Medicinal Plant Trade in Northern Kenya: Economic Importance, Uses, and Origin[1]

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Despite the importance of the medicinal plant trade in Africa, little is known about the existing trade in Kenya outside major urban centers. We assessed the economic importance, uses, and origins of the plants traded in two major towns in northern Kenya. We interviewed vendors, assessed volumes and prices, and collected specimen samples for identification. We also discussed with collectors and made observations on harvesting techniques and species' relative abundance in the wild. Thirty species were found to be traded in Marsabit and Moyale towns, of which only *Myrsine africana* L. was collected in a forest. The seven most frequently traded species accounted for an annual volume of 5500 kg with an annual retail value of US$25,900. Several uses mentioned by vendors had not been previously reported in the literature. Interestingly, some species high in demand in major urban centers are abundant in these montane forests. Our study highlights the substantial economic importance of the medicinal plant trade in the area and the strong effect ethnicity has on plant use. While more research is needed on the previously undocumented uses of certain plant species, it seems that the trade of certain species could be further promoted.

Key Words: Ethnicity, montane forests, market surveys, medicinal plants, ethnobotany..

Introduction

Despite the growing availability and accessibility of Western medicine in the tropics, medicinal plants cover the basic health needs of most people in Africa (WHO 2003). Medicinal plants are those used to diagnose, prevent, or eliminate physical and mental diseases, knowledge and use of which are mainly based on practical experience and observations and are mostly handed down from generation to generation (Kokwaro 2009). The number of African plant species with medicinal uses is estimated to be close to 6000 (Schmelzer and Gurib-Fakim 2008). Medicinal plants are widely used because of their low cost, their effectiveness, the reduced access to modern medicine in many areas, and cultural or religious preferences (Sheldon et al. 1997). Medicinal plants are sometimes preferred because of the dissatisfaction with conventional medicine, perceived as ineffective or unsafe (Njoroge 2012). The economic importance of medicinal plant trade is significant. For example, this trade is valued at US$0.1–0.3 million in Johannesburg, South Africa, US$7.8 million in Ghana, and US$1.5 million in Gabon (Towns et al. 2014; van Andel et al. 2012; Williams et al. 2007).

Because of its economic importance, the medicinal plant trade has been identified as an alternative livelihood strategy for forest-edge communities, and thus, it has been suggested that it could be used to promote forest conservation (Jusu and Cuni-Sanchez 2014). Forest-edge communities are often subsistence farmers or herders heavily dependent on forest resources for their livelihoods (c.f. Cuni-Sanchez et al. 2016). Although the co-benefits of selling non-timber forest products (NTFPs), including medicinal plants, for forest conservation and development have been discussed (Arnold and Ruiz-Perez 2001), this could be context-specific,

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and few studies have actually addressed this topic in Africa.

Unsustainable harvesting and trading medicinal plants may be a threat to biodiversity. This is not only because the rate of survival, growth, and reproduction of the species traded can be reduced due to overharvesting (Gaoue and Ticktin 2007) but also because the removal of certain canopy species might affect the whole ecosystem (e.g., more light reaching the forest floor and change in species' composition). Overharvesting of medicinal plants can also negatively affect the long-term livelihoods of the communities that depend on them (Hamilton 2004; van Andel and Havinga 2008). The removal of wood, roots, or whole plants generally leads to the death of an individual, as does the cutting of bark when ring debarking takes place (Cunningham 1993). One example of unsustainable ring bark harvesting is *Prunus africana* (Hook.f.) Kalkman, traded for its use against benign prostatic hyperplasia (Stewart 2009). The harvest of leaves, fruits, or seeds is considered less destructive, however, especially if they are collected from the ground. The vegetation type from which wild plants are collected, their abundance, and growth rates are other major determinants of the sustainability of their extraction. For example, slow-growing, old-growth forest species that occur in low densities are particularly vulnerable to overharvest (Peters 1996). However, a recent meta-analysis of over 100 publications on tropical countries reported that NTFP extraction was sustainable or likely to be so in two thirds of the studies assessed (Stanley et al. 2012). This meta-analysis also highlighted, however, that much more is known about the ecological consequences of extractivism in Latin America than in Asia or Africa. Often, the lack of knowledge on harvesting techniques, local abundance, and growth rates hinders the identification of sustainable harvesting levels or methods and, therefore, management and conservation decisions (McGeoch et al. 2008).

Market surveys, together with field observations on relative abundance and harvesting techniques, are becoming a new tool to assess those species that could be further promoted for trade and those that need management interventions (e.g., Jusu and Cuni-Sanchez 2014). In the past few years, the number of quantitative market surveys of medicinal plants and their implications for conservation has increased considerably, but most have focused in West Africa (e.g., Jusu and Cuni-Sanchez 2013; Quiroz et al. 2014; van Andel et al. 2012), with only three studies assessing East Africa: McMillen (2012) and Posthouwer (2015) in Tanzania and Njoroge (2012) in central Kenya. The latter, however, did not assess volumes, plant parts traded, harvesting techniques, or the origin of the species traded.

Montane forests, particularly in drylands, provide key ecosystem services to surrounding communities, which depend on them for their livelihoods (Cuni-Sanchez et al. 2016). In northern Kenya, the population near montane forests has increased significantly in the last 40 years due to the droughts and war in neighboring areas (Dietz et al. 2015). With increasing droughts, water scarcity, and human population pressure, conserving these fragile ecosystems is challenging. For example, in Mt. Marsabit forest, which is an important elephant habitat in northern Kenya (Ngene et al. 2009), ten plant species are Red Listed by the IUCN and deforestation and forest degradation are major problems, mainly linked to fuelwood harvest and increased demand for agricultural land for food production (Githae et al. 2008; Shibia 2010). Located in isolated parts of the country, with very limited infrastructure, these montane forests have limited options for other potential conservation finance mechanisms, such as tourism (Cuni-Sanchez, personal observation).

The objectives of this study were to determine (1) which medicinal plants are traded in northern Kenya and for which purpose, (2) what are the prices and volumes marketed, and (3) where they were collected, so that suggestions for sustainable management and potential further trade could be made.

Methodology

Study Area

Marsabit County is the largest and second poorest in Kenya, with a poverty rate of 83.5% (GoK 2011). Most of the county is in lowlands, with few scattered mountains and hills. The lowlands, with annual rainfall between 150 and 350 mm, are classified as very arid (zone VII; Sombroek et al. 1982). The mountains and hilltops, with annual rainfall between 800 and 1400 mm, maintain montane forests (semi-humid area, zone III; Sombroek et al. 1982). Rainfall is concentrated in two wet seasons, from March to May and from October to December, but great interannual variation occurs, with some years having only one or no rainy season. The two largest towns in this county are Marsabit town (the headquarters) and Moyale

town (at the border with Ethiopia), with 15,000 and 30,000 people, respectively, in 2013 (http://softkenya.com/marsabit-county/).

Marsabit town (2.248 N and 37.956 E, 1300 m a.s.l.), 500 km north from Nairobi, is located next to the Marsabit Forest Reserve (FR; Fig. 1). The vegetation in Mt. Marsabit, like in all montane forests in the region, varies with altitude and wind exposure. Below the sub-humid montane mixed-species forest, there is *Olea europaea* subsp. *cuspidata* (Wall. & G. Don) Cif. dominated forest, *Acacia* spp. woodlands, dry bushland, and shrubby vegetation (Bussmann 2002). The main ethnic groups in Marsabit town are Burgi, Borana, and Gabra, most of which are Muslim. The same groups dominate the villages on the northeastern part of the mountain, while Rendile and Samburu dominate the villages on the southwestern side. Most residents in town are subsistence farmers who often engage in casual labor, but residents in the surrounding villages are agro-pastoralists who own goats and cattle; some families are still nomadic, but this is a decreasing trend (Dietz et al. 2015). Moyale town (3.527 N and 39.056 E, 1000 m a.s.l.), 650 km north of Nairobi, is located next to the border with Ethiopia. This active market center has a similar climate to Marsabit town, but with slightly more rainfall. While the Borana ethnic group is also predominant here and most people engage in either subsistence farming or trade, the vegetation is quite different from Marsabit. There is no forest nearby, and the town is surrounded by *Acacia-Commiphora* woodland (Cuni-Sanchez, personal observation).

Market survey

Semi-structured interviews were conducted with 19 vendors in Marsabit town and 15 in Moyale town. While no more vendors could be identified in Marsabit, time constraints did not allow a longer field period in Moyale. Although this might seem a small number of vendors, the species accumulation curves (see "Results") indicate that we captured the great majority of floristic diversity sold in these markets. All vendors were selected on a voluntary basis. The interviews focused on the use of each

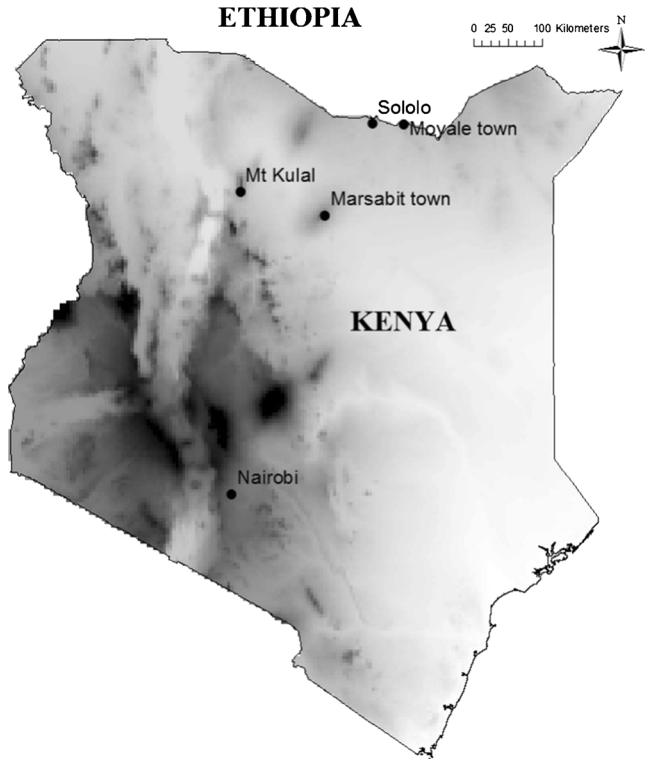

Fig. 1. Study areas: Marsabit and Moyale towns in northern Kenya. Background data refers to altitude a.s.l. in *gray color scale*; the darker, the higher. Mt. Kulal, 2278 m; Mt. Marsabit, 1700 m.

plant traded, quantities sold, and origin of the species traded. The age, gender, and socio-ethnic group of all vendors were also recorded. For each vendor, all the plant products sold were counted, plant parts and prices of sale units (e.g., bundle) recorded, and whether the products were sold in dried or fresh form was also noted.

For the seven most frequently traded products (for which daily sales did not vary between vendors and seasons), an average sales unit was weighted with a scale. With this data, we calculated annual volumes for sale and price per kilogram, following methods adapted from similar studies (Jusu and Cuni-Sanchez 2013; van Andel et al. 2012). In Moyale town, only three species were included in these calculations as great variation in the quantity of sales unit sold daily was observed for the other four species. The average volume annually traded (V) was calculated as

$$V = n \times q \times w \times y$$

where n is the number of vendors trading the species (of those interviewed); q the quantity of sales unit sold daily (calculated from the frequency mentioned by vendor); w is the mean weight of each sale unit; and y is the number of days/year.

The annual retail value of a species (R) was calculated as

$$R = V \times p$$

where V is the volume traded annually and P is the price per kilogram.

Plant samples were identified both by matching local names with literature and by collecting fresh plant material that was deposited at the Herbarium of the University of Nairobi for identification. Unfortunately, the quality of some samples collected did not permit their identification, and they are reported in their local name in Boran language (see Table 1). It should be noted that while a considerable amount of information on the ethnobotany of several ethnic groups in Kenya (such as Maasai and Samburu; see Bussmann 2006 and references therein) is available, including local and corresponding Latin names, the local names for Boran and Gabra (who also speak Boran) have received little attention. All local names are spelled in accordance to Beentje (1994) and Latin names according to The Plant List 2013 (http://www.theplantlist.org/).

Sample Selection and Size

We produced a species accumulation curve to ensure an adequate sampling effort (see van Andel et al. 2012), with the cumulative number of plant products and species recorded as a function of the number of vendors interviewed (Fig. 2). In Marsabit town, after interviewing 17 vendors, all the species observed in the market had already been recorded. Although the curve did not flatten completely, we captured the diversity of medicinal plants traded as no more vendors could be located. In Moyale town, the curve almost flattened, indicating that we captured the great majority of floristic diversity sold in that market. Although we carried out the market survey during the dry season, vendors mentioned that plant products did not change during the whole year, and this was confirmed by subsequent visits to the market by a field assistant.

Complementary Data

In order to better understand species' abundance and harvesting techniques, we followed several collectors (selected on a voluntary basis) to the areas where they gather medicinal plants and discussed their business with them. Trips with collectors were completed around Marsabit and Moyale towns, in Sololo, and in Mt. Kulal (Fig. 1). After these trips, species' habitat type was classified into three categories: forest, bushland, and farmers' fields (bushland also includes the *Acacia-Commiphora* woodland around Moyale, as considered by local collectors). The relative abundance of each species was classified into three categories (high, medium, or low), reflecting how difficult each species was to find in the wild compared with other species. We are aware that this is a very coarse indicator, but it still gives an indication of how easy it is to find and collect each species. Additionally, we carried out semi-structured interviews with six traditional healers, three medical clinics, two pharmacies, and the doctor in charge of the hospital in Marsabit town. A literature review was also conducted to check the medicinal uses, ecology, distribution, and conservation status of all the species traded, and current trends in medicinal plant trade in major urban markets (e.g., Muriuki et al. 2012; Njoroge 2012). The IUCN Red List of Threatened Species version 2015.2 (http://www.iucnredlist.org) was accessed to check their conservation status. Plant collecting permit and the interview questionnaires were submitted to NACOSTI (National Council for Science

TABLE 1. PLANTS TRADED IN MARSABIT AND MOYALE TOWNS: LATIN AND LOCAL NAME, TOWNS WHERE IT IS BEING TRADED, PLANT PARTS TRADED, LOCALITY WHERE IT IS SOURCED, RELATIVE ABUNDANCE, PLANT TYPE, DISEASES AS REPORTED BY VENDORS AND THE LITERATURE, AND IF THEY ARE TRADED IN KENYA'S MAJOR TOWNS.

Latin name	Local name in Boran	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)	Traded in major urban markets (literature)
Acacia brevispica Harms	Amarich	Marsabit	Root/stem	Marsabit	Bushland	High	Tree	Malaria, stomach ache, women's health	Aphrodisiac, itching, snake bites	
Albizia anthelmintica Brongn.	Hawacho	Marsabit, Moyale	Bark	Marsabit	Bushland	High	Tree	Bone and joint pain, headache, stomach ache, stomach infections and worms, women's health	Gonorrhea, malaria, veterinary diseases	Yes
Allium sativum L.	Garlic	Marsabit	Fruits	Moyale	Cultivated	–	Herb	High blood pressure, respiratory diseases, stomach ache	Anticancer, general cardiovascular diseases, diabetes, general bacterial, fungal and viral infections	
Carissa spinarum L.	Dagams	Marsabit	Root	Marsabit	Bushland	High	Bush	Bone and joint pain, stomach ache, toothache, women's health	Epilepsy, gonorrhea, kidney diseases, malaria, yellow fever	

TABLE 1. (CONTINUED).

Latin name	Local name in Boran	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)	Traded in major urban markets (literature)
Croton dichogamus Pax	Mokorf	Moyale	Root	Moyale	Bushland	High	Bush	Bone and joint pain, respiratory diseases	n.a.	
Euphorbia heterochroma Pax	Arken	Marsabit, Moyale	Root/stem	Marsabit	Bushland	Low	Small succulent plant	Fever, gland complications, respiratory diseases	Diarrhea, fever, sexually transmitted diseases	
Euphorbia tirucalli L.	Anon	Moyale	Bark	Moyale	Cultivated	–	Tree	Women's health	Snake bites, stomach ache, throat infections	
Lepidium sativum L.	Fito	Marsabit, Moyale	Seeds	Moyale	Cultivated	–	Herb	Bone and joint pain, fever, respiratory diseases, stomach ache	na	
Lycium europaeum L.	Bursh	Marsabit, Moyale	Root/stem	Sololo	Bushland	Low	Bush	Headache, respiratory diseases	Women's health	
Maerua subcordata (Gilg) DeWolf	Hagar nyab	Marsabit, Moyale	Root	Sololo	Bushland	Low	Shrub	Bone and joint pain, gland complications, stomach ache, toothache, women's health	na	
	Walda		Root	Sololo	Bushland	Low	Shrub		na	

TABLE 1. (CONTINUED).

Latin name	Local name in Boran	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)	Traded in major urban markets (literature)
Momordica spinosa Chiov.		Marsabit, Moyale						Respiratory diseases, fever, headache, malaria		
Myrsine africana L.	Angu	Marsabit	Seeds	Mt Kulal	Forest	Medium	Bush	Bone and joint pain, gonorrhea, kidney diseases, women's health	Diarrhea, respiratory diseases, rheumatic diseases, toothache, veterinary diseases	Yes
Nigella sativa L.	Kimami gurati	Marsabit, Moyale	Seeds	Moyale	Cultivated	–	Herb	Headache, high blood pressure, stomach ache	n.a.	
Platycelyphium voense (Engl.) Wild	Sottawesa	Marsabit, Moyale	Bark	Marsabit	Bushland	High	Tree	Bone and joint pain, yellow fever	n.a.	
Rotheca myricoides (Hochst.) Steane & Mabb.	Mara sisa	Marsabit, Moyale	Root	Marsabit	Bushland	High	Bush	Bone and joint pain, gland complications, malaria, respiratory diseases, stomach ache	Aphrodisiac, gonorrhea, itching, toothache	
Tamarindus indica L.	Groha	Marsabit, Moyale	Fruits	Moyale	Cultivated	–	Tree	Stomach ache, throat	Anticancer, diabetes, eye diseases, general	

TABLE 1. (CONTINUED).

Latin name	Local name in Boran	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)	Traded in major urban markets (literature)
								infections, women's health	infections, gonorrhea high blood pressure, malaria	
Terminalia brownii Fresen.	Biress	Marsabit, Moyale	Bark	Marsabit	Bushland	Low	Tree	Yellow fever	Stomach ache, women's health	
Terminalia orbicularis Engl. & Wild	Bissik	Marsabit	Bark	Marsabit	Bushland	Low	Tree	Bone and joint pain	n.a.	
Nicotiana tabacum L.	Geise/Tobacco	Marsabit	Leaves	Moyale	Cultivated	–	Herb	Stomach infections	n.a.	
Turraea sp.	Injirmocho	Marsabit	Root	Marsabit	Bushland	Low	Bush	Women's health	n.a.	
Zanthoxylum usambarense (Engl.) Kokwaro	Gadah	Marsabit	Bark	Marsabit	Bushland	High	Tree	Throat infections	n.a.	Yes
Zingiber officinale Roscoe	Tangawizi/ginger	Marsabit	Rhizome	Moyale	Cultivated	–	Herb	Respiratory diseases, throat infections	Alzheimer's/dementia, bone and joint pain (osteoarthritis)	
	Araq	Marsabit	Root	Marsabit	Bushland	–	–	Fever, respiratory diseases	n.a.	
	Arsa	Marsabit	Stem	Marsabit	Bushland	–	–	Malaria, respiratory diseases	n.a.	
	Gis	Moyale	Gum/root	Moyale	Bushland	–	–	Bone and joint pain, stomach infections,	n.a.	

TABLE 1. (CONTINUED).

Latin name	Local name in Boran	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)	Traded in major urban markets (literature)
								women's health		
	Gororsa	Marsabit	Root	Marsabit	Bushland	–	–	Throat infections	n.a.	
	Idjujumma	Moyale	Root	Moyale	Bushland	–	–	Women's health	n.a.	
	Kumbi	Marsabit	Gum	Moyale	Bushland	–	–	Epilepsy, itching, throat infections	n.a.	
	Natura	Marsabit	Leaves	Marsabit	Cultivated	–	–	Stomach infections	n.a.	
	Safara	Moyale	Root	Moyale	Bushland	–	–	Bone and joint pain, high blood pressure, respiratory diseases	n.a.	

All local names are spelled in accordance to Beentje 1994 and Latin names according to The Plant List 2013 (http://www.theplantlist.org/). Uses reported in the literature refer to Beentje (1994), Nagourney (1998), Afzal et al. (2000), Gathuma et al. (2004), Maundu and Tengnäs (2005), Leach and Saravana (2008), Zou et al. (2008), Kokwaro (2009), Azam et al. (2011), Santosh et al. (2011), Rehmann et al. (2012), and Moon et al. (2014). The PROTA database (http://database.prota.org/) was also checked. Traded in major urban markets refers to Muriuki et al. (2012) and Njoroge (2012).
n.a. not available

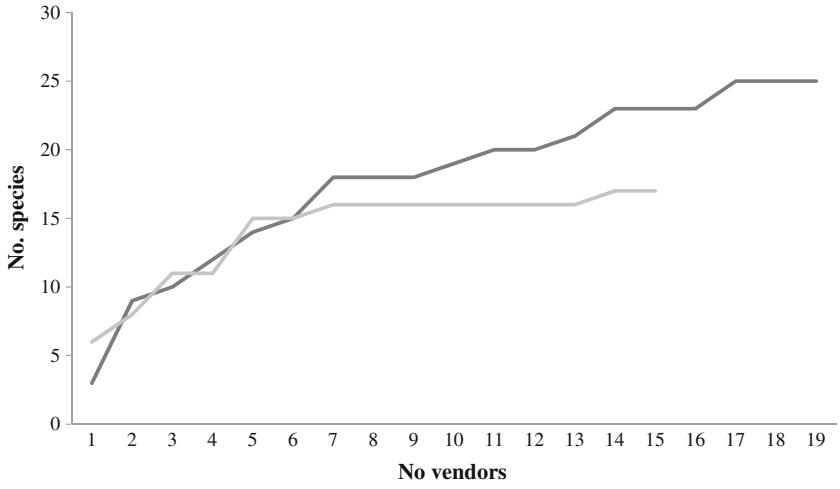

Fig. 2. Cumulative number of species offered for sale in Marsabit (*dark gray*) and Moyale (*pale gray*) towns, depicted as a function of the number of vendors interviewed.

and Technology in Kenya), but no ethical review committee permission was needed. As most informants were not able to read and write, they were informed of our intent and their verbal permission was obtained. All informants were rewarded with a small sum of money to compensate for their time and for sharing their knowledge with us.

Results

Plants Traded and Origin

In Marsabit town, 25 species were traded for medicinal purposes. Eight species were traded by >40% of the vendors: *Acacia brevispica* Harms, *Albizia anthelmintica* Brongn., *Carissa spinarum* L., *Lepidium sativum* L., *Momordica spinosa* Chiov., *Myrsine africana* L., *Maerua subcordata* (Gilg) DeWolf, and *Rotheca myricoides* (Hochst.) Steane & Mabb. (Fig. 3). The majority of the plants offered for sale were sold in the form of root, followed by bark and stem (Fig. 4). All products were sold in dried form, but vendors mentioned that they could also be used fresh, in which case the quantity needed was smaller.

Of these 25 species, six species were not native to Africa (garlic *Allium sativum* L., ginger *Zingiber officinale* Roscoe, tobacco *Nicotiana tabacum* L., *Nigella sativa* L., *Tamarindus indica* L., and *L. sativum*). These non-native African species were brought from Ethiopia where they were being cultivated. Four species (*M. subcordata*, *M. spinosa*, *Lycium europaeum* L., and "kumbi") were collected from the woodland around Sololo and Moyale areas, roughly 200 km north from Marsabit town. *M. africana* was brought from Mt. Kulal, a montane forest 150 km west from Marsabit town. The remaining species (14) were collected around Marsabit town, in the dry bushland (Table 1). It should be noted that only *M. africana*, the species brought from Mt. Kulal, was a forest species (Table 1). Some of the species traded were not found to be abundant in their natural habitat, neither in the dry bushland around Marsabit town nor in the woodland around Sololo and Moyale (as reported by vendors and Cuni-Sanchez, personal observation; see Table 1).

In Moyale town, 17 species were traded for medicinal purposes. While three of the most frequently traded species (*A. anthelmintica, M. spinosa*, and *L. sativum*) were also among the most frequently traded in Marsabit town (Fig. 3), five species had not been recorded in Marsabit town (Table 1 and Fig. 3). Similar to observations in Marsabit town, the plant part most frequently traded was roots (47%), and most species were sold in dried form (two vendors sold *M. spinosa*, *T. indica*, and "Safara" fresh). However, contrary to observations in Marsabit, all the species traded there had been collected from the nearby bushland or were cultivated, with no species coming from great distances or a forest habitat. In total, our study identified 30 medicinal plants being traded in northern Kenya's major towns.

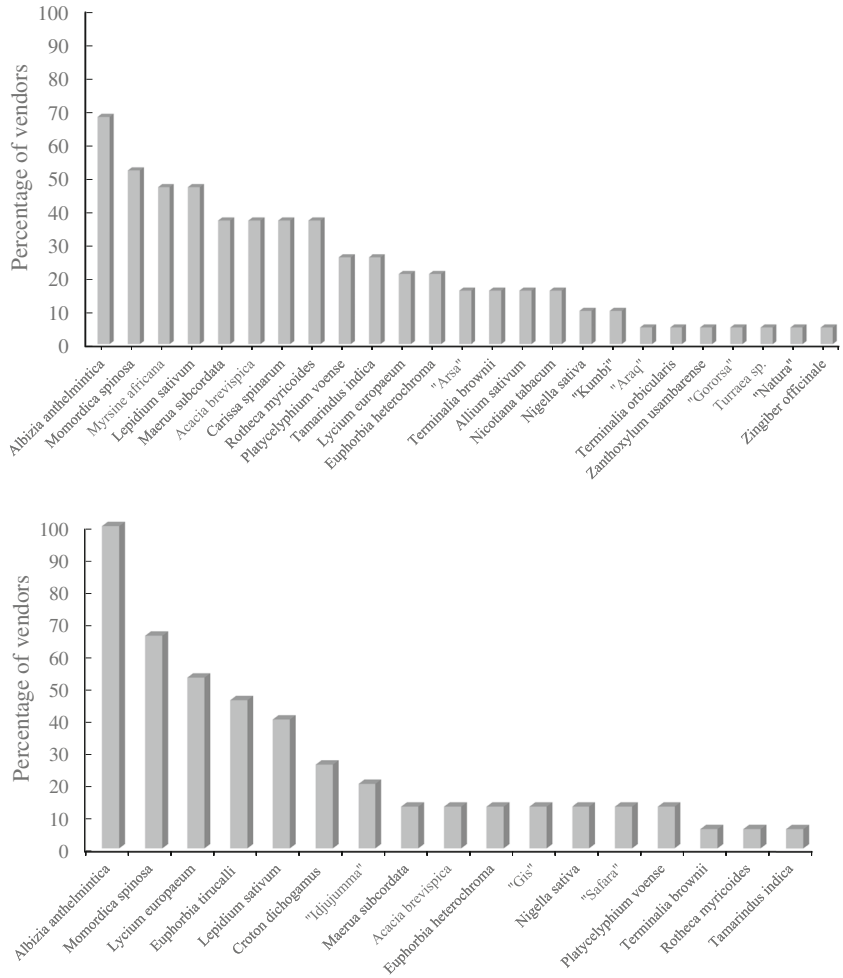

Fig. 3. Percentage of vendors selling each medicinal plant in Marsabit (*top*) and Moyale (*bottom*) towns.

Main Uses, Prices, and Volumes

The medicinal plants traded in Marsabit and Moyale towns were used to treat 17 different diseases. Most diseases were related to the respiratory system, bone and joint pain, stomach ache, and women's health (menstruation pain or irregularity, pregnancy, and delivery; Table 1). Several plant species had more than one medicinal use, *R. myricoides* having six uses. All medicinal uses mentioned in Moyale were also mentioned in Marsabit. Several uses mentioned by vendors had not been previously reported in the literature: the use of *A. brevispica* or *Euphorbia tirucalli* L. for women's health, use of *Platycelyphium voense* (Engl.) Wild against yellow fever, use of *L. europaeum* against headache, and the use of *M. spinosa* or *R. myricoides* for respiratory diseases. Vendors did not mention any veterinary use; however, our literature review revealed that some species traded do have veterinary uses (Table 1).

In Marsabit town, the seven most frequently traded species were sold for a price ranging between US$2/kg (*C. spinarum*) and US$9/kg (*L. sativum*; Fig. 5). They accounted for an annual volume of 4200 kg, ranging between 100 kg for *M. subcordata* and 2000 kg for *A. anthelmintica* (Fig. 5). The estimated annual retail value for these seven species was US$19,600. In Moyale town, the three most frequently traded species were sold between US$3/kg (*M. spinosa*) and US$7/kg (*L. europaeum*; Fig. 5). *L. sativum* and

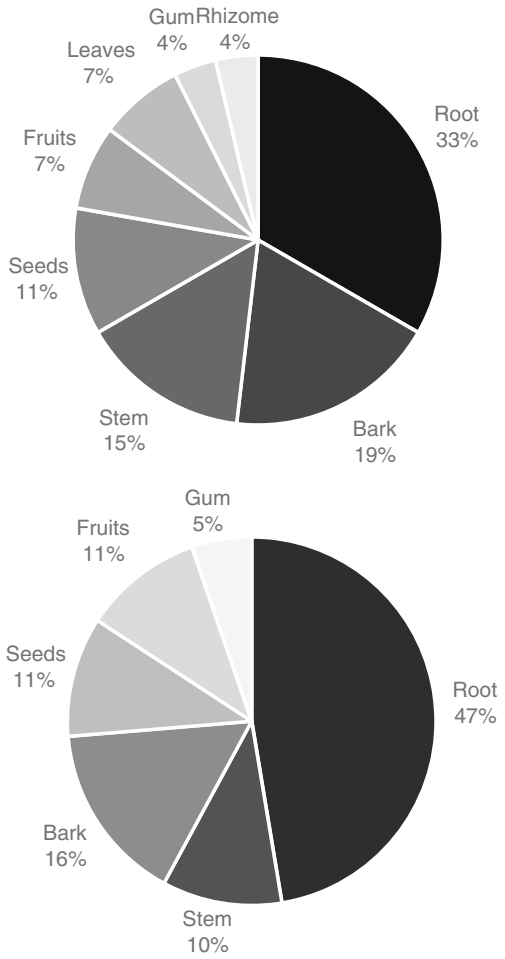

Fig. 4. Plant parts traded in Marsabit (*left*) and Moyale (*right*) towns as percentage of the total number of species.

M. spinosa were cheaper in Moyale (Fig. 5). It was estimated that 1300 kg of plant material was traded each year in Moyale (three most frequently traded species only), with an annual retail value of US$6300. Vendors reported that the prices and volumes sold did not change between the rainy and the dry seasons. Most vendors also mentioned that they did not sell most medicinal plant species on a daily basis as they did not have customers for them.

The Vendors

On average, vendors in Marsabit town sold eight medicinal plant species. All vendors also sold other items such as food, clothes, or jewelry because medicinal plant trade was "*not profitable enough*," and there "*were not enough costumers*" (vendors' comments). Vendors did not collect any plant material themselves; they either bought certain species from collectors going to the bushland around Marsabit town (those species found around Marsabit town) or from other vendors in Moyale (see Table 1). Most vendors in this town were women aged between 30 and 65 years, from the Boran ethnic group (a few Burgi and Gabra females were also interviewed). Vendors in Moyale town sold four medicinal plant species, on average. Like in Marsabit, all vendors in Moyale town were women aged between 30 and 55 years, mostly from the Boran ethnic group. Vendors did not collect the plants themselves, and they also traded other products such as food or clothes.

Complementary Data

The traditional healers in Marsabit town, mainly elderly women from the Boran ethnic group, were organized in an association in which each healer was specialized in a certain field (e.g., pregnancy problems). They communicated frequently so that they could send patients to each other. Most healers collected the medicinal plants they prescribed themselves, and they did not send patients to the market to buy them. Healers get some money once their costumer's health improves, regardless of how many plants the healer gives him/her or times the costumer visits the healer. Healers reported that the most common diseases in Marsabit town (respiratory diseases and stomach infections, as stated by them) could be treated with the medicinal plants available in the market, so that patients did not need their help for those common ailments, but only for more severe diseases (e.g., pneumonia). Traditional healers mentioned that they collected plant species mostly outside Marsabit FR. The doctors at the health centers in Marsabit town also reported that the most common health problems were respiratory diseases, stomach infections, and malaria, the treatment for the latter being subsidized by the Kenyan government.

The literature review revealed that no medicinal plant species identified in this study is considered endangered or vulnerable under the IUCN Red List. No species traded was found to be endemic to Marsabit FR or northern Kenya. Among the species mentioned in this study, *A. anthelmintica, M. africana*, and *Zanthoxylum usambarense* (Engl.)

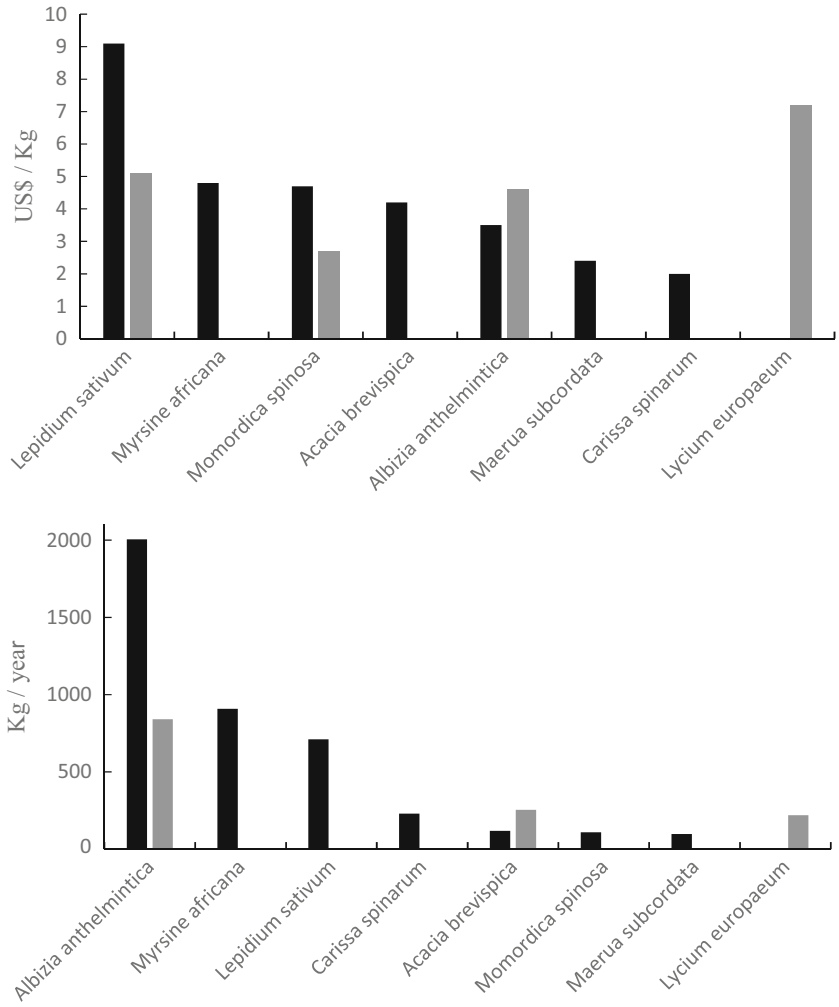

Fig. 5. Prices per kilogramg (*top*) and annual volumes in kilogram sold (*bottom*) of the most frequently traded species in Marsabit and Moyale towns (*black and gray columns*, respectively).

Kokwaro were among the species most traded in Kenya's major cities (Table 1).

Discussion

The Plants Traded and their Economic Importance

A total of 25 and 18 species were found to be traded in Marsabit and Moyale towns, respectively, making a total number of 30 species. Compared with other similar recent studies (e.g., Jusu and Cuni-Sanchez 2013; Posthouwer 2015; Quiroz et al. 2014; Towns et al. 2014; van Andel et al. 2012), the floristic diversity of the medicinal plant products traded in northern Kenya's major towns is relatively low. The annual volume traded (about 5500 kg, seven species only) was also lower than in the other above-mentioned studies. However, it should be noted that these other studies included several urban centers as well as the country capital, and we only studied two towns in one county. For example, Posthouwer (2015) assessed medicinal plant trade in Dar es Salaam in Tanzania and found at least 55 species being traded and an annual volume over 61,000 kg of non-powdered material.

Although we found fewer species and smaller volumes than in the other studies, the annual retail

value of medicinal plants just in Marsabit town (US$19,600 for the seven most frequently traded species) was considerable: it was about one third of the annual retail value of the three major cities in Sierra Leone together (Jusu and Cuni-Sanchez 2013). None of the species traded in Marsabit or Moyale towns had been reported in any of the above-mentioned other market surveys, including in Dar es Salaam. This is most likely related to the differences in vegetation. Most of these other surveys were conducted in the rainforest zone, whereas Marsabit town is located next to a montane forest and dry bushland and Moyale is a town surrounded by *Acacia-Commiphora* woodland.

Compared with studies from Kenya, the floristic diversity of the medicinal plant products traded in northern Kenya's major towns is also lower. Njoroge (2012) found that 89 species were traded by vendors in Nairobi and Thika, but only 43 species were mentioned more than 15 times. Muriuki et al. (2012) reported that 150 species were traded by herbal medicine enterprises in Kenya's four major cities, but that only 27 species were mentioned traded by more than 5% of the enterprises. These studies did not indicate the origin of the plant species traded. Considering the wide range of ecosystems that exist in Kenya, it is likely that they were collected from a range of ecosystems, not only dry montane forests or dry bushland, like in the two towns studied. Three species traded in northern Kenya's major towns (*A. anthelmintica, M. africana*, and *Z. usambarense*) were among the species most traded in Kenya's major cities (Muriuki et al. 2012; Njoroge 2012).

With regard to the plant parts traded, we found that roots were the most frequently traded plant part, similar to the case in Ghana (van Andel et al. 2012), but not in Sierra Leone (Jusu and Cuni-Sanchez 2013). Roots, seeds, and bark have a long shelf life, so they are transportable over long distances without perishing, making these plant parts more suitable for trade (van Andel et al. 2012). However, Muriuki et al. (2012) found that mostly leaves were traded by herbal medicine enterprises in Kenya's four major cities. In our study, we only found three fresh products in Moyale, which is likely because both towns studied are located in a dry area where fresh leaves or fruits could deteriorate before being sold, making their trade in fresh form unviable. Our observations show that the most expensive species traded was *L. sativum* (seeds). It has been argued that there is an inverse and disproportionate relationship between the price per kilogram and the mass of the plant part traded. Therefore, seeds are often the most expensive products (Williams et al. 2007), which was also the case in our study.

Main Uses and Origin of the Plants Traded

In this study, the medicinal plants traded were mainly used to treat respiratory diseases, although bone and joint pain, stomach ache, and women's health were other major aliments frequently treated. This differs from surveys in other countries. While in Benin the main uses of medicinal plants traded in urban markets were women's health and malaria, and in Ghana women's health, in Sierra Leone they were malaria and worms, and in Uganda malaria and cough (Jusu and Cuni-Sanchez 2013; Namukobe et al. 2011; Quiroz et al. 2014; van Andel et al. 2012). In Dar es Salaam in Tanzania, digestive disorders and women's health were also among the major aliments treated with medicinal plants (Posthouwer 2015).

Respiratory diseases are likely to be predominant in northern Kenya because of two factors. First, traditional houses and huts are very smoky because of the small opening left for smoke to escape when cooking with firewood and warming the room during the rainy season (Bussmann 2006). And second, there are large quantities of sand and dust carried by the wind during the dry season (Cuni-Sanchez, personal observation). The relatively frequent need to treat bone and joint pain in Marsabit town may be linked to the large number of female firewood collectors who harvest firewood in the lowlands and carry it on their backs uphill over a long distance (Cuni-Sanchez, personal observation). Stomach ache and women's health are common ailments addressed with medicinal plants elsewhere, the latter often related to cultural or religious preferences (e.g., "*most doctors in health centers are male in Marsabit and most women do not feel at ease with them*," traditional healer's comment). Indeed, other studies have highlighted the limited access to reliable reproductive health care in Sub-Saharan Africa as one of the major drivers behind medicinal plant use (e.g., Towns 2014; van Andel et al. 2012). The case of malaria is different. Although malaria is prevalent in many communities in Kenya (Njoroge and Bussmann 2006), the fact that in northern Kenya malaria was not treated with medicinal plants can be explained by the relative ease of access to subsidized treatment in health centers. In this study, no vendor reported the uses of medicinal plants in the market as being male aphrodisiac.

Subsequent discussions with costumers, though, indicated that some plants such as garlic and *Moringa oleifera* Lam. seeds are frequently used for this purpose. The literature review also highlighted that some of the species traded can be used as a male aphrodisiac. It is possible that, because most vendors were Muslim women, they were unwilling to discuss this use openly.

The medicinal uses of several species found in this study have not been previously reported in the literature (e.g., Beentje 1994; Kokwaro 2009), for example, the uses of *A. brevispica* and *E. tirucalli* for women's health and *M. spinosa* and *R. myricoides* for respiratory diseases. More research is needed for these understudied species.

We were surprised to discover that of the 25 species traded in Marsabit town, only one was collected from a forest habitat: *M. africana*. This species is not found in Marsabit FR because it only grows at higher altitudes (Beentje 1994). In Moyale town, all species were collected nearby or were cultivated. The fact that no species traded were collected from Marsabit FR was an unexpected finding, which might be related to two factors: (1) local people in Marsabit town collect plants for themselves, or (2) local people prefer to use the plants that grow where their ethnic group was originally located (i.e., Ethiopia) even if plants available in Marsabit FR could be used to treat the same aliment. After discussions with traditional healers and patients, it seems that the latter explanation is correct. In fact, findings from interviews in other villages around Marsabit FR indicate that Samburu and Rendile people frequently collect and use plants from the forest (such as *Toddalia asiatica*), whereas Borana and Gabra people only collect and use plants from the bushland outside the FR, and they do not know the medicinal use of certain forest species such as *T. asiatica* (Cuni-Sanchez et al. 2016). *T. asiatica* is a forest liana used traditionally in the treatment of malaria, sprains, cough, fever, neuralgia, epilepsy, and dyspepsia, and extracts of the plant have been reported to have anticancer, anti-HIV, and antimicrobial properties (Rajkumar et al. 2008).

As noted above, the main ethnic groups in Marsabit town are Boran, Burgi, and Gabra. Historically, Gabra were nomadic pastoralists owning camels and living in the driest part of northern Kenya drylands (north of Marsabit town). The Boran were nomadic pastoralists owning cattle and goats and lived in the drylands along the Kenya–Ethiopian border. And the Burgi were farmers from the southern part of the Ethiopian highlands, growing teff (*Eragrostis tef* (Zucc.) Trotter) among other cereals (Fratkin and Roth 2005). These three ethnic groups settled in and around Marsabit town during colonial times, following a series of schemes towards the "sedentarization of pastoralists" (Fratkin and Roth 2005). More people settled in the past few years as they fled droughts and war (Dietz et al. 2015). Their original environment does not comprise a forest similar to Marsabit FR, which could explain why they, and their traditional healers, prefer to use "*the plants we know*" (participants' comment) such as those from the lowlands or cultivated in Ethiopia. Many plants traded in Marsabit town were also traded in Moyale, which is dominated by the Boran ethnic group. This finding highlights the strong effect ethnicity has on plant use, as has been previously reported by several authors (e.g., Assogbadjo et al. 2012).

The Vendors

In Marsabit and Moyale towns, middle-aged women were in charge of the medicinal plant trade. This is also often the case elsewhere in Africa (van Andel et al. 2012), although it was not the case in Dar es Salaam, Tanzania (Posthouwer 2015). In this study, vendors were not collectors and also were not specialized on medicinal plants, but combined this trade with other products because medicinal plant trade was "*not profitable enough*" (vendors' comment). This is different from other studies in which (1) vendors of medicinal plants only sell medicinal plants, (2) they mainly collect the plants themselves, and (3) they often act as healers (van Andel et al. 2012; Jusu and Cuni-Sanchez 2013). Because the vendors in our study area do not act as traditional healers, costumers only buy medicinal plants in the market to treat minor diseases (which can be self-medicated), while they would visit a traditional healer (who would collect and give them the plants directly) for more complicated aliments. This might be the reason why vendors cannot make a living solely from the medicinal plant trade.

Implications and Future Work

With regard to the sustainability of the existing trade, our results suggest that four species traded might be of conservation concern. These are non-abundant and located in very specific areas only (e.g., *Euphorbia heterochroma* Pax only found in Goff Crater, north of Marsabit town). Two of these species (*E. heterochroma* and *Turraea* sp.) were

collected for their roots, which were unsustainably harvested as the whole plant dies when it is uprooted. Informal discussions with collectors revealed that these two species "*are becoming difficult to find*," which suggests possible overexploitation. It should also be mentioned that there are two native subspecies of *E. heterochroma* in Kenya, and each might be considered "vulnerable" (Roy Gereau, personal communication), although the species as such is considered of "Least Concern" in the IUCN Red List. Comments like "*this species is becoming difficult to find*" were also made by collectors around Sololo area (e.g., for *M. spinosa* used for its roots). More research is needed to assess not only the relative abundance and distribution of these species but also current and potential alternative harvesting techniques. As mentioned by Schmelzer and Gurib-Fakim (2008), only about half the tropical African medicinal plant species have been studied enough in terms of ecology, biochemistry, general biology, etc., to understand the potential effects of harvesting on their conservation.

With regard to opportunities for further trade, our results indicate that there is a potential. As mentioned above, three species traded in Marsabit and Moyale towns were also among the species most traded in major urban markets in Kenya. Several other species commonly traded in major urban markets (Muriuki et al. 2012; Njoroge 2012) are abundant in Marsabit FR and Mt. Kulal forest (e.g., *O. europaea*, *Dovyalis abyssinica* (A. Rich.) Warb., *Strychnos henningsii* Gilg, *Croton megalocarpus* Hutch., and *T. asiatica* (L.) Lam.; see Cuni-Sanchez et al. 2016). While the demand trend for *A. anthelmintica*, *C. megalocarpus*, and *T. asiatica* is rising (Muriuki et al. 2012), *S. henningsii* is particularly short in supply (Njoroge 2012). Most herbal medicine enterprises prefer herbal materials from the wild (Muriuki et al. 2012). With improvement in road access (tarmac of the Moyale–Marsabit–Isiolo road to be completed by early 2017), these species could be sourced from northern Kenya. A central issue to be considered is harvesting techniques. A number of species which can be sustainably harvested often are not (e.g., *S. henningsii* roots and stem; see Kuria et al. 2012). Training workshops could be organized to teach sustainable harvest practices, as has been done for devil's claw (*Harpagophytum* spp.) in southern Africa (Stewart and Cole 2005). As formal enterprises on herbal medicine continue to establish and grow in trade in Kenya, there will be greater opportunities for more players to participate in business as collectors, producer business groups, or others in the trade chains (Muriuki et al. 2012). Forest-edge communities around Marsabit FR and other montane forests in northern Kenya could be some of these players. However, they will have to organize themselves (e.g., in forests' users groups), the harvesting, and the trade (strong links with end buyers such as formal enterprises on herbal medicine in major cities) if the medicinal plant trade is to help improve their livelihoods without negatively affecting the species' populations traded.

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