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IMPLICATION FOR *in situ* CONSERVATION OF INDIGENOUS SPECIES WITH SPECIAL REFERENCE TO WILD *Coffea arabica* L. POPULATION IN MOUNT MARSABIT FOREST, KENYA

[IMPLICACIONES PARA LA CONSERVACIÓN *in situ* DE ESPECIES INDIGÉNAS CON ESPECIAL REFERENCIA A LA POBLACIÓN SILVESTRE DE *Coffea arabica* L. EN EL BOSQUE DE LA MONTAÑA MARSABIT, KENYA]

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SUMMARY

Mt. Marsabit forest is the only forest in Kenya where *Coffea arabica* L. (Rubiaceae) occurs naturally in wild populations. This forest however is highly fragmented and decreasing at a rapid rate due to anthropogenic activities. This study assesses the diversity and structure of species of conservation concern with reference to wild coffee as basis for management, conservation and use of wild genetic resources in Kenya. A botanical inventory and diversity study identified 52 species of trees and shrubs, 12 species of herbs and six species of climbers and lianas were recorded and belonged to 35 families and 64 genera. Rubiaceae (Coffee family) was the richest family with nine species followed by Euphorbiaceae with six species. *Rinorea convallarioides* (Bak.f.) Eyles ssp. *marsabitensis* Grey-Wilson (Violaceae), an endemic species, and *Drypetes gerrardii* Hutch. (Euphorbiaceae), were the two most important species, accounting for more than third of the combined importance value. *Coffea arabica* was dominant in the forest undergrowth with a higher density occurring in the open patches where it was competing with other shrubs and small trees in the undergrowth. The success and future management and conservation strategy of this forest depend on how to conserve the forest genetic resources especially of this wild species.

Key words: Conservation; *Coffea Arabica*; Mt. Marsabit forest

RESUMEN

El bosque de la montaña Marsabit es el único bosque de Kenia donde se encuentran población silvestres de *Coffea arabica* L. (Rubiaceae) de manera natural. Este bosque se encuentra en un proceso rápida reducción y fragmentación debido a actividades antropogénicas. Se evaluó la diversidad y estructura de especies de interés para su conservación con referencias al café silvestre como una base para el manejo, conservación y aprovechamiento de recursos genéticos en Kenia. Se realizó un inventario y se identificaron 52 especies de árboles y arbustivas, 12 de herbáceas y 6 de trepadoras y lianas pertenecientes a 35 familias y 64 géneros. Rubiaceae (familia del café) fue la familia con mayor riqueza (9 especies) seguido de Euphorbiaceae (6 especies). *Rinorea convallarioides* (Bak.f.) Eyles ssp. *marsabitensis* Grey-Wilson (Violaceae), una especie endémica, y *Drypetes gerrardii* Hutch. (Euphorbiaceae), fueron las dos especies más importantes y representaron más de un tercio del valor combinado de importancia. *Coffea arabica* fue dominante bajo el dosel del bosque, con una mayor densidad en las áreas abiertas donde competía con otras especies de arbustivas y árboles pequeños en crecimiento. El éxito, manejo futuro y estrategia de conservación de este bosque dependerá de cómo conservar los recursos genéticos, en especial las especies silvestres.

Palabras clave: Conservación; *Coffea Arabica*; Bosque de montaña.

INTRODUCTION

Biodiversity inventory as a tool for guiding conservation planning at a local scale is under utilized, especially in tropical countries where technical capacity is often limited (Gordon and Newton, 2006). This tool is able to distinguish between sites not only by number of species (richness), but also by number of threatened species. Quantitative inventories provide vital information for identifying economically useful plants as well as rare, threatened or vulnerable species, which may require urgent conservation (e.g. Ssegawa and Nkuutu, 2006). Conserving species of special interest in tropical forest ecosystems ensures that the vital socio-economic and environmental services (e.g. wood and non-wood products, and soil and water conservation) are sustained for the livelihoods of the dependent or adjacent communities. However, many forests in the tropics currently face a variety of threats, which include: unsustainable harvesting practices, illegal encroachment, poor management, as well as degradation by the dependent communities (United Nations Development Programme [UNDP], 2006).

Coffea arabica originates from southwest and south Ethiopia, where it occurs naturally in the undergrowth of the montane rainforests between 1,000 and 2,000 m-asl (Schmitt *et al.*, 2005). Other places where it is found outside Ethiopia is Mt. Marsabit in northern Kenya and Mt. Boma in southeast Sudan. However, these areas and the respective coffee populations have not been sufficiently investigated (Gole, 2003). This study highlights the occurrence and distribution of species with conservation significance together with wild coffee in Mt. Marsabit forest. Mt Marsabit is an ecologically and socio-economically important ecosystem, located in Marsabit National Reserve. The reserve was established by the Kenya Government Notice 936 in 1948 (Synott, 1979) and is the only government gazetted forest in Marsabit district (Government of Kenya [GOK], 1996). The forested mountain is surrounded by a vast area of open dryland savanna thus attracting a variety of wildlife and is the only source of permanent surface water in the region. Communities living around the forest utilize it for fuel wood, timber and medicinal plants. They also obtain all their water from the wells and springs fed by the forest. Wild *Coffea arabica* is among the species of conservation concern in this forest. The highly diverse gene pool of these wild coffee populations is of international importance, because it constitutes an important potential for the breeding of new varieties.

Mt. Marsabit forest therefore has a high potential for genetic resources and needs to be preserved as a crucial water catchment and unique biodiversity refugia in the surrounding harsh arid environment. The aim of this study was to undertake a vegetation inventory and identify the structure of wild coffee and other associated species in Mt. Marsabit forest for the purpose of conservation of genetic resources and sustainable use of wild populations. This information will be essential in informing policies and strategies for ecological research and conservation of this unique island forest ecosystem in the arid lands of northern Kenya.

MATERIALS AND METHODS

Study site

The study was conducted within Mt. Marsabit forest in Marsabit district in the Eastern Province of Kenya, which lies between latitude 2°45' N and 4°7' N and longitude 37°57' E and 39°21' E. Mt. Marsabit forest covers an area of about 150 km^2, and has a unique floral and faunal biodiversity (Beentje, 1994; Adano, 2002). The forest is located on an extinct Holocene shield volcano with an old crater, Lake Paradise (Monr, 1962). It is a sub-humid cloud-montane forest of several hills surrounded at lower altitudes by arid and semi arid areas, and is isolated from the other dry zone forests of Samburu and Marsabit districts (Adano, 2002). It has an elevation of about 1700 m above sea level (m asl) with a mean maximum temperature of 26-28°C and a mean minimum temperature of 14-16°C. The mean annual rainfall is 800-1400 mm while the mean annual evaporation rate is 1450-2200 mm (Sombroek *et al.*, 1982). It has rich volcanic soils, which are well developed with high water retention capacity (GOK, 1996).

Forest sampling, measurement and species identification

Three belt transects of 18 × 1.2 km, 12 × 1.2 km and 5 × 1 km were laid in three parts of Mt. Marsabit forest representative of the vegetation. They were subdivided into 400 × 400 m quadrats, which were further subdivided into plots of 20 × 5 m. Sampling, assessments and measurements were carried out on randomly distributed plots among the quadrats. Eighty-one plots were sampled in the first transect, 61 in the second and twelve in the third transect giving a total of 154 sampled plots. In each plot, all trees and shrubs (≥5 cm dbh), herbs, climbers and lianas were identified and enumerated. The number of individuals of each tree and shrub species were counted and recorded. The cover of five vegetation layers: emergent (trees above 25 m high), overstorey (trees ranging between 9-24.9 m high), understorey (young trees and shrubs ranging 2-8.9 m high), shrub/ saplings (ranging 1-1.9 m high) and herb/seedling layer (<one meter high) were estimated. Environmental parameters such as slope and altitude were recorded. Voucher specimens were collected in duplicate for identification and deposited in the University of Nairobi herbarium.

The following values were calculated for every tree and shrub encountered: (1) relative frequency (Rf), which is the number of plots in which a species occurs divided by the total number of occurrences of all species in plots; (2) relative density (Rd), which is the number of individuals of a species divided by the total number of individuals of all species; (3) relative dominance (RD), which is the basal area of a species divided by the sum of basal areas of all species; (4) importance value (Iv), which was calculated by summation of Rf + Rd + RD. Vegetation data were analyzed with *Biodiversity.R* software version 2.1.0 (Kindt and Coe, 2005).

RESULTS

Species composition

A total number of 70 plant species was recorded belonging to 35 families and 64 genera. These were 52 species of trees and shrubs, twelve species of herbs and six species of climbers and lianas. The family represented by the highest number of species was Rubiaceae (Coffee family) with nine species followed by Euphorbiaceae (six), Oleaceae (five), Rutaceae (four), Capparaceae, Labiatae and Leguminosae (three each). *Rinorea convallarioides* (Bak.f.) Eyles ssp. *marsabitensis* Grey-Wilson (Violaceae), an endemic species, and *Drypetes gerrardii* Hutch. (Euphorbiaceae), were the two most important species, accounting for more than third of the combined importance value. The cumulative species area curve showed that all the species were detected in the study area. *Coffea arabica* had the highest density in the Rubiaceae family with an abundance of 80 trees/ha, which was higher than the abundance of some highly utilized trees in Kenya that were found in this forest, such as *Olea capensis* with 73 trees/ha, *Casaeria battiscombei* with 36, *Ocotea kenyensis* with 11, *Prunus africana* with 10, and *Osyris lanceolata* with two (Table 1). *Coffea arabica* was most dominant in the forest understorey together with *Erythroxylum emarginatum, Rytigynia bugoyensis, Dracaena laxixima, Heinsenia diervilleoides, Teclea hanangensis, Clausena anisata, Diospyros abyssinica* and *Ochna insculpta.*

The dbh of coffee was between 2-7 cm. It grew well and fruited in open patches with disturbed canopy and in the forest valleys with open sunlight as compared to the one under the canopy, which carried only a few fruits. This is because other shrubs and tree species that are apparently more competitive than coffee grow in the shade (e.g. *Chionanthus*, *Oxyanthus* and *Psychotria*). The coffee plants under the canopy were thinned out but very large and bushy

Impacts of human activities on species composition

Human activities such as firewood harvesting led to removal of canopy cover and undergrowth whereby more light reached the forest floor. This led to increase in species number and abundance of coffee plants together with herbs (e.g. *Barleria volkensii* Lindau, *Achyranthes aspera* L, *Vernonia brachycalyx* O. Hoffm., *Ricinus communis* L., *Ocimum gratissimum*, *Plectranthus ignarius* (Schweinf.) Agnew, *Indigofera arrecta* A.Rich., *Hibiscus calyphyllus* Car., *Pentas schimperiana* (A.Rich) Vatke ssp. *schimperiana*, *Solanum giganteum* Jacq. *Wuthamnia somnifera* (L.) Duna and *Triumfetta rhomboidea* Jacq.) and herbaceous climbers such as *Ryttya fruticosa* Lindau, *Dregea abyssinica* (Hochst.) K.Schum, *Jasminum abyssinicum* DC, *Jasminum fluminense* Vell., *Helinus mystacinus* (Ait.) Steud. and *Toddalia asiatica* (L.) Lam. The same holds true for shrubs and small trees that compete with coffee in the undergrowth (e.g. *Chionanthus*, *Oxyanthus* and *Psychotria*). Saplings of pioneer species like *Clausena anisata*, *Albizia gummifera*, *Olea capensis* and *Diospyros abyssinica* and were the most abundant in the open patches.

Other agroforestry species of conservation concern

Out of the 52 species of trees and shrubs identified in Mt. Marsabit forest, and according to the literature (e.g. from Maundu and Tengnäs, 2005 and Beetje, 1994), ten species were found to be of conservation concern in Kenya (Table 2). These were *Rinorea convallarioides* ssp. *marsabitensis* (Iv= 53.59), *Olea europaea* ssp. *Africana* (Iv= 14.99), *Teclea hanangensis* var. *hanangensis* (Iv= 9.83), *Olea capensis* (Iv= 5.34), *Coffea arabica* (Iv= 2.55), *Prunus Africana* (0.86), *Ocotea kenyensis* (0.55), *Cordia africana* (0.45), *Osyris lanceolata* (0.09) and *Premna maxima* (0.09). Except the first two, which were among the majority of the species, the rest were of low importance value indicating poor representation in the forest. The species density was significantly different indicating that some species were more preferred by the local people than others (Fig. 1). *R. convallarioides* ssp. *marsabitensis* was the most dominant species despite being endemic to this forest.

Table 1. Relative density (Rd), relative frequency (Rf), relative dominance (RD), importance value (Iv) abundance and canopy position of trees and shrubs encountered in Mt. Marsabit forest

Species	Habit	Rd	Rf	RD	Iv	Abundance (trees/ha)	Canopy position
Acacia brevispica	Shrub	0.445	0.500	0.07	1.02	42	s
Albizia gummifera	Tree	1.995	1.015	4.31	7.32	151	o
Apodytes dimidiata	Tree	0.755	2.745	3.04	6.54	61	o
Asparagus spp.	Shrub	0.165	0.350	0.25	0.77	34	s
Bauhinia tomentosa	Shrub	1.450	1.400	0.06	2.91	133	u
Boscia angustifolia	Tree	0.595	0.500	0.22	1.32	15	u
Casaeria battiscombei	Tree	0.110	0.495	0.06	0.67	36	o
Cassipourea malosana	Tree	6.590	4.685	6.66	17.94	512	o
Chionanthus battiscombei	Tree	0.340	0.805	0.35	1.49	32	o
Clausena anisata	Shrub	2.980	3.765	3.64	10.39	246	o
Coffea arabica	Shrub	1.040	1.490	0.02	2.55	80	s
Cordia africana	Tree	0.035	0.195	0.22	0.45	3	e
Croton dichogamous	Shrub	0.785	1.405	0.08	2.27	74	u
Croton megalocarpus	Tree	3.545	6.715	12.80	23.06	330	e
Diospyros abyssinica	Shrub	1.865	5.100	0.09	7.05	172	s
Dovyalis abyssinica	Shrub	0.755	2.445	0.84	4.04	66	o
Dracaena laxixima	Shrub	0.025	0.145	0.00	0.17	2	s
Drypetes gerrardii	Tree	18.235	8.605	23.18	50.02	1907	o
Ekerbegia capensis	Tree	0.195	0.795	0.69	1.68	17	o
Erythoxylum emarginatum	Shrub	6.140	6.350	0.30	12.79	12	u
Erythrococca bongensis	Tree	0.135	0.495	0.01	0.64	554	u
Euclea divinorum	Tree	0.210	0.650	0.03	0.89	20	u
Ficus natalensis	Tree	0.065	0.345	0.41	0.82	6	e
Flueggea virosa	Tree	0.085	0.150	0.02	0.25	8	u
Grewia fallax	Shrub	0.140	0.400	0.09	0.63	13	u
Heinsenia diervillioides	Shrub	0.140	1.540	0.07	1.75	43	u
Maerua crassifolia	Tree	0.380	0.400	0.04	0.82	56	u
Maytenus heterophylla	Tree	0.160	0.200	0.02	0.36	9	u
Ochna insculpta	Shrub	2.640	5.055	0.11	7.81	248	u
Ocimum suave	Shrub	1.410	0.805	0.03	2.24	299	u
Ocotea kenyensis	Tree	0.145	0.395	0.01	0.55	11	o
Olea capensis	Tree	0.920	2.49	1.93	5.34	73	o
Olea europaea	Tree	1.065	2.555	11.37	14.99	103	e
Osyris lanceolata	Shrub	0.020	0.050	0.02	0.09	2	u
Oxyanthus speciosus	Shrub	0.675	1.340	0.20	2.22	52	u
Premna maxima	Tree	0.010	0.050	0.03	0.09	1	o
Prunus africana	Tree	0.105	0.450	0.31	0.86	10	o
Psyadrax schimperiana	Tree	0.505	1.755	0.50	2.76	46	o
Psychotria kirkii	Shrub	0.040	0.100	0.02	0.16	8	s
Rhus natalensis	Tree	0.030	0.100	0.25	0.38	3	u
Rinorea convallarioides	Tree	27.230	8.015	18.34	53.59	2274	o
Ritchea albersii	Tree	0.405	1.145	0.10	1.65	24	u
Rytigynia bugoyensis	Shrub	0.530	1.240	0.09	1.86	41	u
Scutia myrtina	Shrub	0.105	0.495	0.06	0.66	9	u
Strychnos henningsii	Tree	5.310	4.760	3.64	13.71	718	u
Strychnos mitis	Tree	2.305	4.595	3.51	10.41	193	o
Tarenna graveolens	Tree	0.700	2.390	0.48	3.57	61	o
Teclea hanangensis	Tree	3.785	5.905	0.14	9.83	334	u
Teclea simplicifolia	Tree	1.460	0.700	0.09	2.25	138	u
Trema orientalis	Tree	0.080	0.195	0.08	0.36	6	o
Trichilia emetica	Tree	1.070	2.435	1.18	4.68	50	o
Vangueria madagascariensis	Tree	0.105	0.400	0.05	0.55	39	u

e- emergents, o- overstorey, u- understorey and s- shrub layer

Table 2. Description of species of conservation concern encountered in Mt. Marsabit forest

Species	Description	Growth	Significance
C. arabica	Endemic	Fast growing	Agroforestry
C. africana	Threatened	Moderate- slow growing	Fodder tree during dry season
O. kenyensis	Rare	Fairly slow growing	Hard wood
O. capensis	Rare	Poor seeder Slow growing	Termite- resistant timber
O.europaea ssp. *africana*	Threatened	Poor seeder Very slow growing Low germination rate	Heaviest wood known
O. lanceolata	Endangered	Poor seeder Very slow growing	Perfume extraction
P. maxima	Rare/ vulnerable	Slow growing	Hardwood
P. africana	Endangered	Fairly slow growing	Drug industry
R. convallarioides ssp. *marsabitensis*	Endemic/ rare	Fast growing	Fodder tree during the dry season Firewood
T. hanangensis var. *hanangensis*	Rare	Fairly fast growing	Timber

DISCUSSIONS

Diversity and structure of coffee in Mt. Marsabit forest

In the past, Mt. Marsabit forest has been recognized for its socio-economic and ecological services for the local communities but not for its unique floristic richness. Several species are under threat because of rarity or, as this study has shown, unsustainable methods of utilization. This forest is geographically isolated from others, and has several endemic, rare, threatened or vulnerable species of national and regional importance; all of which are important characteristics for determining areas of conservation priority (Githae *et al.,* 2007). Mt. Marsabit forest is the only source of wild coffee in Kenya. The shade loving species was widely distributed in the forest understorey and grew well in the open patches as compared with the undisturbed vegetation structure and deeply shaded understorey. This is the same case as observed in the montane rainforest of southwestern Ethiopia (Shmitt *et al.,* 2008).

This wild coffee is an important gene pool for future selection and breeding of improved cultivars (Denich *et al.,* 2003). Natural populations of coffee are likely to be the source of new resistance genes needed to cope with future evolution in the pathogens of a crop (Aga *et al.,* 2003). Some of these resistant cultivars have been identified through molecular markers (e.g. by Aga *et al.,* 2003 and Sera *et al.,* 2003). This will especially be the case if host populations are maintained *in situ* to allow co-evolution to occur and therefore, information on the amount and pattern of genetic variation of forest coffee populations in Kenya is a crucial variable in the planning process. This also requires limitations for the removal of canopy trees and undergrowth vegetation with particular attention to the protection and rejuvenation of old growth canopy species (Shmitt *et al.,* 2005).

Coffee is a crop that can grow intermixed with tropical trees and be produced in a habitat that can maintain birds and other important species (UNDP-GEF, 2004). Several shrubs and small trees that compete with coffee in the undergrowth were observed in this forest (e.g. *Chionanthus*, *Oxyanthus* and *Psychitria*). This small scale differences in the amount of shade and competing vegetation from different natural forest areas leads to a high variability in wild coffee yields among these forests (Shmitt *et al.,* 2008). Wild *C. arabica* will only be conserved in Mt. Marsabit forest when the potential value of the coffee genetic diversity can be transformed into real benefits for the communities in the forest regions. Furthermore, recent initiatives have shown that wild coffee can attain high prices on the international specialty market by emphasizing its wild provenance (Gole, 2003).

Other agroforestry species of conservation concern

Ten forest species were observed to be of economic significance and majority being threatened and rare. *R. convallarioides* ssp. *marsabitensis* is endemic to Mt. Marsabit forest and listed in the IUCN red list of threatened plants (Walter and Gillett, 1998). It was the most dominant species but also critically threatened by its use as dry season fodder. Harvesting of the whole tree/shrub for products other than timber, as is the case of this species, implies that the population size is remarkably reduced and this will have a serious genetic impact. Reproduction capacity of the affected population is affected and this may impact on the genetic viability by reducing it and therefore affecting future adaptability of future generations (Kigomo, 2001). Another species, *T. hanangensis* var. *hanangensis,* is a shrub, which is rare and only found in three other localities in Kenya namely: Matakweni hills, Moyale and Kilibasi (Beentje, 1994). This species was among the most dominant in the forest understorey. *O. europaea* spp. *africana* (Brown/wild olive) is an evergreen tree and once established can withstand poor soils with little moisture (Maundu and Tengnäs, 2005). It was the main emergent tree together with *Croton megalocarpus*. This species has the heaviest wood known and the most valuable firewood plant. The main firewood sold in Marsabit town comes from this species giving a reason for its selection. *O. capensis* (East African olive) is another species related to *O. europaea* and was common in the forest overstorey. It is becoming rare in Kenya due to over exploitation and has valuable termite-resistant timber. *O. lanceolata* (African sandal wood) is the only species in Santalaceae family and is an evergreen shrub (Beentje, 1994). It is endangered in Kenya having been heavily exploited for extraction of perfumes and is currently the subject of domestication and conservation. Farmers should be encouraged to plant this tree as an agroforestry species since it improves the soil. *P. africana* (Prunus) is an evergreen tree and rare in the wild due to bark extraction for medicinal purposes (Maundu and Tengnäs, 2005). It is used in manufacturing of drug used to manage complications associated with prostatism. Harvesting non-productive parts such as leaves or bark for medicine, as is the case with *P. africana*, will have indirect selection effects on viability and reproductivity of affected individuals (Kigomo, 2001). The heartwood of this species is very resistant to termite and fungal attacks and is favorable in agroforestry and afforestation (Mburu *et al.,* 2007). *P. maxima* is a hard wood with good timber and is vulnerable in Kenya (Beentje, 1994), and is also listed in the IUCN red list of threatened plants (Walter and Gillett, 1998). Other than Mt. Marsabit, it also occurs in Meru, which is located in the northeastern part of Mt. Kenya (Maundu and Tengnäs, 2005). The species had the least importance value thus confirming its vulnerability in Mt. Marsabit forest too. *O. kenyensis* (Camphor wood) is an evergreen tree and good for timber and is rare due to overexploitation.

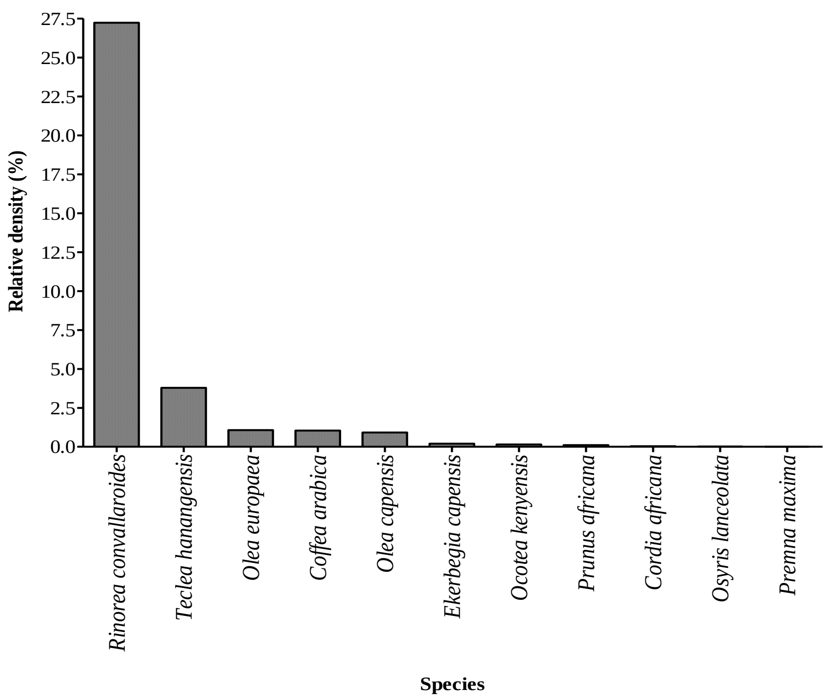

Figure 1. Relative density of all the species of conservation concern in Mt. Marsabit forest

The potential species of conservation significance that are mentioned are evergreen, slow growing and poor seeders and therefore more research should address their germination potential for use in agroforestry and afforestation. Furthermore, wild coffee populations contain germplasm, which are tolerant of coffee leaf rust and coffee berry disease and therefore, this coffee population in Marsabit forest should hence be addressed to provide information about its resistance, yield and conservation.

CONCLUSIONS

Our study has, therefore, shown that Mt. Marsabit forest has species richness with socio-economic and ecological value, and is also refugia for several endemic, rare, threatened and vulnerable plant species, which should be conserved. A conservation concept needs to integrate the remaining forest into a protected area so that the natural structure and species composition of the forest is maintained.

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