replace coffee for the country. This situation should, however, be changed in the light of the current development strategy of the country.

It is suggested that detailed surveys should be made to identify the major species and the potential supply of their products on sustainable basis. Research and development works should focus on the domestication, propagation and harvesting techniques of priority species with due consideration given to local experience. It is necessary to establish *in situ* and *ex situ* conservation strategies for priority species to protect species loss and genetic erosion. Diversification of uses of the products by processing technologies in order to use the untapped potential resources and promotion of local, national and international markets for the products are important.

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Availability, Uses and Trends of Non-Timber Forest Products in Mendi Area, West Wellega

Abebe Yadessa[1], Teshome Takele[2], Mohammed Adilo[1] and Mesfin Haile[3]
[1]Ethiopian Agricultural Research Organization, Forestry Research Center, P.O. Box 30708, Addis, Ababa, Ethiopia.
[2]Bako Agricultural Research Center, P.O. Box 03, Bako, Ethiopia.
[3]Holetta Agricultural Research Center, P.O. Box, 2003, Addis Ababa, Ethiopia.

Summary

Non-timber forest products (NTFPs) directly or indirectly contribute to food security. People in Mendi area of Manasibu Wereda, West Wellega Zone recognize the value of NTFPs they get from natural forests and farm trees. Major NTFPs in the area include; wild fruits, bush meat, fodder, forest honey, traditional medicines, firewood, farm implements, household utensils and coffee shade. However, the availability of these products is continually decreasing as a result of increasing deforestation and termite problem in the area. There is a distinct seasonality of availability of wild fruits, as they are increasingly available during the dry season but scarce in other seasons. Dwindling availability is the main constraint in the use of NTFPs in the area reducing their potential benefit to the people. The objective of this study was to assess the availability, and trends of use of NTFPs and their contribution to the livelihoods of the rural people in Mendi area. Hence, research projects for domestication of important wild indigenous trees preferred by the local people are very essential. Moreover, when selecting these species, their management and marketing should be considered.

Introduction

Livelihoods of the majority of rural people in Africa depend on forests and woodlands as sources of agricultural land, firewood and charcoal, as well Non-timber forest products (NTFPs) such as food, fodder, fiber and medicines. In many developing countries like Ethiopia, rural people have had relatively unrestricted access to forests. The poor have, thus, been able to exploit forests for food, fuel wood and marketable products. Thus, forests and trees have indispensable role in improving food security. Even though forest products are rarely consumed as staple foods of choice, they play an important role when supply of cultivated food crops is scarce either at the end of the agricultural season or in times of famine (FAO, 1989; Pol, 2002). Forests offer a variety of products for household consumption and sale, which can be broadly categorized as timber products and non-timber products (NTFPs).

NTFPs include edible plant products (food, oils, spices, fodder, and others), edible animal products (terrestrial animals, animal products, fish and aquatic invertebrates, other edible animal products), non-edible plant products (rattan, bamboo, sustainably produced wood, ornamental plants, chemical components, other non-edible plant products), non-edible animal products (insect products, wildlife products and live animals, other non-edible animal products) and medicinal products. A forest is a natural ecosystem in which trees are a significant component; however, forest products are derived not only from trees, but also from all plants, fungi and animals for which the forest ecosystem provides habitat (ProFound, electronic source).

NTFPs play significant roles in subsistence, providing food, medicine and local value. They also have cultural values. The contribution of NTFPs to food security is significant in Ethiopia (Pol, 2002), though it is not well documented and not researched for improvement. This calls for undertaking ethnobotanical inventories of indigenous knowledge of plants and their environment to identify species for domestication and commercialization. This study was thus conducted to assess the availability, importance and trends in use of NTFPs and their contribution to the livelihoods of the rural poor in Mendi, Manasibu Wereda, West Wellega Zone, Ethiopia.

Methods

The study area

Mendi is located in Manasibu Wereda, West Wellega Zone of Oromia Region, Ethiopia. It is at about 150 km away from Gimbi town, capital of the Zone and about 590 from Addis Ababa. Gimbi lies in SH_2 sub-agroecology. Manasibu District is bordered by Benishangul Gumuz Region, and Begi, Jarso and Nadjo Weredas. The Wereda has an area of about 2383 km^2 and it is characterized by plateaus, hills, plains and valleys. It lies between 500 and 1740 m and has lowland (68 %) and mid-altitude (32 %) areas. Forest cover of the area is about 4 % of the total area of the Wereda (OBPED, 2000).

Site selection

Three sites were selected based on differences in field type, namely: Qilxu Karra (Coffee-based system), Harawwe Dambi (maize-based system) and Xanqi (tef-based system). At Qilxu Karra, coffee (*Coffea arabica* L.) is the most important crop; at Harawwe Dambi cereals, especially maize (*Zea mays* L.), are most important; and at Xanqi tef (*Eragrotis tef)* is most important. Termite problem is most serious at Xangi as compared to at other sites. This is why tef, which is less susceptible to termites, is dominant in the area.

Data collection

Secondary information related to the study was collected from the Wereda Natural Resources and Agricultural Development Office at Mendi. Also literature and materials from the Planning Office of Oromia Region were used.

Field survey

The survey was conducted using participatory rural appraisal (PRA) techniques such as individual, group and key informant interviews; preference ranking; seasonality calendars; resource mapping; and field observations. Farmers from different socio-economic groups were included in the study. A stakeholders' workshop was conducted to verify the data and information obtained from the survey.

Results

Farming system analysis

Understanding how a system works implies knowing the componets oe the system, and how they relate to each other and to the environment (FAO, 1986).

Components of the farming system and their interactions

It was learnt that Manasibu Wereda has a mixed farming system which constitutes different components (subsystems), including crop and coffee production, animal husbandry, agroforestry, forestry, water bodies, wetlands (Bonee), and the physical environment. The general picture of the farming system and the interaction of the different components to each other, to the household, to the outside market, and to the natural environment was indicated by a model (Figure 1).

Interactions were noted among the different subsystems which are naturally indispensable for the proper functioning of the system as a whole since a single element of the farming system can't exist independently. There was an inevitable interdependence and interrelationship among them in one way or another. The crop component in the system provides crop residues which sereve as feed for livestock, grains that are used as food for households. This component also needs many things from other components like draft power and manure from animals. Forests provide farm implements, litter for crop production, shade for coffee, and fodder for livestock, particularly during the dry season when other feed resources are scarce. Bonee fields are good grazing area for livestock, and are also used for crop production through residual moisture. Household unit, which is located at the center of the system, provides labor in its turn for the different subsystems for the good performance of the system as a whole. Labor is also another source of income for households who can't subsist on from other subsystems, and the household is a source of labor for this subsystem. The household obtains food, income and energy from the different components including crop, coffee, animal and forests. Cash is obtained by selling coffee, livestock and livestock products, and forest products at available market, from where other necessity goods are bought in turn for the household. Rivers and springs are source of water for household use. Crops produced off-season from Bonee fields generate income and food for the household and seed for the next main season crop production.

Competition among components

As termite problem and number and size of households increase, demand for food increases. This has led to the expansion of croplands at the expense of forests and grazing lands. The increase in population number has also resulted in deforestation to fulfill people's needs for energy and construction material. These disturbances caused environmental imbalance, which finally led to low system efficiency. The decrease in grazing land against increase in livestock population indirectly contributed for this low system efficiency. Thus, the system should be balanced for sustainabile efficient production.

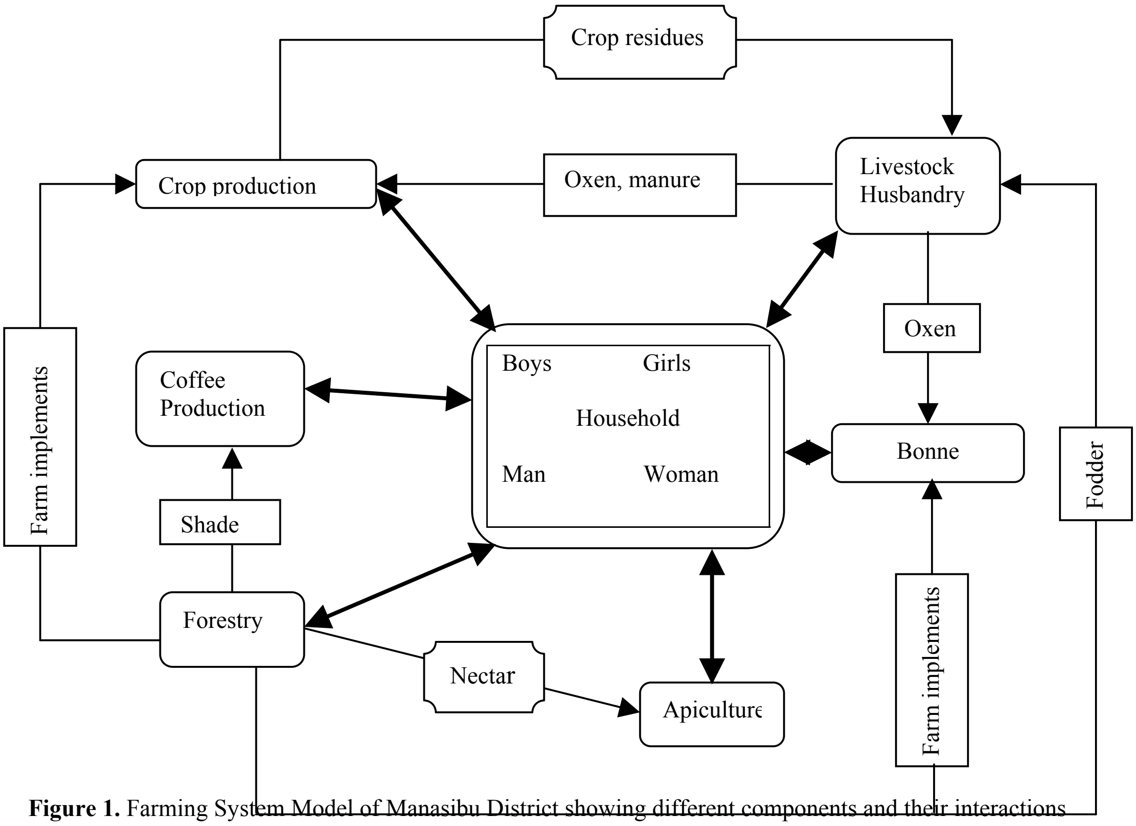

Figure 1. Farming System Model of Manasibu District showing different components and their interactions

Non-timber forest products and services

Fruits

Humankind has been using forests for different goods and services since long ago. Also the result of this study revealed that farmers in Mendi area of Manasibu Wereda have been obtaining many products from the existing forest resources. There are different trees and shrubs growing in the area, which serve different purposes.

Forests provide forest foods for the local community, particularly for the poor. The local people get fruits from naturally growing fruit trees such as *Syzygium guineense* var. *macrocarpum* (goosuu), *Syzygium guineense* subsp. *guineense* (badeessa-lidii), and *Carissa edulis* (hagamsa) in the natural forests (Table 1), and also from planted fruit trees like mango, orange, guava, papaya and banana (Table 2) around homesteads. Mango and papaya are also grown around bonee fields (wetlands). These fruits are commonly consumed raw as snack food especially for children who spend long hours outdoors herding livestock and for schoolchildren who travel long distances to reach home.

Table 1. Important wild fruit tree or shrub species in Mendi area as ranked by children in order of decreasing importance

Scientific name	Family name	Local name	Type
Carissa edulis	Apocynaceae	Hagamsa	
S. guineense var. *macrocarpum*	Myrtaceae	Gosuu	Tree or shrub
S. guineense subsp.*guineense*	Myrtaceae	Badeessa-lidii	Tree
Mimusopis kummel	Sapotaceae	Qolatii	Shrub
Flacourtia indica	Flacourtiaceae	Akukkuu	Shrub
Rubus steudneri	Rosaceae	Goraa	Shrub
Ximenia americana	Olecaceae	Hudhaa	Tree or shrub
Gardenia lutea	Rubiaceae	Gambelloo	Shrub
Grewia ferruginea	Tiliaceae	Bururii	Shrub

Table 2. Important exotic fruit trees in Mendi area

Scientific name	Family	Local name	Occurrence
Mangifera indica	Anacardiaceae	Banga (mango)	Tree
Citrus grandis	Rutaceae	Tiringoo	Shrub
Citrus aurantifolia	Rutaceae	Loomii	Shrub
Citrus sinensis	Rutaceae	Burtukana	Shrub
Musa sapientum	Musaceae	Muuzii	Perennial herb
Carica papaya	Caricaceae	Papayyaa	Shrub

Bush meat

Wild animals were found to be important forest food sources in Mendi area. Hunting wild animals like antelopes, duiker, and guinea, was found a common practice providing nutritious animal protein to Mendi people. Consumption of bush meat is considerable in the area during dry seasons especially around Ester, when labor demand for other agricultural activities is relatively low.

Fodder

The study revealed that trees and shrubs provide valuable forage for animals since long ago and that there are a number of tree species used as fodder (Table 3). They are sources of protein, vitamins and minerals which are lacking in grassland pastures during the dry seasons, or when little forage, except browse trees, is available because of drought (Le Houerou, 1980; Cook, 1972). Browse trees in rangelands also protect and improve soil characteristics (Abebe, 1998), provide fuel and supply raw materials for family utensils, building nuts, and medicine (Rocheleau *et al*., 1988).

Table 3. Important tree species used as fodder for livestock in Mendi area in order of decreasing importance

Scientific name	Family	Local name	Habit	Parts eaten
Ficus vasta	Moraceae	Qilxu	Tree	Leaves, twigs, fruits
Sapium ellipticum	Euphorbiaceae	Bosoqa	Tree	Leaves, twigs
Vernonia amygdalina	Compositae	Ebicha	Tree/shrub	Leaves, twigs
Ficus thinnings	Moraceae	Dambi	Shrub	Leaves, twigs, fruits
Gardenia lutea	Rubiaceae	Gambelloo	Shrub	Leaves
Carissa edulis	Apocynaceae	Hagamsa	Shrub	Leaves
Cordia africana	Boraginaceae	Wadeessa	Tree	Leaves, fruits
Bridelia micrantha	Euphorbiaceae	Galano	Shrub	Leaves
Mangifera indica	Anacardiaceae	Banga	Tree	Leaves, fruits
Premna schemperi	Verbenaceae	Urgeessa	Tree/ shrub	Leaves
Flacourtia indica	Flacourtiaceae	Akukkuu	Shrub	Leaves
Syzygium guineense var. *macrocarpum*	Myrtaceae	Gosuu	Shrub	Leaves, fruits
Coffea arabica L	Rubiacae	Buna	Shrub	Leaves, cherries
Masea lanceolata	Myrsinaceae	Abayyi	Shrub	Leaves
Maytenus ovatus	Celecetraceae	Kombosha	Shrub	Leaves

Honeybee flora

It was realized that the diversity of trees and shrubs in the area has greatly contributed to local honey production. The dominant honeybee trees were identified as *Coffee, Vernonia, Syzygium, Croton, Maytenus, Acacia, Eucalyptus, Cordia, Albizia,* and *Mango* species.

Honey harvesting and seasonality

In the area, honey type is usually named by the name of dominant tree species/flora type at that particular time of the year. Because different plants flower at different times (Table 4), bees make honey types different in quality and quantity. For instance, croton is a widely occurring tree species in the area but its honey is poor in quality as reported by the local farming community. Accordingly, the honey production calendar can vary from place to place depending on the flowering season of the existing plant species. There are four major profusely flowering periods and hence four distinct honey production periods (four honey types) in Manasibu Wereda (Table 4).

Table 4. Flowering period of dominant honey be trees and honey production periods in Manasibu Wereda

Dominant plant species	Flowering period	Honey type (local name)	Color	Remark
Vernonia and coffee	January–February	Vernonia honey (Damma eebicha)	Black	Bitter in taste, but it has medicinal value
Croton macrostachyus	June–July	Croton honey (Damma bakkaniisa)	White	Diluted, poor quality
Syzygium guineense	March–April	Syzygium honey ('Damma goosuu')	Brown	High quality
Guizotia scabra/ G. abyssinica	November–December	Guizotia honey (Damma keelloo)	Yellow	Good for consumption, sweet in taste

Croton honey is white as croton flowers are white and is diluted may be due to high availability of water during the rainy season when the plant blooms. This honey is not preferred, whereas syzygium honey is the most preferred type in the area followed by guizotia honey. The quality, appearance and availability of honey generally depend on flowering seasons of trees, rather than on conscious decision by vendors to sell one product over another during a particular time.

Medicine

Using medicinal plants is common among the people in Mendi area. Herbal medicine has been inherited from old tribes and traditionally used among people. Farmers in the area use different parts of many plant species as traditional medicine for different diseases (Table 5).

Table 5. Some medicinal plants used in Mendi area

Tree species	Vernacular name	Parts used	Disease
Cucurbita species	*Buqqee*	Fruit seed	Diarrhea
Ocimum suave	*Hanquu*	Fruit seed	Tape worm
Croton macrostachyus	*Bakkaniisa*	Latex sap	Dermal disease
Premna resinosa	*Urgeessaa*	Leaves	Hepatitis
Cordia africana	*Baddeessa-abaangee*	Bark	Wound
Aloe abyssinica	*Hargiisa*	Latex	Ophtalmic disease
	Cabbisaa	Latex	Auditor diseases
Croton macrostachys	*Bakkaniisa*	Latex	Dermal disease
Calpurina subdecandra	*Ceekaa*	Leaves	Abdomen /stomachach
Ricinus cuminus	*Qobboo*	Roots	Venereal disease

The list of medicinal plants in the area cannot be complete because of problems related to local patent issues; that is, the people were not willing to tell all what they know. The list here contains medical name of what most people commonly know. It may be very difficult to get knowledge only from few individuals using survey.

Fences

Dead fences and live fences were identified in the area. Live fences are common around houses (homesteads), whereas dead fences are common in areas far from houses.

As for house construction, it was learnt that durable species such as *E. camaldulensis, P. africana,* and *S. guineense* are preferred for homestead fences. In distant fields, thorny species like *Carissa edulis (hagamsa), Rosa abyssinica (qaqawwissa), and Maytenus* spp. *(kombolcha)* were preferred to play a protection role. Species such as *C. macrostachyus* could also be used because it is easily available though it is not thorny like others.

For construction of grain stores, *A. alpina* and q*acama* are mostly preferred. For Kraals, *Hanquu—E. camaldulensis*, *C. arabica, S. guineense* and *Naqaa—Ecamaldulensis,* and *Vernonia amydglana* are preffered.

It was found that tree logs are very important component in road and bridge construction in Mendi area using *E.* using *camaldulensis*, *S. guineense, Sapium ellipticum*, *Milletia ferrugenia*, and C, *macrostachyus*. For instance, bridge of Sachi River was partly made from tree logs and partly from iron steel.

Farm implements

Farm implements are the basic elements in agricultural production. The local farmers use traditional farm implements such as plough and yoke, for crop production. *C. africana, E. camaldulensis, A. gummifera, E. cymosa (ulaagaa)* and *Salix subserrata (alaltuu)* are important tree species used for making these farm implements. They made plough mainly from *C. africana*, *E. camaldulensis, P. africana, F. indica (akuukkuu), Deinbolla kilimandshorica (dabaqqaa), goosuu* and *ulaagaa,* and yoke from *ulaagaa*, *alaltuu*, *C. africana*, *darakkuu, gambeello* and *mukarbaa* (if treated with fire flame). Treating *Albizia gummifera* with fire is believed to reduce its susceptibility to wood-borers, locally called *qinqanii*. *Babattee* is commonly made from *V. amydglana, hoqonuu,* and *E. camaldulensis.* All farmers in the Wereda use these implements, and there was no improved farm implement introduced in the area.

Household utensils

Farmers preferred trees like *C. africana*, *Ficus sur*, and *F. vasta* for making household utensils for household use or for sale.

Hand tools

Tree species like *Stereospermum kunthianum (*botoroo*)*, *Cordia africana* (wadeessaa*)*, and *Acacia* spp. (laftoo) are used for making handles of different tools such as axe, hoe, *gajamoo*, *gasoo* and *buttoo*,

Fuelwood

It was found that fuelwood, including firewood and charcoal, is the main energy source in Mendi area as in other parts of the country. Firewood is the most important source of energy important for food preparation. It is usually collected by women and sometimes by children. Men are usually not involved in gathering firewood except that they help in pollarding branches from big trees, which women can't climb, and heavy logs which women or children can't carry. Crop residues like maize and sorghum stocks are also important source of fuel in the study area. The result revealed that the use of these residues as source of energy, which would have been returned to the system, together with the removal of these residues by termite, has deteriorated the soil through time, and this has made crop production without fertilizers difficult.

Different tree or shrub species can be used for fuel wood, but the commonly used tree species are *Acacia abyssinica, dhandhamsa, hagamsa, gambelloo, Croton macrostachyus, goosuu, Deinbolla (dabaqqaa), Sapium ellipticum (bosoka), Albizia gummifera*, *Sokorruu*, and *E. camaldulensis* (especially in urban areas). Even though all trees can be used as firewood, quality and availability usually matter. For instance, in quality, *A. abyssinica* and *Combretum molle* are the most preferred trees for firewood, but *C. macrostachyus* is the most commonly used because of its availability. Its ability to tolerate termites and relatively less local preference for different purposes made *C. macrostachyus* the dominant species in the Wereda. The purpose for which the firewood is to be used may also be another important issue to consider. For making '*injera'*, for instance, nothing is more preferred than *sokorruu* as firewood.

Although charcoal is not very common in the area, charcoal making in rural areas and selling it in urban or semi-urban areas was identified as one of the off-farm activities, and it was identified as a means of making livelihood for some poor farmers. Tree species such as *S. guineense*, *A. abyssinica*, and *E. camaldulensis* were used for small-scale charcoal making in Mendi area.

According to information obtained from the interview, different attributes dictate the choice of tree species for charcoal making. These include charcoal quality, availability and durability in stoves.

Acacia was ranked first in charcoal quality and durability in stoves; however, it was less commonly used for charcoal making, because it is usually not available except in coffee fields where it serves as coffee shade, which takes precedence over its use for charcoal.

Fragrance

Incense is not produced in the area. However, it was reported that stereospermum and denboilla are commonly used for smoking of milk vessels. Leaves of some plants are used for cleaning them.

Ornament

Tree species such as *Cupressus lusitanica*, *Casuarina equisetifolia*, *Mangifera indica*, and *Spathoda nilotica* give aesthetic value to the surrounding, at the same time serving another purpose. Cupressus leaves are also used as fly repellent.

Shade and shelter

Coffee is an important crop in western Ethiopia in general and in Manasibu Wereda in particular. It is traditionally grown as an understorey plant, consistent with its shade tolerant nature. Different shade trees (Table 6) are very important in coffee production and they shelter the coffee plant from excessive sunlight, high temperature, wind, and erosion.

Table 6. Framers' preference ranking of different trees for coffee shade in Mendi area, using 100 maize seeds for comparison

Species	Local name	Number of maize seeds used indicating preference*	Rank
Vernonia amygdalina	Eebicha	10	5
Cordia africana	Badeessa abangee, Wadeessa	49	1
Albizia gummifera	Mukarbaa, Hambaabessa	16	2
Ficus vasta	Qilxuu	11	4
Acacia abyssinica	Laftoo	14	3
Total		100	

*The numbers denote nominal data (rank) not the ratio scale data.

Although some trees such as *F. vasta* can give good shade, they are not as such preferred for coffee shade because coffee beans under them are reported to be shriveled (small bean size) as compared to others. Besides, the timber value of tree species like *C. africana* makes them preferred over *F. vasta* for coffee shade, as they provide dual advantage (shade and lumber). Some studies showed that shade improves the quality of coffee by slowing down cherry maturation rate and allowing the bean to accumulate much amount of sucrose (Steiman, 2003; Herzog, 1994).

Soil fertility management

The result revealed that there are different traditional agro-forestry practices, involving the integration of the elements of agriculture (crops or livestock) with forestry (trees or shrubs) on the same plot. Many tree species were deliberately retained on croplands, with some being common in the study area (Table 7).

Table 7. Framers' preference ranking of different trees for soil fertility management on farmlands in Mendi area, using 100 maize seeds for comparison

Species	Local name	Number of maize seeds used indicating preference*	Rank
Croton macrostachyus	Bakkannisa	15	2
Vernonia amygdalina	Eebicha	12	5
Cordia africana	Badeessa abangee, Wadeessa	16	1
Albizia gummifera	Mukarbaa, Hambaabessa	14	3
Ficus vasta	Qilxuu	10	6
Acacia abyssinica	Laftoo	13	4
Sapium ellipticum	Bosoqa	8	7
Others	-	12	-
Total		**100**	

*The numbers denote nominal data (rank) not the ratio scale data.

C. africana is the most preferred species for soil fertility management in Mendi area. This was also true in Bako area (Abebe, 1998; Abebe et al, 2001). Cordia was the most important species almost for every use in the area, and Legesse (1993) recommended that cordia be national tree. Croton was preferred more than acacia probably due to its availability because of its tolerance to termite problem.

Cash generation

Marketable forest products provide the opportunity to supplement household income and to relieve income need in times of cash shortage. Considerable money is earned from the sale of *C. africana* timber, mango fruit, eucalyptus timber and charcoal, *Deinbolla* timber and charcoal, syzygium charcoal and fruits from different products of many other trees. The different uses the people get from forest products are interrelated (Figure 2).

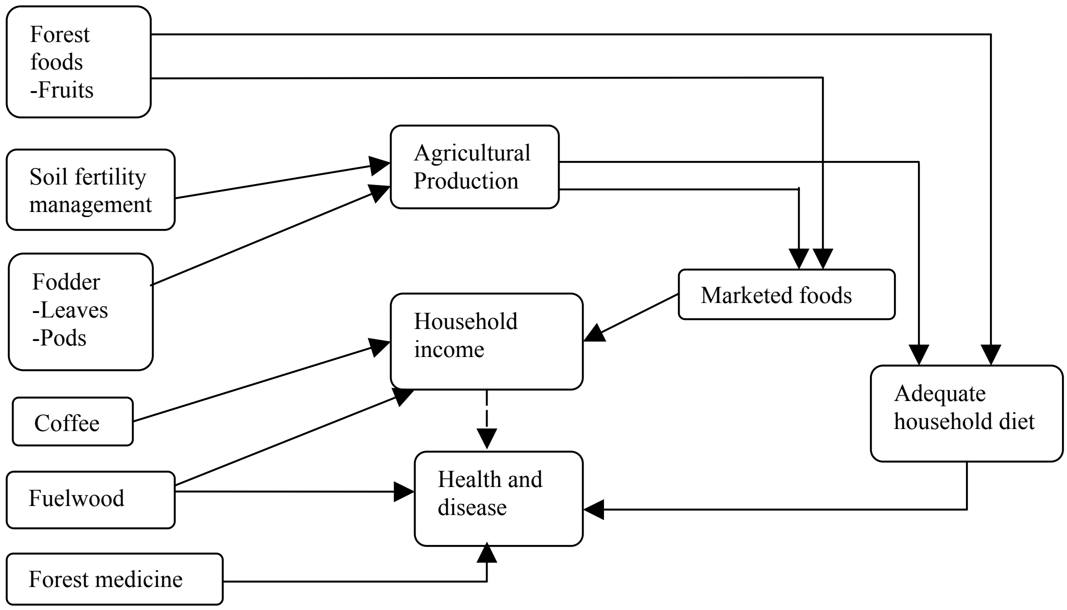

Figure 2. Interrelation of the different uses of forest products to household food security in Mendi area

Forests and farm trees help improve the quality of diets for the rural poor in Mendi area directly through providing fruits and bush meat and indirectly through providing a habitat for wild animals, shade for coffee, fodder for livestock, improving soil fertility, supply of medicines and fuel wood for cooking food.

Trends and dynamism in forestry

As the benefits obtained from forests are diversified, deforestation prevailed with its many consequences like the following.

Change in availability of forest products

Elderly farmers in the area noted that the change that happened in the forest cover has led to change in the availability of forest products like a decrease in the chance of getting bush meat due to less availability of wildlife in the area.

Change in tree species

With the advent of termites, seedlings of economically valuable tree species such as *Cordia*, *Albizia*, and *Acacia*, are disappearing; whereas, seedlings of the less economic species (less desired) are increasing. Selective cutting was also reported important for change in species composition. The less economically important species *Croton*, *Carissa*, *Maytenus*, *Syzygium* spp. were tolerant to termite while alive but loosing their tolerance after cut or dried. Termites affect species composition by affecting regeneration or seedlings. Termites normally don't prefer tree species that are not as such preferred by human beings.

Increasing eucalyptus plantation

The already existing natural forests in this area are rapidly decreasing in extent due to the aforementioned factors, yet the demand for the forest products is increasing very rapidly due to the ever-increasing human population. Expanding plantation of fast growing exotic tree species, *E. camaldulensis* was taken as a way out so as to satisfy the increasing demand at least to some extent. Because of this problem, eucalyptus planting was carried out irrespective of proper site selection, including on farmlands.

Increasing drudgery on rural women

Informants indicated that in the past, when the landscape was covered by forests, the forest products were easily obtained from nearby areas within short time. However, these products are currently either rarely available or available in very remote areas. Hence, the rural women or children have to travel long distances and spare long hours to collect them.

Increasing soil erosion and landslides

It was learnt that the devastation of forests by humans for different purposes and seedlings and grasses by termites has left the land bare, exposing it to soil erosion. This situation has made the ecosystem unstable and led to the formation of active gullies, challenging the livelihood of the rural poor in Mendi area. Farmers expressed the scenario as ''Biyya abbaa koo ti jettee, injiraan moluu irraatti hafte'', meaning "Considering that, it is our fatherland (habitat), the lice remained on hairless (bald) skull''. This shows how serious the problem of land degradation is in the area, and no potential solution obtained to cope up with it."

Wildlife habitat destruction

The problem of wildlife is increasing as the severity of termite infestation increased on previously agriculturally important croplands. It was learned that farmers are forced to move to the existing forestlands in search for new cultivable land (relatively less termite infested). Consequently, forest areas, which were previously habitats of wildlife, are currently under cultivation, and hence farmers and wild animals are competing for the same niche (forestland). Farmers are searching especially for coffee plantation plots, shade trees and rivers for coffee nursery.

Conclusions

The contribution of NTFPs such as wild fruits and bush meat, forest honey, traditional medicines, animal fodder, farm implements, household utensils, firewood, and forest coffee, to food security is significant in Manasibu Wereda. Although the importance of these NTFPs is valuable, their availability is decreasing from time to time as a result of increasing rate of deforestation and termite infestation in the area. Different tree species are used for different purposes, and farmers are normally obliged to use the less preferred species if the more preferred ones are unavailable because of overexploitation. The most preferred species is usually more susceptible to over-utilization by humans and other pests unless it is replaced through planting.

Despite their overall importance, the sale price of NTFPs received by local producers or processors is very small in Ethiopia. The main reason for the low profitability of NTFP enterprises is lack of organized information system to help individual producers organize production and distribution, determine appropriate prices, select markets, and follow supply and demand. Therefore, initiatives should be taken to integrate indigenous trees whose products have traditionally been gathered from natural forests into the existing farming systems, such as coffee farms. This is important to provide marketable timber and non-timber forest products from farms that will enhance rural livelihoods by generating cash for resource-poor rural households and to reduce the pressure on primary forests for supplying subsistence products. Little or no formal research has been carried out to assess the potential of many wild species for genetic improvement, reproductive biology or suitability for cultivation. Hence, domestication of the important wild indigenous trees preferred by local people, management and marketing should be our priority research agenda in the future. Research on identifying termite-resistant appropriate tree species and integrated pest management should also be focused to address the increasing termite problem in the area.

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List of participants

Full Name	Institution	E-Mail	Address
Abebe Yadessa	Forestry Research Center (EARO)	abebeyadessa@hotmail.com	Addis Ababa
Abeje Eshete	Forestry Research Center (EARO)	abejeeshete@yahoo.com	Addis Ababa
Adefris Worku	Forestry Research Center (EARO)	adefris@yahoo.com	Addis Ababa
Ashenafi Degefe	Oromiya Agric. Research Institute	Ashe.dege@freemail.et	Bako
Behailu Kebede	Pawe Agric. Research Center (EARO)		Pawe
Birhane Kidane	Holetta Agric. Research Center (EARO)	birhanekidane@yahoo.com	Holeta
Dechasa Jirru	Forestry Research Center (EARO)	agroforep@telecom.net.et	Addis Ababa
Enyew Adgo (PhD)	Amhara Agricultural Research Institute	enyewadgo@yahoo.com	Bahir Dar
Ermias Alemu	Melkasa Agric. Research Center	Ermias2002@yahoo.com	Melkasa
Getachew Birhan	Institute of Biodiversity Conservation	Getachewb1@yahoo.com	Addis Ababa
Getachew Desalegn	Forestry Research Center (EARO)	getachewma@yahoo.com	Addis Ababa
Getinet Alemaw (PhD)	Essential Oils Research Center (EARO)	eorc@telecom.net.et	Addis Ababa
Girmay Fitwi	Natural Gum Processing & Marketing Enterprise	natgum@telecom.net.et	Addis Ababa
Kasahun Embaye (PhD)	Institute of Biodiversity Conservation	biodiver@telecom.net.et	Addis Ababa
Kindeya G/Hiwot (PhD)	Mekele University	kindeya@softhome.net	Mekele
Mahdere Mulugeta	Forestry Research Center (EARO)		Addis Ababa
Mekonen Assefa	Forestry Research Center (EARO)	mekonnenas@yahoo.com	Addis Ababa
Melaku Abegaz	Forestry Research Center (EARO)	fpurc@telecom.net.et	Addis Ababa
Michael Mbogga	International Plant Genetic Resources Institute (IPGRI)	m.mbogga@cgiar.org	Nairobi/Kenya
Miftah Fekadu	Forestry Research Center (EARO)		Addis Ababa
Mohamed Adilo	Forestry Research Center (EARO)	mchilalo@yahoo.com	Addis Ababa
Motuma Didita	Oromiya Agric. Research Institute (Sinana)	Motumadidita@yahoo.com	Sinana
Muktar Mohamed	Debrezit Agric. Research center (EARO)		Addis Ababa
Negash Mamo	Forestry Research Center (EARO)		Addis Ababa
Seblework Belaineh	Institute of Biodiversity Conservation	bsebwrk@yahoo.com	Addis Ababa
Shiferaw Abebe	Forestry Research Center (EARO)	shiferab@yahoo.com	Addis Ababa
Shimelis Tadesse	Forestry Research Center (EARO)	tshimelis@hotmail.com	Addis Ababa
Sisay Feleke (PhD)	Forestry Research Center (EARO)	fpurc@telecom.net.et	Addis Ababa
Tadesse W/Mariam (PhD)	ZEF-COCE project	w-gole@uni-bonn.de	Addis Ababa
Tairo Vendeline	Addis Ababa University	rpsudeth@telecom.net.et	Addis Ababa
Tamirat Bekele (PhD)	Addis Ababa University	rpsudeth@telecom.net.et	Addis Ababa
Taye Bekele	Institute of Biodiversity Conservation	tayebekele@yahoo.com	Addis Ababa
Tesfaye Bekele (PhD)	Forestry Research Center (EARO)	Nat-forc@telecom.net.et	Addis Ababa
Tesfaye Hunde	Forestry Research Center (EARO)	Frc-head@telecom.net.et	Addis Ababa
Tesfaye Zenebe	Melkasa Agric. Research Center (EARO)	Tesfaye_za@yahoo.com	Melkasa
Teshome Takele	Oromiya Agric. Research Institute	tashomatz@yahoo.com	Bako
Tsegaye Bekele (PhD)	Wondo Genet College of Forestry, Debub University	wgcf@telecom.net.et	Wondo Genet
Wubalem Tadesse (PhD)	Forestry Research center (EARO)	wubalemt@yahoo.com	Addis Ababa
Yitebitu Moges	Forestry Research Center (EARO)	yitebitymoges@yahoo.com	Addis Ababa
Yoseph Amha	Jimma Agricultural Research Center (EARO)	Yosefam2003@yahoo.com	Jimma