A botanical inventory and diversity assessment of Mt. Marsabit forest, a sub-humid montane forest in the arid lands of northern Kenya

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Abstract

A botanical inventory and diversity of trees, shrubs (≥5 cm diameter at breast height [dbh]), herbs, climbers and lianas was assessed in plots (154) of 20 × 5 m in Mt. Marsabit forest, northern Kenya. We recorded 52 species of trees and shrubs, twelve species of herbs and six species of climbers and lianas. They belonged to 35 families and 64 genera. Rubiaceae was the richest family with nine species followed by Euphorbiaceae (six), Oleaceae (five), Rutaceae (four), Capparaceae, Labiatae and Leguminosae (three each). The rest of the families were represented by one or two 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. Species diversity indices were 2.735 (Shannon–Wiener), 0.88 (Simpson's) and 0.296 (Evenness). There was a strong evidence of disturbance arising from anthropogenic and wildlife foraging activities. This inventory has affirmed Mt. Marsabit forest as a unique habitat for several endemic, rare, threatened or vulnerable plant species, which should be conserved.

Key words: conservation, diversity, inventory, Mt. Marsabit forest

Résumé

Il a été procédé à l'inventaire et à l'étude de la diversité botanique des arbres, des arbustes (≥5 cm dbh), des herbes, des plantes grimpantes et des lianes dans 154 plots de 20 × 5 m dans la forêt de Marsabit, dans le nord du Kenya. Nous avons relevé 52 espèces d'arbres et d'arbustes, 12 espèces d'herbes et six espèces de plantes grimpantes et de lianes. Elles appartenaient à 35 familles et à 64 genres. Les Rubiaceae étaient la famille la plus riche, avec neuf espèces, suivie par les Euphorbiaceae (six), les Oleaceae (cinq), les Rutaceae (quatre), les Capparaceae, les Labiatae et les Leguminosae (trois chacune). Les autres familles étaient représentées par une ou deux espèces. *Rinorea convallarioides* (Bak.f.) Eyles ssp. *marsabitensis* Grey-Wilson (Violaceae), une espèce endémique, et *Drypetes gerrardii* Hutch. (Euphorbiaceae), étaient les deux espèces les plus importantes, comptant pour plus d'un tiers de toutes les espèces combinées. Les indices de diversité des espèces étaient de 2.735 (Shannon–Wiener), 0.88 (Simpson's) et 0.296 (régularité). Il y avait des signes évidents de perturbations causées par les activités humaines ou par des animaux en quête de nourriture. Cet inventaire a permis d'affirmer que la forêt du mont Marsabit est un habitat unique pour plusieurs espèces végétales endémiques, rares, menacées ou vulnérables qui devraient être préservées.

Introduction

Botanical assessments are essential because of their value in understanding the extent of plant biodiversity in natural forest ecosystems (World Conservation Monitoring Centre [WCMC], 1992). They have direct implications for conservation and management of forest 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 & Nkuutu, 2006). Conserving species of special interest in tropical forest ecosystems ensures that

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the vital socio-economic and environmental services (e.g. soil and water conservation, and wood and nonwood products) 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).

This study highlights Mt. Marsabit forest, which 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 the district (Government of Kenya [GOK], 1996). Other forests in the district are Hurri hills, Mt. Kulal, Sololo hills, Kofia hills, Moyale hills, Godoma hills and Karare hills. The forested mountain stands alone like an oasis in the desert of wilderness thus attracting a variety of wildlife. It 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.

Although grazing, cutting of poles and collection of dead wood for fuel are controlled through licensing by the Forest Department, destruction of the forest is taking place at an alarming rate through illegal extractive activities and human encroachment from Marsabit town and other forest adjacent dwellers (Gachanja *et al.*, 2001). There is an increasing selective exploitation of ecologically and socio-economically important indigenous tree species, which is likely to lead to loss of plant diversity, environmental functions and services that have sustained the livelihoods of the local human and wildlife populations.

Although numerous botanists have collected plant specimens from the forest, no comprehensive vegetation studies have been undertaken (Synott, 1979). The flora is also poorly represented in herbaria but the isolation of this mountain with its strong Ethiopian links is of particular importance for conservation (Hedberg & Hedberg, 1968). This forest has a high potential for tourism 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 full inventory and evaluate the plant species diversity of Mt. Marsabit forest. A checklist of plant species encountered in Mt. Marsabit forest has been established for future reference. Additionally, the extent of disturbance is also reported. 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 the longitude 37°57′E and 39°21′E (Fig. 1). 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 sited 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 (Campbell & Hammond, 1989; Adano, 2002). It has an elevation of about 1700 m above sea level 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, Braun & Pouw, 1982). It has rich volcanic soils, which are well developed with high water retention capacity (GOK, 1996).

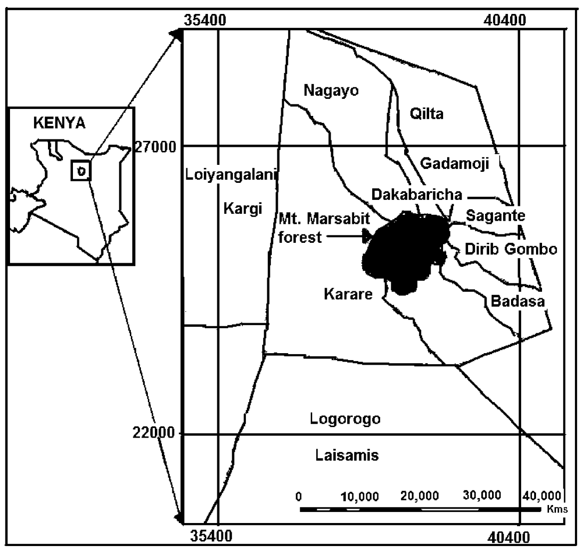

Fig 1 Location of the study site and its immediate environs

Forest sampling, measurement and species identification

Three belt transects of 18 × 1.2, 12 × 1.2 and 5 × 1 km^2 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. Voucher specimens were collected in duplicate for identification and deposited in the University of Nairobi herbarium.

Forest description

The following values were calculated for every tree and shrub encountered: (i) 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; (ii) relative density (Rd), which is the number of individuals of a species divided by the total number of individuals of all species; (iii) relative dominance (RD), which is the basal area of a species divided by the sum of basal areas of all species; and (iv) importance value (Iv), which was calculated by summation of Rf + Rd + RD.

Diversity of the forest community was described by means of diversity indices calculated using *Biodiversity. R* software version 2.1.0 (Kindt & Coe, 2005) as follows:
(1) Shannon–Wiener Index

$$H = -\sum_{i=1}^{s} \left(\frac{ni}{N}\right) \log_2 \left(\frac{ni}{N}\right)$$

(2) Simpson Index

$$D = \sum_{i=1}^{s} pi^2$$

(3) Evenness

$$E = \frac{\bar{H}}{\bar{H}_{\max}}$$

The cumulative number of species were plotted over the combined subplots to ensure that most species were detected in the sampling plots. Disturbance signs, e.g. forest tracks, stumps or damaged trees, and possible causes were also noted.

Results

Floristic richness and composition

A total number of 70 species were recorded. They were distributed as follows: 52 species of trees and shrubs, twelve species of herbs and six species of climbers and lianas. They belonged to 35 families and 64 genera. Rubiaceae was the richest family with nine species followed by Euphorbiaceae (six), Oleaceae (five), Rutaceae (four), Capparaceae, Labiatae and Leguminosae (three each). The rest of the families were represented by one or two species. Species area curve was asymptotic, suggesting that most plant species in the study area were detected (Fig. 2). Table 1 lists the species by family and also indicates their growth habits.

Species diversity indices were 2.735 (Shannon–Wiener), 0.88 (Simpson's) and 0.296 (Evenness). Table 2 presents the list showing relative density, relative frequency, relative dominance and importance values for each species. The most common species were *Rinorea convallaroides* ssp. *marsabitensis* (Violaceae) and *Drypetes gerrardii*

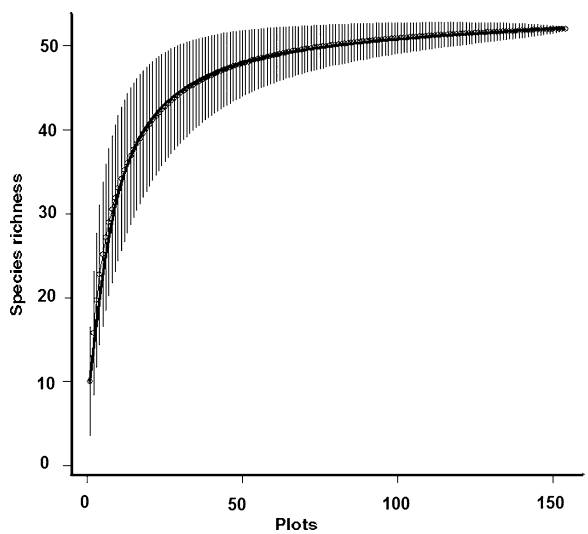

Fig 2 Species-area relationship for the study site based on a cumulative species count on 20 × 5 m plots. Data points plotted are the mean values of the plots with corresponding standard deviations as error bars

Table 1 A checklist of plant species encountered in Mt. Marsabit forest arranged in alphabetical order of families

Family	Species	Habit
Acanthaceae	*Barleria volkensii* Lindau	Herb
	Ryttya fruticosa Lindau	Climber
Agavaceae	*Dracaena laxissima* Engl.	Shrub
Anacardiaceae	*Rhus natalensis* Krauss	Shrub
Amaranthaceae	*Achyranthes aspera* L.	Herb
Asclepidiaceae	*Dregea abyssinica* (Hochst.) K.Schum.	Climber
Boraginaceae	*Cordia africana* Lam.	Tree
Capparaceae	*Boscia angustifolia* A. Rich.	Shrub
	Maerua crassifolia Forssk.	Shrub
	Ritchiea albersii Gilg	Tree
Celastraceae	*Maytenus heterophylla* (Eckl. & Zeyh.) Robson	Shrub
Compositae	*Vernonia brachycalyx* O. Hoffm.	Herb
Ebenaceae	*Diospyros abyssinica* (Hiern) F.White ssp. a*byssinica*	Tree
	Euclea divinorum Hiern	Shrub
Erythroxylaceae	*Erythroxylum emarginatum* Thonn.	Shrub
Euphorbiaceae	*Croton dichogamous* Pax	Tree
	Croton megalocarpus Hutch.	Tree
	Drypetes gerrardii Hutch.	Tree
	Erythrococca bongensis Pax	Shrub
	Flueggea virosa (Willd.) Voigt.	Shrub
	Ricinus communis L.	Herb
Flacourtiaceae	*Casaeria battiscombei* R. E. Fries	Tree
	Dovyalis abyssinica (A.Rich) Warb.	Tree
Icacinaceae	*Apodytes dimidiata* Arn.	Tree
Labiatae	*Ocimum gratissimum* L.	Herb
	Ocimum suave L.	Shrub
	Plectranthus ignarius (Schweinf.) Agnew	Herb
Lauraceae	*Ocotea kenyensis* (Chiov.) Robyns & Wilczek	Tree
Leguminosae	*Acacia brevispica* Harms ssp. *brevispica*	Shrub
	Albizia gummifera (JF Gmel.) C.A. Sm. var. *gummifera*	Tree
	Bauhinia tomentosa L.	Shrub
	Indigofera arrecta A.Rich	Herb
Liliaceae	*Asparagus* spp.	Shrub
Loganiaceae	*Strychnos henningsii* Gilg	Tree
	Strychnos mitis Moore	Tree
Malvaceae	*Hibiscus calyphyllus* Car.	Herb
Meliaceae	*Ekebergia capensis* Sparrm.	Tree
	Trichilia emetica Vahl.	Tree
Moraceae	*Ficus natalensis* Hochst.	Tree
Ochnaceae	*Ochna insculpta* Sleumer	Shrub
Oleaceae	*Chionanthus battiscombei* (Hutch.) Stearn	Tree
	Olea capensis L.	Tree
	Olea europaea L. ssp. *africana* (Mill.) P. Green	Tree
	Jasminum abyssinicum DC	Climber
	Jasminum fluminense Vell	Climber
Rhamnaceae	*Scutia myrtina* (Burm.f.) Kurzs	Shrub
	Helinus mystacinus (Ait.) Steud.	Climber
Rhizophoraceae	*Cassipourea malosana* (Bak.) Alston	Tree
Rosaceae	*Prunus africana* (Hook.f.) Kalkm.	Tree
Rubiaceae	*Coffea arabica* L.	Shrub
	Heinsenia diervilleoides K.Schum.	Shrub
	Oxyanthus speciosus DC. ssp. *stenocarpus* (K.Schum.) Bridson ined.	Tree
	Pentas schimperiana (A.Rich) Vatke ssp. *schimperiana*	Herb
	Psychotria kirkii Hiern	Shrub
	Psydrax schimperiana (A.Rich.) Bridson ssp. *Schimperiana*	Tree
	Rytigynia bugoyensis (K.Krause) Verdc.ssp. *bugoyensis*	Tree
	Tarenna graveolens (S.Moore) Brem.	Tree
	Vangueria madagascariensis Gmel.	Tree
Rutaceae	*Clausena anisata* (Willd.) Benth.	Tree
	Teclea hanangensis Kokwaro var. *hanangensis*	Tree
	Teclea simplicifolia (Engl.) Verdoorn	Tree
	Toddalia asiatica (L.) Lam.	Liana
Santalaceae	*Osyris lanceolata* Hochst. & Steudel	Tree
Solanaceae	*Solanum giganteum* Jacq.	Herb
	Wuthamnia somnifera (L.) Duna	Herb
Tiliaceae	*Grewia fallax* K. Schum.	Shrub
	Triumfetta rhomboidea Jacq.	Herb
Ulmaceae	*Trema orientalis* (L.) Bl.	Tree
Verbenaceae	*Premna maxima* T.C.E. Fries	Tree
Violaceae	*Rinorea convallarioides* (Bak.f.) Eyles ssp. *marsabitensis* Grey-Wilson	Tree

Table 2 Relative density (Rd), relative frequency (Rf), relative dominance (RD) and importance value (Iv) of trees and shrubs encountered in Mt. Marsabit forest

Species	Rd	Rf	RD	Iv
Acacia brevispica	0.445	0.5	0.07	1.015
Albizia gummifera	1.995	1.015	4.31	7.32
Apodytes dimidiata	0.755	2.745	3.04	6.54
Asparagus spp.	0.165	0.35	0.25	0.765
Bauhinia tomentosa	1.45	1.4	0.06	2.91
Boscia angustifolia	0.595	0.5	0.22	1.315
Casaeria battiscombei	0.11	0.495	0.06	0.665
Cassipourea malosana	6.59	4.685	6.66	17.935
Chionanthus battiscombei	0.34	0.805	0.345	1.49
Clausena anisata	2.98	3.765	3.64	10.385
Coffea arabica	1.04	1.49	0.015	2.545
Cordia africana	0.035	0.195	0.22	0.45
Croton dichogamous	0.785	1.405	0.08	2.27
Croton megalocarpus	3.545	6.715	12.8	23.06
Diospyros abyssinica	1.865	5.1	0.085	7.05
Dovyalis abyssinica	0.755	2.445	0.835	4.035
Dracaena laxixima	0.025	0.145	0	0.17
Drypetes gerrardii	18.235	8.605	23.175	50.015
Ekebergia capensis	0.195	0.795	0.69	1.68
Erythoxylum emarginatum	6.14	6.35	0.295	12.785
Erythrococca bongensis	0.135	0.495	0.01	0.64
Euclea divinorum	0.21	0.65	0.025	0.885
Ficus natalensis	0.065	0.345	0.41	0.82
Flueggea virosa	0.085	0.15	0.015	0.25
Grewia fallax	0.14	0.4	0.085	0.625
Heinsenia diervilleoides	0.14	1.54	0.07	1.75
Maerua crassifolia	0.38	0.4	0.04	0.82
Maytenus heterophylla	0.16	0.2	0.015	0.375
Ochna insculpta	2.64	5.055	0.11	7.805
Ocimum suave	1.41	0.805	0.025	2.24
Ocotea kenyensis	0.145	0.395	0.005	0.545
Olea capensis	0.92	2.49	1.93	5.34
Olea europaea	1.065	2.555	11.365	14.985
Osyris lanceolata	0.02	0.05	0.02	0.09
Oxyanthus speciosus	0.675	1.34	0.2	2.215
Premna maxima	0.01	0.05	0.025	0.085
Prunus africana	0.105	0.45	0.305	0.86
Psyadrax schimperiana	0.505	1.755	0.5	2.76
Psychotria kirkii	0.04	0.1	0.015	0.155
Rhus natalensis	0.03	0.1	0.25	0.38
Rinorea convallaroides	27.23	8.015	18.34	53.585
Ritchea albersii	0.405	1.145	0.095	1.645
Rytigynia bugoyensis	0.53	1.24	0.085	1.855
Scutia myrtina	0.105	0.495	0.06	0.66
Strychnos henningsii	5.31	4.76	3.635	13.705
Strychnos mitis	2.305	4.595	3.505	10.405
Tarenna graveolens	0.7	2.39	0.48	3.57
Teclea hanangensis	3.785	5.905	0.14	9.83

Table 2 (Continued)

Species	Rd	Rf	RD	Iv
Teclea simplicifolia	1.46	0.7	0.09	2.25
Trema orientalis	0.08	0.195	0.08	0.355
Trichilia emetica	1.07	2.435	1.175	4.68
Vangueria madagascariensis	0.105	0.4	0.045	0.55

(Euphorbiaceae), which accounted for more than third of the combined importance value. These were followed by *Croton megalocarpus*, *Cassipourea malosana*, *Olea europaea*, *Strychnos henningsii*, *Erythroxylum emarginatum*, *Strychnos mitis*, *Clausena anisata* and *Teclea hanangensis* var. *hanangensis.*

The size class distribution of stems with dbh ≥ 10 cm exhibited a roughly negative exponential, or 'inverse J', curve (Fig. 3). On the other hand, species with dbh < 10 cm (size class 1) had lower density than the next size class of dbh 10–19 cm (size class 2). Species with dbh < 10 cm included seedlings and saplings, and represented 23% of the total number of stems. The lower number of size class 1 than class 2 was attributed to undergrowth disturbance by grazing livestock and wildlife.

Disturbance

The highest incidence of stumps occurred with *R. convallaroides* and *O. europaea*; they were mainly targeted for fodder during the dry season and firewood collection, respectively. Wild browsers, mainly elephants, damaged *Bauhinia tomentosa* and *Vangueria madagascariensis*, while *C. megalocarpus* trees were burnt down or felled in search of

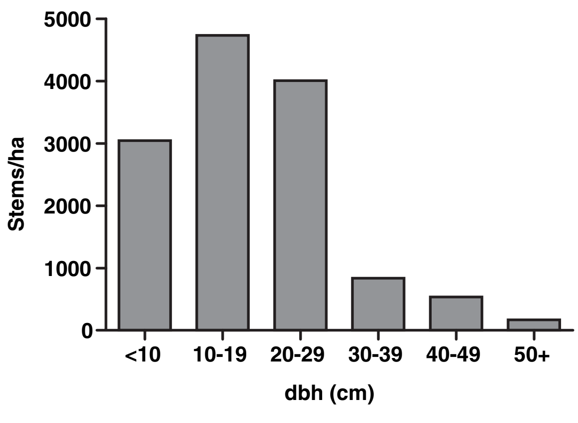

Fig 3 Stem size class distribution in Mt. Marsabit forest

honey by the local communities. Seedlings and saplings of *C. anisata*, *Albizia gummifera* var. *gummifera*, *Coffea arabica*, *Olea capensis* and *Diospyros abyssinica* were partially disturbed by grazing. They constituted the majority of stem size class 1 described above. Forest tracks were mainly caused by the Kenya Wildlife Services (KWS) patrol trucks, animals, and timber and fuel wood collectors.

Discussion

Floristic richness and composition

The species richness recorded for Mt. Marsabit forest lies within the range reported for tropical forests, often higher than 50 (Lind & Morrison, 1974), but was much lower than most East African forests (e.g. Linder, 2001). Species richness in Mt. Marsabit forest was lower than in the other well-known and studied indigenous forests in Kenya. For example, Mutangah, Mwangangi & Mwaura (1992) recorded 147 plant species in Kakamega tropical rainforest whereas Blackett (1994) recorded 161 species in Mt. Kenya moist montane forest. The highest documented species richness in any of Kenya's indigenous forests was 280 plant species for the Mau forest reserve complex, which covers an area of about 360,000 ha (Mutangah, Mwangangi & Mwaura, 1993). One of the possible explanations for low species richness in Mt. Marsabit forest was its low Evenness Index (0.296), compared, for example, to the Kakamega tropical rain forest fragments of Buyangu and Isecheno, which were 0.80 and 0.84, respectively (Fashing & Gathua, 2004). The relatively low Evenness Index indicated that a few species dominated the forest as corroborated by our results.

Most of the plant species found in Mt. Marsabit forest also occur in other indigenous Kenyan forests, for example, *A. gummifera* and *Prunus africana* (Kakamega and Mau forest), *C. megalocarpus* (Mathews range, Mt. Kenya and Kakamega forest) and *O. europaea* (Mathews range, Mt. Kenya and Meru). On the other hand, *Trema orientalis* has a pan-tropical distribution. The families of trees and shrubs that dominated Mt. Marsabit forest were Rubiaceae and Euphorbiaceae. These are often among the most species-rich families in tropical forests, as was also recently reported for a tropical high forest in the Ssese islands of Lake Victoria, central Uganda (Ssegawa & Nkuutu, 2006). The wild coffee plant species, *C. arabica*, had the highest relative density among the Rubiaceae in Mt. Marsabit forest. This documentation signifies an important botanical link with the wild populations of southeastern and southwestern highland forests of Ethiopia. In Euphorbiaceae, *C. megalocarpus*, a pioneer tree species, dominated the emergent layer while *D. gerrardii* had the second highest importance value in the entire forest.

Species of conservation concern

In the past, Mt. Marsabit forest has been recognized for its socio-economic and ecological services for the local communities (e.g. Wass, 1995) 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 (WCMC, 1992). *R. convallarioides* ssp. *marsabitensis* is endemic to Mt. Marsabit forest and listed in the IUCN red list of threatened plants (Walter & Gillett, 1998). It was the most dominant species but also critically threatened by its use as dry season fodder. Another species, *T. hanangensis* var. *hanangensis*, is rare and found in only three other localities in Kenya, namely, Matakweni hills, Moyale and Kilibasi (Beentje, 1994). It was among the most dominant in the forest understorey. *Premna maxima* is vulnerable in Kenya (Beentje, 1994), and is also listed in the IUCN red list of threatened plants (Walter & Gillett, 1998). Other than Mt. Marsabit, it also occurs in Meru, which is located in the northeastern part of Mt. Kenya (Maundu & Tengnäs, 2005). The species had the least importance value thus confirming its vulnerability in Mt. Marsabit forest too. *Osyris lanceolata* is endangered in Kenya due to overexploitation, and is currently the subject of domestication and conservation. *O. capensis* is also becoming rare due to overexploitation for its valuable and termite-resistant timber (Maundu & Tengnäs, 2005). The two species were found in Mt. Marsabit forest in small populations and formed the forest overstorey. *P. africana* is rare in the wild due to bark extraction for medicinal purposes (Maundu & Tengnäs, 2005). In this study, there was no evidence of its exploitation, and it was also part of the forest overstorey.

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. The checklist will provide valuable information for developing management plans to utilize the forest resources sustainably and conserve the rare or threatened species. In undertaking the management plans and conservation actions, the local communities should be involved and empowered to manage the forest through participatory forest management approaches. Pressure on the forest due to illegal extractive activities can be mitigated through introduction of appropriate agroforestry technologies.

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