Ethnobotanical survey of medicinal plants used by communities on the fringes of Budongo Central Forest Reserve, Uganda

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Research

Abstract

Background: The resurgence of interest in traditional medicine, amid growing antimicrobial resistance, underscores the need to document and preserve indigenous ethnobotanical knowledge. Budongo Forest Reserve in Western Uganda is a biodiversity hotspot with communities whose traditional medicinal practices remain underexplored. This study aimed to document medicinal plants used by communities around the Budongo Forest Reserve and their associated ethnomedicinal practices.

Methods: A cross-sectional ethnobotanical survey was conducted in December 2023 among 25 respondents selected via snowball and purposive sampling. Data were collected using semi-structured questionnaires and open interviews, focusing on plant use, preparation methods, and disease treatment. Voucher specimens were identified and authenticated, and data were analysed using descriptive statistics, citation frequency, and preference ranking.

Results: Seventy (70) medicinal plant species belonging to 34 families and 66 genera were documented as treatments for 43 different health conditions. Dominant families included Asteraceae (15.7%) and Fabaceae (8.6%). The most cited species were *Erythrina abyssinica*, *Agapanthus africanus*, and *Hoslundia opposita*, used to manage syphilis, ulcers, erectile dysfunction, and malaria. Leaves (56.2%) were the most used plant parts, with remedies prepared primarily by squeezing (34.7%), decoction (31.9%), or infusion (22.2%), and administered mainly orally (70.3%).

Conclusions: Communities around Budongo Forest Reserve possess rich ethnomedicinal knowledge and are heavily reliant on native flora. Certain species' high citation and preference scores underscore their cultural and therapeutic importance. Bioactivity-guided research is recommended to validate the therapeutic claims, particularly for under-investigated species with high local use values.

Keywords: Ethnobotany, Traditional medicine, Medicinal plants, Budongo Forest, Uganda

Background

The twenty-first century has witnessed a new era of diseases characterised by outbreaks of multidrug-resistant pathogens (Baker *et al*. 2022). In this context, there has been increasing resistance to conventional drugs that has led to treatment failures (Nwobodo *et al*. 2022). The absence of essential medicines (access crisis), inadequate infrastructures, and indiscriminate use of drugs, among other factors, have promoted resistance among pathogenic organisms (Aparicio-Blanco *et al*. 2024). The World Health Organization recently ranked antimicrobial resistance as one of the top global public health threats, responsible for up to 1.2 million deaths (WHO 2023). Thus, there is an increasing need to embrace the diverse nature of traditional, complementary, and integrative medicine utilized among indigenous communities globally, to provide evidence-based, people-centered, and universal health coverage benefits (Patwardhan *et al*. 2023; von Schoen-Angerer *et al*. 2023).

Medicinal plants have a long history of use in disease management, with communities still cherishing the use of herbal formulations in treating some diseases and complex medical conditions (Dal Cero *et al*. 2022; Sánchez *et al*. 2020). Plants have been the source of active pharmaceutical ingredients in most modern drugs, with the potential to provide lead compounds for novel drugs (Muangphrom *et al*. 2016; Nasim *et al*. 2022). Documentation of ethnobotanical knowledge regarding medicinal plants that indigenous communities use is essential because such information can inform scientists about which compound-structure relationships should be investigated (Willsky *et al*. 2020).

In Eastern Africa, more than 1800 bioactive molecules have been isolated from at least 250 plants identified by ethnobotanical surveys (Simoben *et al*. 2020). However, ethnobotanical studies in the region are far from complete due to the large number of ethnic groups and rich floral diversity (Beentje 2015; Du *et al*. 2023; Tabuti *et al*. 2023). Such a gap may lead to loss of ethnomedicinal information due to widespread deforestation, adoption of modern lifestyles, climate change, industrialisation and urbanisation pressures (Arjona-García *et al*. 2021). To our knowledge, previous studies in communities around Ugandan Forest Reserves indicated a rich ethnobotanical knowledge of medicinal plants used by indigenes, with up to 131 plant species identified (Asiimwe *et al*. 2021; Galabuzi *et al*. 2016; Ojelel *et al*. 2019; Tugume *et al*. 2016). A two-decade-old study around Budongo Forest Reserve cited the use of some climbers in herbal medicine, but its focus was not entirely ethnobotanical in nature (Eilu & Bukenya-Ziraba 2004). The present study was explicitly undertaken to unravel the ethnobotanical knowledge of medicinal plants used by local communities around the Budongo Forest Reserve, a biodiversity hotspot with diverse ethnic groups, a rich cultural heritage, and a distinguished use of plants in herbal medicine.

Materials and Methods

Study area

This study was conducted in Budongo Sub-County, Bujenje County, on the fringes of the Budongo Forest Reserve in Masindi District (Figure 1). Budongo Forest Reserve, Budongo Central Forest Reserve or simply Budongo Forest, is a typical semi-deciduous tropical rain forest situated at the top of the Albertine Rift (01°43’27”N 31°32’45”E). It is a rich forest which is globally known for endemic and endangered/critically endangered species such as the Eastern chimpanzees (*Pan troglodytes schweinfurthii),* the parasitic plant (*Afrothismia winkleri*), *Brazzeia longipedicellata*, *Dialium excelsum*, essential birds such as Puvel's illadopsis *Illadopsis puveli* and the Yellow-footed Flycatcher *Muscicapa sethsmithi* (Hobaiter et al. 2017; NEMA 2018). Budongo is an 82,530-hectare Central Forest Reserve with six forest blocks namely: Biiso, Busaju, Kaniyo-Pabidi, Nyakafunjo, Siba and Waibira. These blocks are eco-tourism sites (Ahimbisibwe 2018; Uganda Wildlife Authority 2020). The forest is at an average altitude of 1,100 m above sea level. It is drained by four rivers (Waisoke, Sonso, Kamirambwa, and Siba) that snake northwest to the Albertine Rift (Babweteera 2014).

The annual rainfall in Budongo Forest Reserve is 1200-2200 mm (average 1600 mm), with a characteristic wet season between March and May and September and November, while the dry months are December and February. The temperatures fluctuate from 19°C to 32°C (Ahimbisibwe 2018; Babweteera 2014). Most of the land around Budongo Forest Reserve is under cultivation, especially for sugarcane (Ateenyi 2018). To the North is Murchison Falls National Park, while in the West are the fishing villages of Lake Albert, the latter currently being the source of the discovered Ugandan oil, characterised by various construction activities (Babweteera 2014). Recently, the United Nations Commission on Human Rights launched a campaign to specifically conserve trees in the Budongo Forest Reserve, which further inspired the current study.

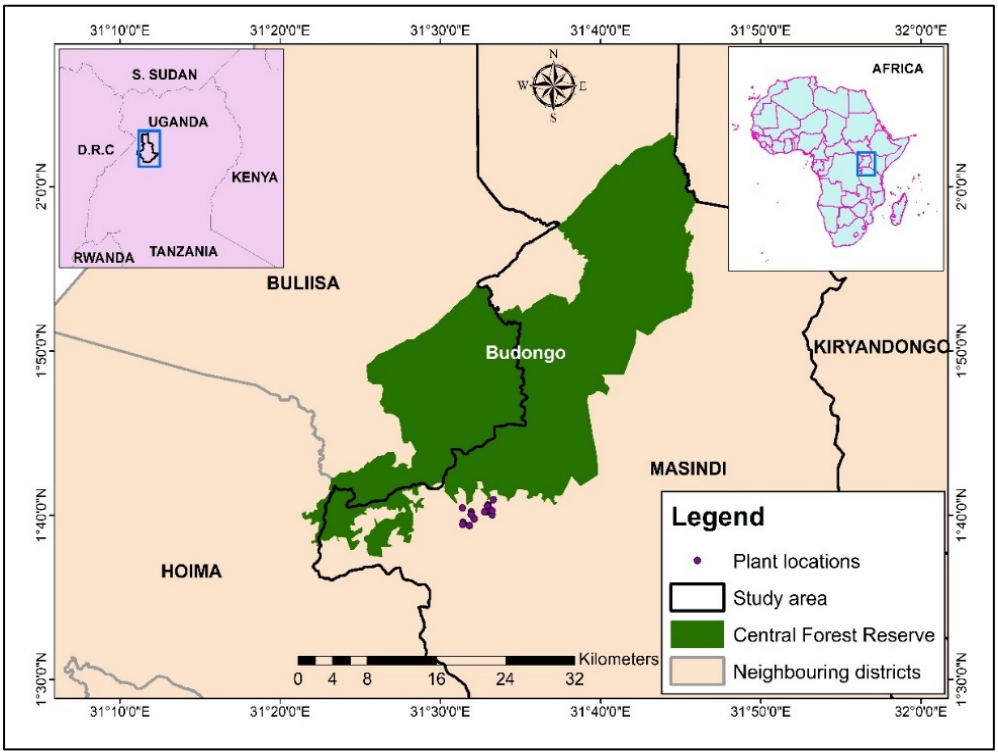

Figure 1. Map of Uganda showing the location of the study area around Budongo Forest Reserve, Masindi District

Sampling design

A cross-sectional survey was done in Budongo Sub-County in December 2023, a month after a reconnaissance study in the same area. The villages considered were Nyabyeya 1, Nyabyeya 2, Nabyeya Trading Center, Kisarabwire (in Nyabyeya Parish), Kyempunu, Marram, and Nyabigoma (in Karongo Parish). With the help of local representatives, the most renowned herbalists and knowledgeable community members were sampled using snowball and purposive sampling techniques until saturation was attained (Asiimwe *et al*. 2021; Tabuti *et al*. 2023). Based on these sampling methods, herbalists were interviewed, but in each case, they were asked to refer the researchers to another herbalist they knew. The study was primarily conducted in Runyoro, the principal language spoken in the area.

Collection and analysis of ethnobotanical data

Semi-structured pre-tested questionnaires were used to collect ethnobotanical data on medicinal plants used in the area (Supplementary File S1). The questionnaires probed into the demographic characteristics, knowledge, attitudes, and practices related to the treatment of diseases in the area, including plant species used and their sources, the methods of preparation, administration, and the ailments or conditions for which the species are used. All the plants cited by the respondents were obtained during field tours. A botanist from the Department of Pharmacy at Mbarara University of Science and Technology (Uganda) authenticated the prepared voucher specimens. The botanical names of the cited species followed the nomenclature in the International Plant Name Index and the World Flora Online.

Ethnobotanical data were collated in Microsoft Excel (Microsoft Corporation, USA). Qualitative data were subjected to descriptive statistical analysis to provide percentages and frequencies. On the one hand, quantitative ethnobotanical data were used to calculate the frequency of citation (FC). On the other hand, preference ranking of the ten most used plant species and diseases commonly treated by them was done by ten key informants according to the importance of the species as FC and known effectiveness. The values assigned for each species were summed up for all the informants to get an overall rank value (Martin 1995; Tugume *et al*. 2016).

Results and Discussion

Socio-demographic characteristics of the respondents

In this study, the 25 informants were primarily females (60%), aged 40-60 years (60%) (Table 1). They were married farmers (60%) who stopped at primary level (52%) and therefore earned less than or about 100,000 Ugandan shillings (approximately $ 26) per month. This aligns well with previous studies in Western Uganda, where females over 40 years old were the most

significant number of respondents (Asiimwe *et al*. 2021; Gumisiriza *et al*. 2023). Ethnobotanical studies in Uganda have reported higher participation rates among females than males, most likely because females are often responsible for their families' healthcare (Adia *et al*. 2014; Gumisiriza *et al*. 2023). It is also known that females tend to participate in ethnobotanical studies owing to their rich indigenous knowledge of herbal recipes (Asiimwe *et al*. 2014; Nalumansi *et al*. 2014). Interestingly, most respondents earned less than or about 100,000 Ugandan shillings per month, which is typical of a developing country. Such low monthly incomes, in addition to the availability and satisfaction they provide to the population, could be a contributing factor to the preference for herbal medicine over conventional medicine (Olukya 2022). We identified incidences of concurrent utilization of herbal and orthodox medicine in treating diseases among the studied communities, corroborating previous reports from Uganda (Apolot *et al*. 2023; Logiel *et al*. 2021; Tabuti *et al*. 2023). This is also an expected treatment-seeking behaviour in most developing countries (Beiersmann *et al*. 2007; Diallo *et al*. 2006; Orellana-Paucar *et al*. 2021), likely be instigated by the sturdy resistance of pathogenic microorganisms and changes in the sociodemographic, economic and cultural landscapes (Chali *et al*. 2021).

Table 1 Socio-demographic characteristics of the respondents (n = 25)

Characteristic	Categories	Frequency	Percentage
Gender	Male	10	40
	Female	15	60
Age (years)	20-40	05	20
	40-60	15	60
	≥60	05	20
Occupation	Farmer	15	60
	Trader	05	20
	Herbalist	05	20
Marital status	Married	15	60
	Widowed	05	20
	Single	04	16
	Divorced	01	04
Level of education	Illiterate	05	20
	Primary	13	52
	Secondary	06	24
	College	01	04
Monthly income (Ugandan shillings)	Unemployed	01	04
	≤100,000	18	72
	100,000-300,000	03	12
	300,000-500,000	03	12

Knowledge of herbal medicine and treatment-seeking behaviour

Most respondents reported using herbal medicine due to its effectiveness (60%, n = 15), affordability (28%, n = 7), and ease of accessibility (12%, n = 3). They reported using traditional medicine for 5-20 years (76%, n = 19) and 20-50 years (20%, n = 5), while one respondent (4%) had used herbal medicine for more than 50 years. It was found that knowledge of traditional medicine is acquired mainly through family members (92%, n = 23) or rarely through community members (8%, n = 2). Regarding treatment options, herbal medicine was the most preferred treatment sought (56%, n = 14), followed by a combination of both herbal and modern medicine (36%, n = 9) but in extreme cases, modern/conventional medicine (8%, n = 2) becomes the only option. This aligns with previous findings that knowledge of traditional medicine in African societies is often passed down through heredity, as it remains highly guarded family secrets (Bagwana 2015). In most instances, knowledge is maintained through continual practice, which may be transmitted verbally from one generation to the next (Ouma 2022).

Plant species usage, ailments and conditions treated

This study identified 70 medicinal plant species from 34 families, spread across 66 genera (Table 2). *Asteraceae* (15.7%), followed by *Fabaceae* (8.6%), *Acanthaceae*, *Lamiaceae*, and *Solanaceae* (5.7% each) were the major families (Figure 2). The most represented genera were *Solanum* (3 species), *Annona* and *Gymnanthemum* (2 species each). Overall, the most frequently mentioned species were *Erythrina abyssinica* Lam. (7 times) and *Agapanthus africanus* (L.) Hoffmanns (5 times), *Hoslundia opposita* Vahl (4 times), *Bidens pilosa* L., *Conyza sumatrensis* (Retz.) E. Walker, *Gymnanthemum amygdalinum* (Delile) Sch. Bip., *Hydnora abyssinica* A. Braun, *Lantana camara* L. and *Ricinus communis* L. (3 times each). Regarding

preference for medicinal plants, *Erythrina abyssinica* Lam. was the most highly ranked of the ten medicinal plants. It featured as the only plant exclusively used to treat syphilis in the study area (Table 3). The species identified in this study were primarily members of well-known botanical families that tend to dominate the results of ethnobotanical surveys due to their widespread global distribution (Ajao *et al*. 2019). Moreover, members of the Asteraceae and Fabaceae families are well known for their phytochemicals, such as phenolics, tannins and alkaloids, which have therapeutic effects (Tanase *et al*. 2019; Tungmunnithum *et al*. 2018). Some of the most frequently cited species in this study have been reported to treat these diseases in other studies. For example, *Erythrina abyssinica* has been cited for the treatment of venereal diseases (Schultz *et al*. 2020), specifically syphilis (Musinguzi *et al*. 2017). Similarly, *Albizia coriaria*, *Gymnanthemum amygdalinum* (synonym: *Vernonia amygdalina*) and *Carica papaya* have been cited for treating malaria in Uganda (Adia *et al*. 2014; Anywar *et al*. 2016; Tabuti *et al*. 2023), Zimbabwe (Ngarivhume *et al*. 2015), Cameroon (Pierre *et al*. 2011) and Kenya (Omara 2020). *Tamarindus indica*, indicated for treating throat cancer in this study, was recently cited as an ingredient of preparation for the treatment of prostate and cervical cancers (Kudamba *et al*. 2023). Roots and barks of *Citropsis articulata* (Kamatenesi-Mugisha and Oryem-Origa, 2005; Ssegawa and Kasenene 2007) and *Mondia whitei* (Agea *et al*. 2008; Asiimwe *et al*. 2021; Kamatenesi-Mugisha and Oryem-Origa 2005; Kokwaro 2009; Mbuni *et al*. 2020; Tolo *et al*. 2023; Tugume *et al*. 2016) are used in Uganda and Kenya for the management of erectile dysfunction.

The tendency to use more than a single plant part in herbal formularies is often due to specific reasons such as masking the adverse effects of toxic but therapeutic herbal remedies or due to possible synergistic effects of such plants (Stangeland *et al*. 2011; Tugume *et al*. 2016) but in some cases are used as a trick of hiding the secrecy of the formularies (Kuria *et al*. 2001; Omara 2020). It was interesting to note that most herbal preparations were made from materials collected from the wild, suggesting the communities' dependence on wild-crafted materials. It was interesting to realize that some herbalists were interested in conserving the species by growing them in their gardens, consistent with a previous observation (Tabuti *et al*. 2023).

The medicinal plants were used to treat only one to two diseases or conditions, except for a few species like *Agapanthus africanus*, *Annona muricata*, *Bidens pilosa*, *Coffea canephora* and *Solanum gilo* that were indicated to be used for the treatment of up to five diseases. About 43 diseases or complex conditions are treated using herbal preparations (Figure 3; Table 2). Of these, prolapsed rectum, ulcers (7.6% each), syphilis, wounds (6.3% each), erectile dysfunction and malaria (5.1% each) were the most treated.

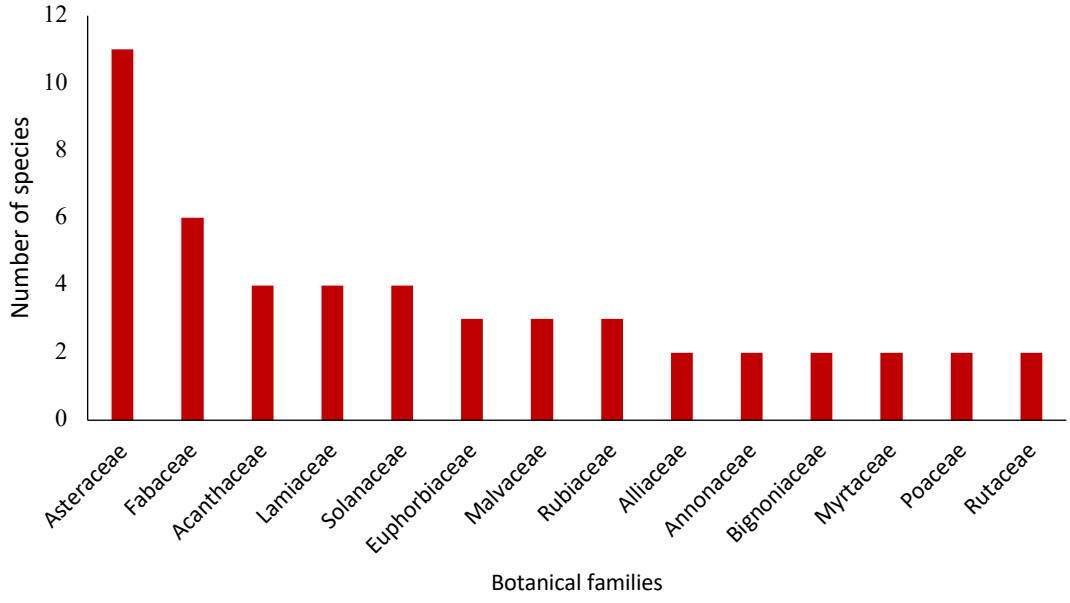

Figure 2. Family wise distribution of medicinal plant species used by communities around Budongo Forest Reserve, Western Uganda.

Table 2. Inventory of medicinal plants used by communities around Budongo Forest Conserve, Western Uganda

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
KI01	Muzabibu (Runyoro)	*Annona muricata* L. (Annonaceae)	Headache	Stem bark	Dried and pulverised	Nasal. A little powder is sniffed thrice/day	Tree/garden	2	Least Concern
			Joint pains Vomiting Malaria	Fresh leaves	Mixed with leaves of *Persea americana* and roots of *Carica papaya* and then decocted together to treat	Oral. One full cup of the decoction is taken thrice/day			
KI02	Ekiko (Runyoro)	*Erythrina abyssinica* Lam. (Fabaceae)	Syphilis	Fresh stem bark	Mixed with water and decocted	Oral. One full cup of the decoction is taken thrice/day until healing is observed	Tree/bush	7	Least Concern
KI03	Omutima gwensi (Runyoro)	*Hydnora abyssinica* A. Braun (Hydnoraceae)	Ulcers Hypertension	Whole plant	Ground and mixed with seeds of *Persea americana*, and then the mixture is decocted	Oral. The mixture is taken thrice/day using a cup	Herb/bush	2	Least Concern
			Prolapsed rectum Heart diseases		The whole plant is decocted	Topical. The decoction is applied to the protruding rectum thrice /day Oral. For heart disease, half a cup is taken thrice/day			
KI04	Omurondwa (Runyoro)	*Mondia whitei* Skeels (Apocynaceae)	Erectile dysfunction	Fresh roots	Dried and ground. Powder is used to make an infusion	Oral. Half teaspoon is taken thrice/day	Climber/ forest	1	Endangered
KI05	Katimboro (Runyoro)	*Citropsis articulata* Swingle & Kellerman (Rutaceae)	Erectile dysfunction	Dried stem bark	Ground to form a powder and infusion made	Oral. Half a teaspoon is taken thrice/day	Shrub/forest	1	N.A
KI06	Neem (Runyoro)	*Azadirachta indica* A.Juss. (Meliaceae)	Malaria	Fresh leaves	Infusion made	Oral. Half cup is taken thrice/day	Tree/garden	2	Least Concern
KI07	Omusikambuzi (Runyoro)	*Warburgia ugandensis* Sprague (Canellaceae)	Malaria Chest pain	Stem bark	Dried stem barks are pulverised, and the powder is decocted.	Oral. A teaspoon of the decoction is drunk twice/day	Tree/forest	2	Endangered
KI08	Paipai-bwana (Swahili)	*Carica papaya* L. (Caricaceae)	Yellow fever	Fresh roots	Mixed with roots of *Musa* ssp., and red sugar cane juice is added; then the mixture is decocted	Oral. Half a cup is taken twice/day	Tree/garden	2	Data Deficient

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
KI09	Mapera (Runyoro/Swahili)	*Psidium guajava* L. (Myrtaceae)	Diarrhoea	Fresh leaves	Squeezed, infusion made	Oral. A cup of the infusion is taken twice/day	Shrub/garden	2	Least Concern
			Prolapsed rectum		Infusion made	Rectal. The patient sits in a basin full of the infusion 5 times/day			
KI10	Omujaja (Runyoro)	*Ocimum tenuiflorum* L. (Lamiaceae)	Hypertension	Leaves	The mixture of the plant parts is decocted together	Oral. A full glass of the mixture is taken thrice/day until the patient sweats	Grass/garden	1	N.A
KI11	Ekijanicai (Runyoro)	*Cymbopogon citratus* (hort. ex DC.) Stapf (Poaceae)		Leaves				1	N.A
KI12	Ovocado (Runyoro)	*Persea americana* Mill. (Lauraceae)		Seeds			Tree/garden	1	Least Concern
KI13	Ekibirizi (Runyoro)	*Gymnanthemum amygdalinum* (Delile) Sch. Bip. (Asteraceae; Synonym: *Vernonia amygdalina* Delile)	Malaria	Leaves/roots	The mixture of all the plants is decocted, and *Carica papaya* leaves are added	Oral. The patient takes one full glass of the mixture three times a day until he/she develops sweat	Shrub/bush	3	N.A
KI14	Ekisogasoga (Runyoro)	*Ricinus communis* L. (Euphorbiaceae)		Leaves			Shrub/bush	3	Least Concern
KI15	Akasekera (Runyoro)	*Lantana camara* L. (Verbenaceae)		Leaves			Shrub/bush	3	N.A
KI16	Omukasiya (Runyoro)	*Cassia spectabilis* DC. (Fabaceae)		Leaves			Tree/bush	1	Least Concern
KI17	Akitunguru ekikoto (Runyoro)	*Allium cepa* L. (Alliaceae)		Bulb			Bulb/garden	1	N.A
KI18	Hibiscus (English)	*Hibiscus sabdariffa* L. (Malvaceae)	Sickle cell anaemia	Leaves	Infusion prepared	Oral. A full cup is drunk once a day	Shrub/garden	1	N.A
KI19	Omusambya (Runyoro)	*Markhamia lutea* K.Schum. (Bignoniaceae)	Alcoholic disorders	Flowers	The fresh flowers are mixed with the roots and flowers of coffee plants and boiled together to form a decoction	Oral. A little of the mixture is added to alcohol, and the patient takes twice/day	Tree/bush	1	Least Concern
KI20	Omuyembe (Runyoro)	*Mangifera indica* L. (Anacardiaceae)	Cough and flue	Leaves	The two plants' fresh leaves are mixed with *Lantana camara* leaves, and infusion is prepared	Oral. A cup of the mixture is drunk thrice/day	Tree/garden	1	Data Deficient
KI21	Omukalitunsi (Runyoro)	*Eucalyptus globulus* Labill. (Myrtaceae)					Tree/garden	1	Least Concern

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
KI22	Lenga (Alur)	*Agapanthus africanus* (L.) Hoffmanns (Alliaceae)	Back pain	Fresh leaves	Squeezed and juice used	Topical. The mixture is applied once/day on the back after making some cuts for 3 days	Bulb/bush	5	N.A
			Syphilis		Squeezed, and a little water is added	Oral. A glass of the mixture is drunk once/day until the patient gets well			
			Discoid eczema and swollen legs		Pounded and juice made	Oral/topical. The paste is applied three times a day to the skin, and three tablespoons of the juice formed are drunk thrice daily			
			Bone setting and dislocations		Pounded, and the juice is use	Topical. The mixture is applied thrice/week to the affected part (wrapped with a bandage, accompanied by small sticks to keep the bones in shape) until the patient heals			
			Prolapsed rectum		Fresh leaves are squeezed and mixed with powdered sprouts of germinating millet	Oral. Half a cup of the mixture is drunk thrice daily			
KI23	Omutugunda (Runyoro)	*Vangueria apiculata* K.Schum. (Rubiaceae)	Fresh wounds	Leaves	Fresh leaves are squeezed and wrapped on the wound in a poultice	Topical. 1 poultice is put on the wound once a day until recovery	Tree/bush	1	Least Concern
KI24		*Jatropha curcas* Wall. (Euphorbiaceae)	Wounds	Sap	Used directly	Topical. A small drop of the sap is put twice/day.	Shrub/garden	1	Least Concern
KI25	Ekinyamusunsu (Runyoro)	*Tetradenia riparia* (Hochst.) Codd (Lamiaceae)	Cough	Fresh leaves	Squeezed, and a little water is added	Oral. A full glass of the mixture is drunk thrice/day	Shrub/bush	1	Least Concern
KI26	Enzitoima (Runyoro)	*Hoslundia opposita* Vahl (Lamiaceae)	Ulcers, wounds	Fresh leaves	Boiled to make an infusion	Oral. A full cup of the infusion is taken twice/day	Shrub/bush	4	N.A
KI27	Enkuku	*Cajanus cajan* (L.) Millsp.		Leaves			Shrub/garden	1	N.A

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
	(Runyoro)	(Fabaceae)	"Ebihara" (abnormal swelling of the stomach), wounds and ulcers		Leaves from all the herbs are mixed together and boiled to form an infusion	Oral. One full cup of the mixture is taken thrice/day			
KI28	Enjagi (Runyoro)	*Solanum gilo* Raddi. (Solanaceae)		Leaves			Shrub/garden	2	N.A
KI29	Omukura (Runyoro)	*Bidens pilosa* L. (Asteraceae)		Leaves			Herb/bush	3	N.A
KI30	Omwani (Runyoro)	*Coffea canephora* Pierre ex A.Froehner (Rubiaceae)		Leaves			Tree/garden	1	Least Concern
KI31	Omucuya (Runyoro)	*Sida acuta* Burm.f. (Malvaceae)	Paronychia	Fresh leaves	Squeezed to make a juice	Topical. The mixture is used once a day until the paronychia bursts (tightened on the affected part with a cloth to remove pus)	Shrub/bush	2	N.A
			Migraine		Squeezed to make juice	Topical. The paste is applied once a day			
KI32	Obucumita bagenge (Runyoro)	*Oxygonum sinuatum* (Hochst. & Steud. ex A.Rich.) Benth. & Hook.f. ex Dammer (Polygonaceae)	Paronychia	Fresh leaves	Wrapped in plantain leaves and warmed in hot ash to soften the tissues	Topical. The leaves are wrapped on the Paronychia twice/day	Herb/bush	1	N.A
KI33	Ekitojo (Runyoro)	*Acanthus pubescens.* Thomson ex Oliv. Engl. (Acanthaceae)	Syphilis	Fresh roots	Washed, chopped and then decocted	Oral. A full cup is taken twice/day until recovery	Shrub/bush	2	N.A
KI34		*Conyza sumatrensis* (Retz.) E.Walker (Asteraceae)	Toothache	Fresh leaves	Used directly	Oral. The leaves are chewed twice/day	Herb/bush	3	N.A
			Ulcers		Infusion made	Oral. One full cup of the infusion of the infusion is taken thrice/day			N.A
KI35	Kavamagombe (Luganda)	*Cissampelos mucronata* A. Rich. (Menispermaceae)	Erectile dysfunction	Fresh roots	Cleaned, pounded with water and then decocted	Oral. Half nice cup of the decoction is taken twice/day	Climber/bush	1	N.A
KI36	Omuhotora (Runyoro)	*Xymalos monospora* Baill. (Monimiaceae)	Sickle cell anaemia	Fresh roots	Cleaned, chopped and decocted. Germinated millet powder is then added to the decoction and stirred well	Oral. 1 glass of the mixture is taken thrice/day for 1 year	Tree/forest	1	Least Concern

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
KI37	Ekikaijo (Runyoro)	*Saccharum officinarum* L. (Poaceae)	Prolapsed rectum	Stem (peelings)	Dried and burnt to form ash, which is later put on the rectum	Topical. A small amount of the ash is applied thrice/day	Grass/garden	1	N.A
KI38	Kamara mahano (Runyoro)	*Euphorbia hirta* L. (Euphorbiaceae)	Asthma	Fresh roots	Cleaned, dried and pulverised and infusion made	Oral. A teaspoon of the powder is used thrice/day	Herb/bush	1	N.A
KI39	Omutatembwa (Runyoro)	*Zanthoxylum gilletii* (De Wild.) P.G.Waterman (Rutaceae)	Ulcers	Fresh stem bark	Decocted	Oral. A small glass of the mixture is taken twice/day	Tree/forest	1	Least Concern
KI40	Entutu (Runyoro)	*Physalis peruviana* L. (Solanaceae)	Allergy	Fresh leaves	Squeezed, and a little water is added to make the juice	Oral. A small glass of the juice is taken twice/day	Herb/bush	2	Least Concern
			Difficulty in breathing		Squeezed to obtain juice	Nasal. A few drops of juice are put in the nostrils twice/day until the patient recovers.			
KI41	Entanga luyira (Luganda)	*Tridax procumbens* L. (Asteraceae)	Ear discharge (otorrhea)	Fresh leaves	Squeezed (a little water added) to make juice, which is dropped into the infected ear. Sometimes used with *Gymnanthemum amygdalinum* leaves	Auricular. A few drops of the juice are put twice/a day	Herb/bush	1	N.A
KI42	Obugora (Runyoro)	*Solanum aethiopicum* Jacq. (Solanaceae)	Dizziness	Ripe fruits	Pounded to form juice. Sometimes fruits of *Solanum gilo* Raddi.	Oral. A full glass of the juice is taken twice/day	Shrub/garden	1	N.A
KI43	Engango (Runyoro)	*Solanecio mannii* (Hook.f.) C.Jeffrey (Asteraceae)	Shortness of breath (dyspnea)	Fresh roots	Cleaned and decocted	Oral. The decoction is drunk until the patient gets healed	Shrub/bush	2	Least Concern
			Asthma	Fresh leaves	Squeezed and juice drunk	Oral. 1 cup full cup of the juice is taken until the patient vomits			
KI44	Omufoka/ omuhindukira (Runyoro)	*Dicliptera laxata* C.B. Clarke (Acanthaceae)	Stunted growth in women	Leaves	Fresh leaves are squeezed and drunk	Oral. 1 cup is taken twice/ day until results are observed.	Herb/garden	1	N.A
KI45	Karandaranda (Rutooro)	*Galinsoga parviflora Cav.* (Asteraceae)	Syphilis	Fresh leaves	Squeezed and later, juice from the leaves of *Conyza*	Oral. The mixture is drunk by taking 1 glass twice a	Herb/garden	1	N.A

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
					sumatrensis is extract is added	day, and the marc from the juice is applied to the body			
KI46	Omusisa (Runyoro)	*Albizia coriaria* Welw ex Oliver (Fabaceae)	Genital warts	Fresh stem bark	Decocted	Oral. Two teaspoons of the decoction are taken twice/day	Tree/forest	1	Least Concern
KI47	Omubengeya (Runyoro)	*Annona senegalensis* Pers. (Annonaceae)	Prolapsed rectum	Fresh stem bark	Pounded and mixed with a little water in a basin, and the patient is made to sit in	Rectal. The patient sits in the basin twice/day until healing is observed	Tree/forest	1	Least Concern
KI48	Omukoma (Runyoro)	*Grewia bicolor* Juss (Malvaceae)	Prolapsed rectum	Fresh stem bark	Pounded and mixed with a little water in a basin, and the patient is made to sit in	Rectal. The patient sits in the basin twice/day until healing is observed	Tree/bush	1	N.A
KI49	Kanyamwani (Runyoro)	*Oxyanthus speciosus W.T.Aiton* (Rubiaceae)	Antidote for poisoning	Fresh stem bark	Decocted	Oral. A cup of the decoction is drunk, and the patient vomits immediately. It is advised the patient chews sugarcane	Shrub/bush	1	Least Concern
KI50	Ekimyula (Luganda)	*Tithonia diversifolia* (Hemsl.) A.Gray (Asteraceae)	Abdominal pains and menorrhagia	Fresh leaves	Mixed with those of *Hoslundia opposita* Vahl and then squeezed to form juice	Oral. 2 cups of the juice are drunk twice/day	Shrub/bush	1	N.A
KI51	Ekyango/ Ekijuba nkuba (Runyoro)	*Luffa aegyptiaca* Mill. (Cucurbitaceae)	Ringworms	Fresh leaves	Squeezed to form a paste and rubbed on the affected area	Topical. The paste is applied twice/day	Climber/bush	1	N.A
KI52	Akajuma (Runyoro)	*Gymnanthemum auriculiferum* (Hiern) Isawumi (Asteraceae)	Erectile dysfunction	Fresh roots	Fresh roots are mixed with those of *Acanthus pubescens a*nd decocted	Oral. Two glasses of the decoction are taken twice/day	Tree/bush	1	Least Concern
KI53	Nalongo (Luganda)	*Justicia betonica* L. (Acanthaceae)	Malaria	Fresh leaves	Boiled to make an infusion	Oral. Half cup of the infusion is drunk twice/day.	Herb/bush	1	N.A
KI54	Orugusuru (Runyoro)	*Solanum incanum* L. (Solanaceae)	Enlarged prostate glands	Fruits	The ripe fruits are heated on fire, then cut, and the juice is squeezed out and	Topical. This is applied every day until the patient heals.	Shrub/bush	2	Least Concern

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
					applied to the area around the glands				
			Tooth decay	Fresh roots	Cleaned and pounded to form a paste	Oral. The paste is put directly on the cavity twice /day.			
KI55	Omusomoro (Runyoro)	*Ficus exasperata* Vahl (Moraceae)	Swollen limbs	Fresh stem bark	Decocted with germinated millet sprout powder to enable extraction of ingredients	Oral. A glass of the mixture is taken twice/day	Tree/bush	1	Least Concern
KI56	Omulemangundu (Runyoro)	*Stereospermum kunthianum* Cham. (Bignoniaceae)	Antidote for poisoning	Fresh stem bark	Chewed	Oral. A few stem barks are chewed twice daily until the poison is urinated.	Tree/bush	1	Least Concern
KI57	Omugorogoro (Runyoro)	*Dracaena fragrans* (L.) Ker Gawl. (Asparagaceae)	Syphilis and gonorrhoea	Stem bark	Fresh stem barks are decocted	Oral. The decoction is taken until the patient gets better	Shrub/bush	2	Least Concern
KI58	Eyobyo (Runyoro), Akeyu (Alur)	*Cleome gynandra* L. (Capparaceae)	Labour pains	Roots	Fresh roots are washed and chewed	Oral. ½ pieces of the roots are chewed once a day	Herb/bush	1	N.A
KI59	Utwiyu (Alur)	*Indigofera arrecta* Hochst. ex A.Rich. (Fabaceae)	Haemophilia	Leaves	Fresh leaves are pounded to make juice.	Oral. Two cups of juice are taken twice/day	Shrub/bush	1	N.A
KI60	Aliya (Alur)	*Thunbergia alata* Bojer ex Sims (Acanthaceae)	Diarrhoea	Leaves	Fresh leaves are squeezed to make juice	Oral. 1 cup of the juice is drunk twice/day	Climber/bush	1	N.A
KI61	Ukwiyu (Alur)	*Dysphania ambrosioides* (L.) Mosyakin & Clemants (Amaranthaceae)	Migraine	Leaves	Fresh leaves are squeezed to make a paste, which is applied to the forehead	Topical. The paste is applied twice a day until recovery	Herb/bush	1	N.A
KI62	Cwa (Alur)	*Tamarindus indica* L. (Fabaceae)	Throat cancer	Fruits	The ripe fruit is mixed with water or put in porridge	Oral. A cup of the mixture is taken thrice/day	Tree/bush	1	Least Concern
KI63	Kanyunyambuzi (Runyoro)	*Oxalis corniculata* L. (Oxalidaceae)	Sores on the tongue	Fresh leaves	Wrapped in banana leaves and put in hot ash	Oral. The soft leaves are rubbed against the sores twice a day	Herb/bush	1	N.A
KI64	Embiribiri (Runyoro)	*Crassocephalum vitellinum* S.Moore (Asteraceae)	Abdominal pain	Leaves	Fresh leaves are boiled to make an infusion	Oral. A cup of the infusion is taken twice/day	Herb/bush	1	N.A

Voucher no.	Local name	Botanical name (Family)	Diseases treated	Part(s) used	Method of preparation	Mode of administration/Dosage	Habit/source	Frequency of citation	IUCN status
KI65	Akarandarugo (Runyoro)	*Ipomoea cairica* (L.) Sweet (Convolvulaceae)	Syphilis	Leaves	Fresh leaves are boiled to make an infusion	Oral. A cup of the infusion is drunk thrice/day	Climber/bush	1	Least Concern
KI66	Ekibuza (Runyoro)	*Dichrocephala integrifolia* (L.f.) Kuntze (Asteraceae)	Menorrhagia	Leaves	Fresh leaves squeezed to make juice	Oral. A cup of the juice is taken thrice/day	Herb/bush	1	N.A
KI67	Ekicumucumu (Runyoro)	*Leonotis nepetifolia* (L.) R.Br. (Lamiaceae)	Stomach pain	Leaves	Fresh leaves squeezed to make juice, and a little water is added	Oral. Half a cup of the juice is taken twice/day	Herb/bush	1	N.A
KI68	Enderema (Runyoro)	*Basella alba* L. (Basellaceae)	After labour wounds	Leaves	Fresh leaves are boiled to form soup.	Oral. A plate of soup is eaten twice/day	Climber/bush	1	N.A
KI69	Entanyenka (Runyoro)	*Ageratum conyzoides* L. (Asteraceae)	Ulcers	Leaves	Fresh leaves are boiled to make an infusion.	Oral. A cup of the infusion is taken thrice/day	Herb/garden	1	Least Concern
KI70	Eteke (Alur)	*Sesamum angustifolium* (Oliv.) Engl. (Pedaliaceae)	Dryness in women	Leaves	Fresh leaves are boiled and mixed with any type of sauce, like beans or greens	Oral. A plate is eaten thrice/day	Shrub/bush	1	N.A

N.A = Not Available

Table 3. Preference scores (1-10) assigned by key informants (n = 10) to ten commonly used medicinal plants for treating diseases in communities around Budongo Forest Reserve, Western Uganda. A score of 10 indicates highest perceived importance, and 1 the lowest. Total scores (out of 100) were used to rank the plants by overall perceived importance.

Name of species	Key informants (n = 10)										Score (/100)	Rank
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}		
Erythrina abyssinica Lam.	10	9	10	9	10	10	10	10	10	10	98	1st
Agapanthus africanus (L.) Hoffmanns	9	10	10	10	8	9	8	10	10	8	92	2nd
Hoslundia opposita Vahl.	10	10	7	9	8	10	9	8	7	9	87	3rd
Bidens pilosa L.	8	8	9	10	9	8	7	7	8	8	82	4th
Lantana camara L.	7	7	6	7	10	8	9	6	10	7	71	5th
Ricinus communis L.	5	9	8	5	6	9	8	7	5	6	67	6th
Gymnanthemum amygdalinum (Delile) Sch. Bip.	10	8	5	7	4	6	7	5	4	5	61	7th
Hydnora abyssinica A. Braun	6	5	5	6	4	4	9	6	6	4	55	8th
Annona muricata L.	6	5	4	4	5	5	5	5	5	3	47	9th
Conyza sumatrensis (Retz.) E.Walker	5	3	3	5	4	4	4	3	4	4	39	10th

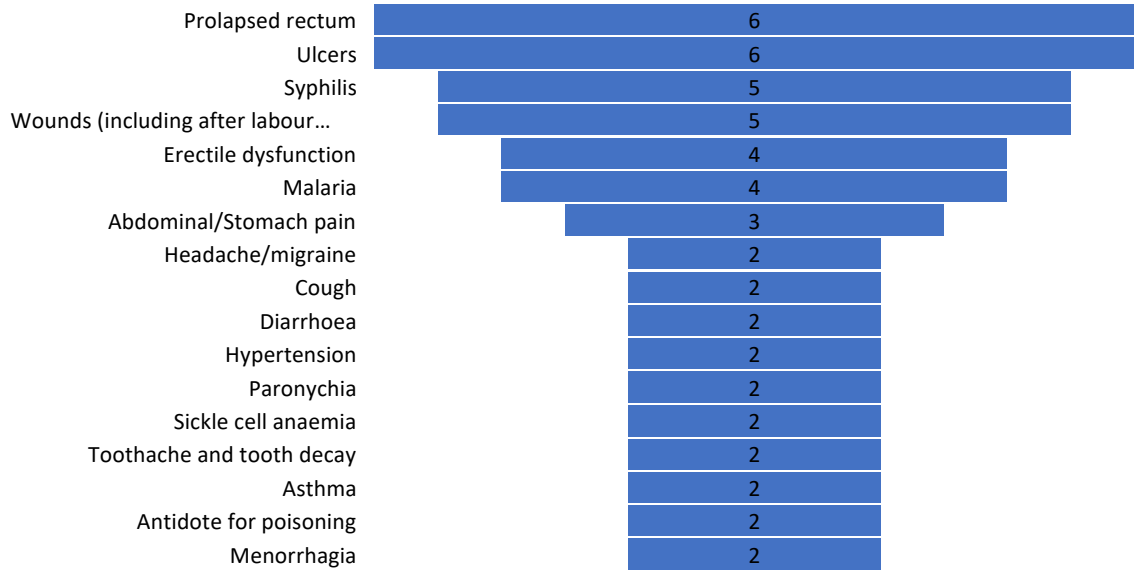

Figure 3. A funnel chart showing the frequency of mention of ailments and conditions treated using medicinal plants by communities around Budongo Forest Reserve, Western Uganda

Growth habit, plant parts, preparation and administration of herbal remedies

The species inventoried consisted of herbs, trees, and shrubs (each at 30%), with climbers (9%) and grass (1%) being the minor life forms (Figure 4a). These were sourced from bushes (62.9%), gardens (27.1%) and the forest (10.0%). Leaves were the most used (56.2%), followed by the stem bark (17.8%) (Figure 4b). There was a tendency to use more than one plant in herbal remedies. For example, fresh roots of *Gymnanthemum auriculiferum* are mixed with those of *Acanthus pubescens*, decocted and taken to treat erectile dysfunction. *Tithonia diversifolia* leaves are similarly used along with those of *Hoslundia opposita*, the squeezed juice of which is used for abdominal pains or menorrhagia. *Galinsoga parviflora* and *Conyza sumatrensis* leaf extracts are used to treat syphilis. Other combinations were *Solanum aethiopicum* and *Solanum gilo* fruits to treat dizziness, *Tridax procumbens* and *Gymnanthemum amygdalinum* leaves to treat ear discharge, *Mangifera indica* and *Eucalyptus globulus* leaves for cough and flue, *Ocimum tenuiflorum*, *Cymbopogon citratus* and *Persea americana* to manage hypertension as shown in Table 2 . Malaria was treated with a combination of six plant parts: *Gymnanthemum amygdalinum* leaves and roots, *Carica papaya* leaves, *Ricinus communis*, *Lantana camara*, *Cassia spectabilis*, and *Allium cepa* bulb. None of the respondents, however, mentioned the use of non-plant materials or adjuvants in their herbal medicaments.

Most plants in this study were herbs, trees and shrubs, which aligns well with reports from other ethnobotanical surveys in Uganda (Asiimwe *et al.* 2021; Gumisiriza *et al.* 2023; Tabuti *et al.* 2023). The dominance of leaves as the primary plant organs used for the preparation of herbal remedies is a common feature of traditional medicine in Uganda (Adia *et al.* 2014; Asiimwe *et al.* 2021; Gumisiriza *et al.* 2023; Stangeland *et al.* 2011; Tabuti *et al.* 2023). The preference for leaves is often associated

with their ease of regeneration, year-round availability and central role as the photosynthetic sheet of plants responsible for the production and storage of most bioactive plant molecules (Machado *et al.* 2018; Ssenku *et al.* 2022). We found that most herbal preparations in the study area were achieved through squeezing to produce juice, decocting plant materials or obtaining infusions. These results partially align with previous studies, which have found decoction to be the primary method of herbal medicine preparation (Asiimwe *et al.* 2021; Gumisiriza *et al.* 2023; Tabuti *et al.* 2023). Decoction facilitates the better extraction of bioactive phytochemicals from plant matrices (Zhang *et al.* 2018). Therefore, the dominance of squeezing to produce juice in this study may be related to the nature of diseases to be treated. The oral route was cited as the primary mode of administration of herbal remedies, which aligns with previous studies elsewhere (Asiimwe *et al.* 2021; Gumisiriza *et al.* 2023; Tabuti *et al.* 2023). It has already been reported that oral dosage forms are easily prepared and administered (Murphy *et al.* 2001).

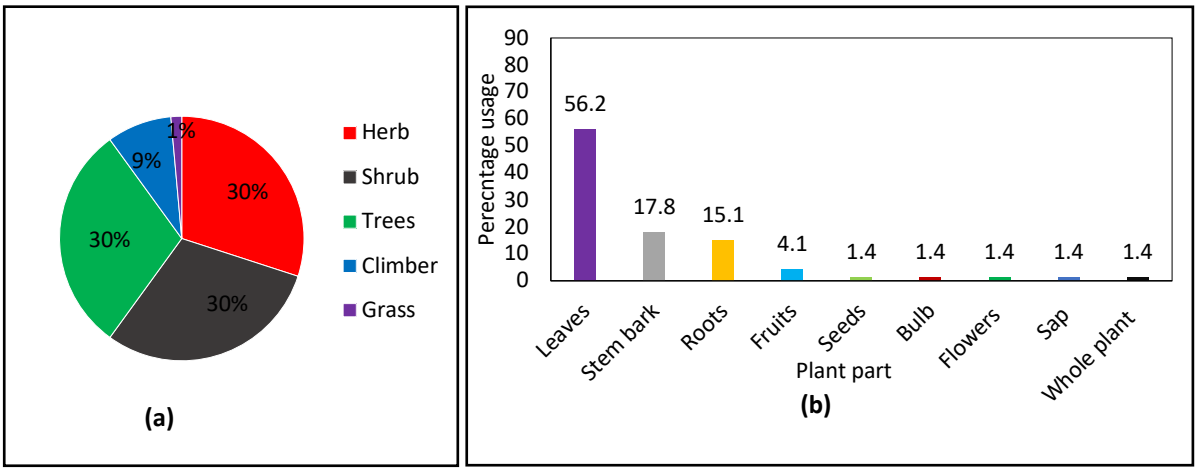

Figure 4. Medicinal plants used in managing diseases by communities around Budongo Forest Reserve, Western Uganda: (a) life forms, (b) parts utilized.

The most common preparation methods were squeezing to produce juices (34.7%), decoction (31.9%) or infusion (22.2%) (Table 2). Sometimes, plant parts were used directly (8.3%), powdered for topical application (1.4%) or applied as ashes (1.4%). The preparations are frequently administered orally (70.3%) or topically (23.0%). There were distinct cases where the formularies were applied through rectal (2.7%), nasal (2.7%) or auricular (1.4%) routes, to treat prolapsed rectum and otorrhea, respectively. These conditions are very sensitive to manage locally and only a few experienced herbalists would treat them. The posology for oral administration ranged from half a cup of the preparation to a full cup. It was administered either once, twice, or three times per day, but was mainly continued until the patients recorded significant improvement or total recovery. Still, the topical application and administration through rectal, nasal, and auricular routes in this study suggest that internally mediated healing effects would be unlikely when such plant remedies are taken orally (Omara *et al.* 2021). Moreover, such routes are non-invasive, permit self-controlled application, avoid first-pass metabolism in the liver, and reduce systemic side effects or possible drug interactions (Sanz *et al.* 2015).

An overview of the bioactivity of some inventoried species indicated that most of them have relevant reports supporting their claimed uses. For example, *Erythrina abyssinica* has antimicrobial compounds such as lupinifolin and sigmoidin E (Obakiro *et al.* 2021). Extracts and pure compounds from plants such as *Albizia coriaria* (Muthaura *et al.* 2015), *Azadirachta indica* (Khalid 1989; Kirira *et al.* 2006), *Gymnanthemum amygdalinum* (Challand and Willcox 2009; Omoregie *et al.* 2011; Stangeland *et al.* 2011) and *Carica papaya* (Teng *et al.* 2019) have been found to have antimalarial and anti-plasmodial activities. *Mondia whitei* cited for the management of erectile dysfunction in this study, was reported to increase sexual arousal (Gundidza *et al.* 2009; Watcho *et al.* 2004) through activation/stimulation of nitric oxide synthase activity, resulting in the elevation of levels of cyclic guanosine monophosphate (Quasie *et al.* 2010). We note that plants such as *Hibiscus sabdariffa* (for treating sickle cell), *Agapanthus africanus* (for bone setting and dislocations), *Gymnanthemum auriculiferum* and *Cissampelos mucronata* (for erectile dysfunction) could be investigated for their relevant bioactivities since this is the first time that they have been mentioned by herbalists for the treatment of these unique health conditions.

Conclusion

We documented 70 medicinal plant species from 34 families, distributed among 66 genera, used by communities around the Budongo Forest Reserve to treat up to 43 diseases and conditions. *Erythrina abyssinica*, *Agapanthus africanus*, and *Hoslundia*

opposita were the most used plants for treating prolapsed rectum, ulcers, syphilis, wounds, erectile dysfunction, and malaria. Leaves, stem bark, and roots of herbs, trees, and shrubs were the most utilized plant organs for preparing juices, decoctions, and infusions, which were administered orally or applied topically. These findings highlight the rich cultural heritage of medicinal plants used among communities around Budongo Forest Reserve. Future research should aim to isolate and characterize bioactive compounds responsible for the claimed bioactivities from the understudied species.

Declarations

Ethical approval and consent to participate: All participants were informed about the purpose of this research, and verbal consent was obtained from both local council leaders and the participants before conducting the research. For field visits, permission was requested from individuals with plants within local communities along the Budongo Forest fringes to confirm the presence of certain medicinal plants.

Consent for publication: Not applicable

Availability of data and materials: All the data collected and analyzed are within this article and its supplementary files.

Competing interests: The authors declare that they have no conflicts of interest.

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Authors' contributions: Conceptualization: IK, TO; Methodology and Data collection: IK and MA; Formal analysis: IK ,TO,MA,UN,COA; Writing -original draft and final copy: IK, TO; Writing -review & editing: IK, TO, MA, UN, COA. All authors read and agreed to the published version of the manuscript.

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