Ethnobotanical use and conservation assessment of medicinal plants sold in markets of Burkina Faso

Lassané Ouédraogo, Josef Endl, Pierre Alexandre Eric Djifaby Sombié, Hanno Schaefer and Martin Kiendrebeogo

Research

Abstract

Background: A comprehensive survey on the trade and use of medicinal plants in Burkina Faso was carried out with the aim of identifying the most relevant species and their conservation status.

Methods: Interviews of 30 medicinal plant traders in six major cities was carried out and the data on medicinal plant species were recorded using a structured questionnaire.

Results: A total of 104 medicinal plant species, belonging to 39 families and 81 genera were reported to treat various health problems. Most of the medicinal plant species found in the markets were used for gastrointestinal diseases (48%), e.g., *Pteleopsis suberosa* (Combretaceae) and *Bauhinia rufescens* (Fabaceae). The combination of fidelity level and preference ranking identified *Gardenia sokotensis*, *Combretum micranthum* and *Maytensus senegalensis* as particularly important species for treatment of malaria. Four species found in local markets are listed as vulnerable in the IUCN red list of threatened species (*Afzelia africana*, *Vitellaria paradoxa*, *Khaya senegalensis* and *Tapinanthus globiferus*). For many species that are traded in large quantities sufficient data for precise assessment of their conservation status do not yet exist. Some species such as *Securidaca longipedunculata* and *Zanthoxylum zanthoxyloides* are already rare in nature and sold at high price on the stalls.

Conclusions: There is an urgent need to collect distribution data for the medicinal plant species of Burkina Faso and design conservation plans in order to preserve their natural populations.

Keywords: Ethnobotanical survey; Medicinal plants; Conservation status; Traditional knowledge; Diseases; Burkina Faso

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Background

Traditional medicine has played a key role in many developing countries and continues to do so (World Health Organization, WHO 2004). In this area, it is estimated that more than 80% of the people rely on plants for their primary healthcare requirements (Senthilkumar *et al.* 2013).

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In West African countries, particularly in Burkina Faso, traditional medicine and pharmacopoeia remain the main source of primary health care for an estimated 70% of the population (Zerbo *et al*. 2011). The main reasons for this dependence on herbal medicine are its therapeutic efficacy, accessibility and low costs compared to modern medicine and that it is deeply intertwined with traditional beliefs (Benoît 2008).

But the increased use of herbal medicines has also negative consequences. It propels safety concerns to both national health authorities and the general public, mostly due to misidentification, substitution of rare species with cheaper plant material from species which are more readily available and infection of herbs with fungi (Kool *et al*. 2012). In addition, it could negatively impact natural plant resources when exploitation is performed in an unsustainable way (WHO 2004).

Meticulous documentation, sustainable use and conservation efforts are therefore essential. Traditional medicine practitioners are officially recognized by the authorities of Burkina Faso in order to regulate their activities in collecting and selling medicinal plants ("Assemblée Nationale", AN 1994). These regulations are recorded in two national codes of Burkina Faso. In the Public Health Code recipes and use of medicinal plants are described (AN 1994). In the Forest Code traditional use rights are recognized for the benefit of local residents, allowing picking of fruits and harvesting of medicinal plants (AN 1997). Most of the medicinal plants are sold in urban markets (Cunningham 2014) and market surveys have become an efficient way of acquiring data on local consumption and conservation status of medicinal plant species (Idu *et al.* 2010).

It seems necessary to inform on the composition of medicinal plants traded in Burkina Faso, the quantities sold, the provenance of the plant material and the indigenous uses for disease treatment. Documentation of traditional uses of medicinal plants sold in the markets is important for several reasons. The identification of local names, scientific names and indigenous uses of plants not only preserves indigenous knowledge but also contributes to future research in order to improve the safety and efficacy of medicinal plants in the treatment of various ailments (Tugume *et al*. 2016). This will facilitate the integration of herbal medicine into the main health care system. In addition, this knowledge will support the conservation of cultural traditions and help to preserve the diversity of wild plant resources.
The knowledge on traditional medicinal uses of plants is disappearing at an alarming rate in Burkina Faso mainly because this information is only orally transmitted to the younger generation. Many of these custodians die before passing on the information to the next generations. The importance of saving this traditional knowledge is convincingly demonstrated by the fact that an estimated 25% of prescription drugs and 11% of drugs considered essential by WHO are based on active compounds first isolated from wild plants (Maroyi *et al*. 2011). Thus, a thorough knowledge of traditionally used medicinal plants could help to fully exploit their potential for discovering new sources of drugs and promote the sustainable use of these natural resources in Burkina Faso.

Therefore, we conducted this study on medicinal plant trade in the main local markets in six major cities (Ouagadougou, Fada, Dédougou, Léo, Ouahigouya, and Bobo-Dioulasso) of Burkina Faso. The study aims to deliver a comprehensive list of the medicinal plants together with their suggested applications. To assess the conservation status of each species, the provenance and estimated quantities of plant material offered by the sellers was documented and compared to International Union for Conservation of Nature (IUCN) red list status. Finally, we provide suggestions how to avoid overexploitation of selected species in order to preserve them for the benefit of future generations.

Materials and Methods

Study sites

The study focused on 18 markets of six cities in different climatic and vegetation zones of Burkina Faso. Selected cities for the survey were Ouagadougou, Ouahigouya, Fada N'Gourma, Dédougou, Bobo Dioulasso, and Léo (Figure 1). The target cities were chosen randomly in the four agro-ecological zones defined by Fontès and Guinko (2012). The three biggest markets of each city were selected as study sites. Ouagadougou and Ouahigouya are located in the Sahelian zone dominated by shrub savanna with annual rainfall less than 600 mm. Dédougou and Fada N'Gourma belong to the northern Sudanese zone of the country where woody and shrubby savannas dominate and rainfall ranges from 600-900 mm. Bobo-Dioulasso and Léo are located in the southern Sudanese zone with open forests and islands of dense dry forest with rainfall up to 900 mm (MAHRH 2007).

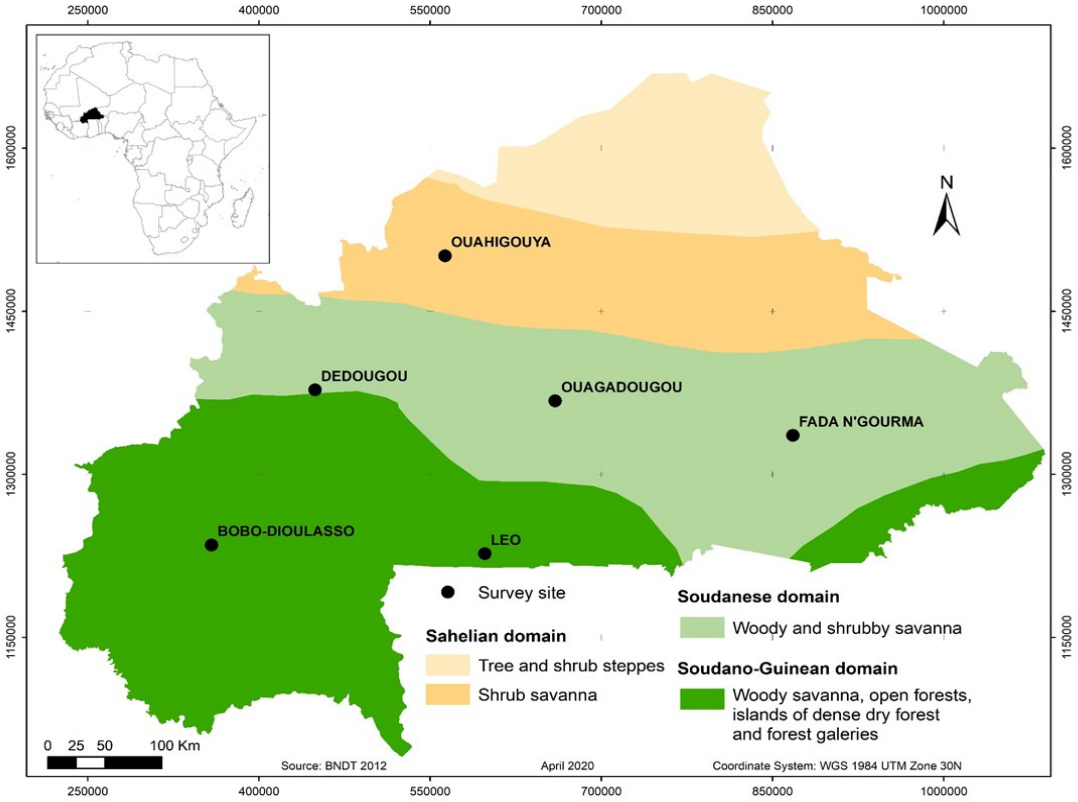

Figure 1. Ethnobotanical surveys sites

Data collection

This survey targeted herbal traders selling medical plants in the markets. Herbal traders in the surveyed markets belonged mainly to the following ethnic groups: Mossi, Dioula, Gourmantché, Gourounsi, and Fulfudé (FAO 1996). Interviews were conducted in the local language using guided semi-structured questionnaires according to the procedure described by Martin (1995) with slight modification (see in appendix 1 an example questionnaire). The survey was conducted from December 2015 to January 2016. For each market the representative of the sellers of medicinal plants was consulted, who suggested the traders with the most experience in the field of medicinal plant trade or application. Markets were visited once and 1- 2 medicinal plant vendors or traditional healers, who agreed to participate in the survey were interviewed per market, summing up to a total of 30 interviews at 18 local markets. The traders chosen provided information on local names of the plants, plant parts used, quantities offered, prices, plant provenances, methods of preparation, and diseases/symptoms targeted. Botanical samples were acquired from all participants of the survey.

Species identification

Plant identification was partly carried out in the markets based on field manuals for plant identification encompassing trees, shrubs and lianas from West African dry zones (Arbonnier 2000). In addition, voucher specimens of all plant species were identified at the herbarium “Herbier National du Burkina Faso" (HNBU).

Estimation of plant quantities offered and prices

The quantities of plant samples sold in the markets were determined using common estimates based on the hand-circumference of bundles (Figure 2) (Martin 1995) and prices were recorded according to this unit.

Species use value

The use value of a certain plant species for treating a given category of disease was assessed by asking nine key informants. These were selected on the following criteria i) wide range of plants offered, ii) long experience in medicinal plant trade or application and iii) consent to supply the information. They were asked to assign a value between 1 and 10 (10 for the most frequently used plant) to the ten most available medicinal plant species (Martin 1995). Values assigned to each species were summed up for all informants to get an overall rank value. The species were then ranked in descending order.

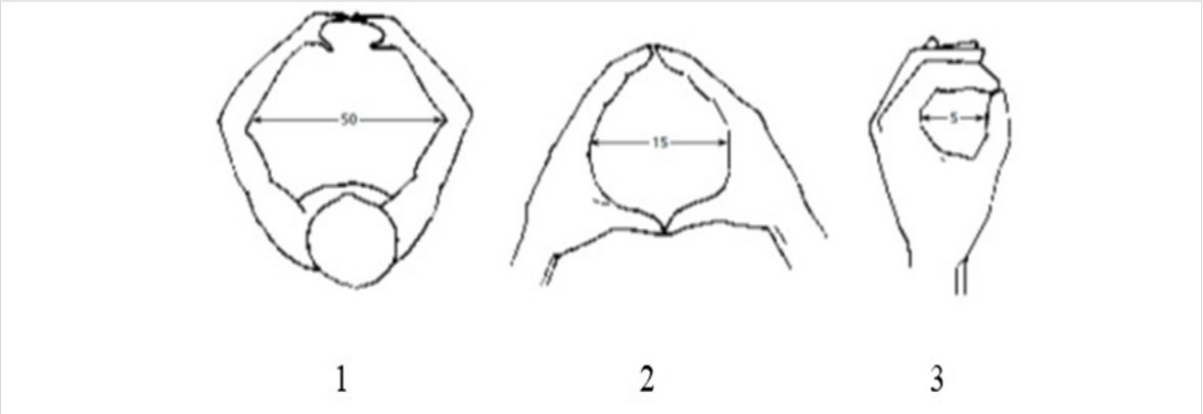

Figure 2. Commonly used local estimates of circumference for different-sized bundles of plant products (Martin 1995).

1 = 50 cm of 'arm-circumference' diameters; 2 = 15 cm of 'two hands-circumference' diameters; 3 = 5 cm of 'one hand-circumference' diameters.

Frequency of citation

The frequency of the most cited species was calculated according to Dossou *et al*. (2012) in order to identify the species most valued by the traders.

$$Fc = (Nc/Ns) \times 100\ [\%]$$

Where, Fc = frequency of citation in percentage; Nc = number of traders citing the species and Ns = total number of traders surveyed.

By convention, a low frequency (≤30%) indicates that the species is little known and little used. A frequency range between 30 and 60% denotes that the species is moderately known and moderately used, while a range between 60 and 100% reveals that the species is very well known and widely used.

Informant consensus factor (FIC)

The informant consensus factor was calculated according to Uddin and Hassan (2014).

$$FIC = (N_{ur} - N)/(N_{ur} - 1)$$

Where N_{ur} = number of use reports for a specific ailment category from vendors in the markets and N = number of species listed in each category from all vendors.

FIC values can range from 0 (lowest level) to 1 (highest level). FIC values are low when plants are randomly selected or if there is no consensus among informants on their use for the treatment of a certain disease category or if there is no exchange among informants. Values are close to 1 if a large proportion of sellers prefer certain species for a specific disease category or if information is exchanged between informants. In short, medicinal plants with high FIC are believed to be effective in treating a certain disease category.

The main purpose of FIC is to select disease categories for which there is consensus on the use of plants among the informants and to identify species with particular importance in a culture.

Fidelity level (FL)

The fidelity level (FL) is defined as the ratio between the number of informants who independently suggested the use of a species for the same particular disease and the total number of informants who mentioned the plant for any use (Andrade-Cetto and Heinrich 2011).

$$FL = (I_p/I_u) \times 100\ [\%]$$

Where, I_p = number of informants using the medicinal plants for a specific disease and I_u = number of informants reporting the use of the species for any ailment.

Conservation status of medicinal plants in the markets

The conservation status of all species recorded was assessed on the basis of the IUCN red list database (IUCN 2018).

Data analysis

Data collected were tabulated and analyzed by using Microsoft Excel. For calculation of the informant consensus factor the ailments/symptoms treated by the medicinal plants were grouped into 13 different categories according to the Economic Botany Data Collection Standard with slight modifications (Iwu 1993).

Results

Information on vendors and plant taxa sold

Of the 30 vendors interviewed in 18 markets, women predominated, accounting for 87% of the vendors. The age of the informants ranged between 45 and 64 years. Twenty vendors were affiliated to an association involved in the field of traditional medicine and ten vendors had no affiliation. Half of the informants had received formal training from private schools and non-governmental organizations involved in the area of medicinal plants.

In total, 104 species of medicinal plants distributed in 39 families and 81 genera could be identified in the survey (Table 1). The dominant plant families were Fabaceae (16 species), followed by Rubiaceae (7 species), and Combretaceae (5 species). Twenty-one species were present in at least 50% of the stalls, 38 species were sold only by 3% of the vendors (Table 1). The highest numbers of different medicinal plant species were encountered in the two largest cities of Burkina Faso, in Ougadougou (n=48) and Bobo-Dioulasso (n=40). The most unique species collection in relation to the total number of species offered was found in the cities of Fada N'Gourma and Léo: approximately 50% of the species offered in these two cities were only found there.

Plant parts, provenance and growth forms of plants used for herbal preparations

The most commonly used plant parts were leaves with a proportion of 47.0% of all nominations (Table 2), followed by stem bark (34.0%) and roots (17.2%). Inflorescences, gums and seeds were rarely used. In many cases, more than one part of the same plant species was used, for instance often leaves, stem bark and roots of the same species were employed to prepare remedies. Most of the medicinal plants sold on the stalls came from the savanna (86.3% of the samples, Table 3). The species collected in the forests included only trees with a proportion of 2.6%. Ligneous material from fields or gardens, respectively, and herbs from gardens comprised only a very small proportion of the material found in the markets.

Only rarely medicinal plant species sold in the markets came from cultivated sources, such as hedgerows (*Bauhinia rufescens* Lam., *Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.), or home gardens (*B. rufescens*, *Cymbopogon citratus* (DC.) Stapf, *Moringa oleïfera* Lam.).

Medicinal plants recipe preparation and administration

We recorded six types of methods for recipe preparation, namely decoction, trituration, infusion, cataplasm, calcination and crushed mixture with water. Decoction was the most common method of preparation (87.5%), followed by trituration (14.4%) and infusion (12.5%) (Figure 3). The medicinal plant preparations were administered through different routes including drink, bath, gargle, purgative, application, massage, inhalation, toothbrush, instillation and enema. The main mode of administration was the drink (65.4%) followed by the bath (35.6%) (Figure 4).

Range of ailments treated by medicinal plants

According to the information supplied by the vendors a total of 31 conditions were treated with medicinal plants. In order to calculate various ethnobotanical indices these conditions were classified into 13 disease categories. First the number of species used for treatment of a certain disease categories was analyzed (Table 4). The largest number of plant species was used for treatment of gastrointestinal diseases (48.1%) followed by malaria (19.2%), general pathology symptoms (18.3) dermatosis and respiratory diseases (each 17.3%). The range of disease categories treated by a particular species varied from 1 to 4. The species for which the most diverse healing potential was assigned by the traders were *Phyllanthus amarus* Schum. & Thonn. (gastrointestinal diseases, hemorrhoids, liver disorders, arthritis) and *Moringa oleïfera* Lam. (gastrointestinal diseases, malaria, general pathology symptoms, cardiovascular diseases).

Factor of informant consensus (FIC)

For this factor calculation, the 13 disease categories as defined in Table 4 were used. Exceptional high consensus about plant usage among informants was found for childhood illnesses (FIC=0.9) and cardiovascular diseases (FIC=0.8) followed by respiratory diseases, general pathology symptoms, arthritis and other infections (each FIC=0.7) (Table 5). Very low FIC values (≤0.4), as observed for urogenital and internal organ diseases, indicate that informants mostly disagreed on which plants to use for these diseases. The most important plants used for the category of childhood illnesses were *Lepidagathis anobrya* (Pers.) Decne. *Walteria indica* L., and *Ocimum basilicum* L. (Table 1). For the category of cardiovascular diseases, *Mitragyna inermis* (Willd.) Kuntze was the species most cited.

Table 1. List of medicinal plants reported in the markets of six cities of Burkina Faso

Family, Scientific name Voucher specimen number	Local name	City	Provenance		Part used	Preparation	Ailment/ Symptoms Treated	Administration	Frequency of citation (%)	Estimated quantity by hand-circumference (average quantity offered by the vendors)	Price by hand-circumference [FCFA]
			Savanna	Forest							
Acanthaceae											
Hygrophila auriculata (Schum.) Heine 2243	Kocenkoéré (M)	2	H	NI	Sb	Trituration	Respiratory diseases	Drink	10	Two hands-circumference of stem	100
Lepidagathis anobrya Nees 540	Gnuy-nakida (M), Gonwou nouman (D)	1,2,3	H	NI	L	Decoction	Growth retardation, stomachache	Drink	50	One hand-circumference of plant	50
Amaranthaceae											
Alternanthera nodiflora R. Br. 2055	Sibgponré (M)	1	H	NI	L	Cataplasm	Growth retardation	Purgative	17	One hand-circumference of plant	50
Pupalia lappacea (L.) Juss. 5599	Nwestabdo (M)	1	H	NI	L	Calcination	Wound healing stomachache	Application	3	One hand-circumference of plant	50
Anacardiaceae											
Anacardium occidentale L. 2010	Finzan(D)	2	Li	NI	Sb	Infusion	Hypertension	Drink	7	One hand-circumference stem bark	50
Lannea acida A. Rich. 2596	Sabtulga (M), Eberg (G)	3,4	Li	NI	Sb R	Decoction	Stomachache, ulcer	Drink	3	One hand-circumference stem bark	50
Lannea velutina A. Rich. 8203	Wâamsâbga (M)	6	Li	NI	L, Sb	Decoction	Tonic	Bath	3	Two hands-circumference of leafy stem	50
Sclerocarya birrea (A. Rich.) Hochst. N360	Noabega (M)	2, 4	Li	NI	Sb	Decoction, infusion	Dysentery, Ulcer	Drink	50	One hand-circumference of stem bark	50
Annonaceae											
Annona senegalensis Pers. 2083	Sunsun (D), Barkudga (M)	1,2,3,5	Li	NI	L, Sb, R	Decoction, calcination	Wound healing, stomachache, somniferous malaria	Drink, bath, application, enema	67	One hand-circumference of leafy stem	50

Baissea multiflora A.DC. 8403	Nonguem taaba, Nongsego (M)	2	Li/La	NI	L, Sb, R	Decoction	Tonic, diarrhea	Drink	10	Two hands-circumference of leafy stem	50
Apocynaceae											
Saba senegalensis (A. DC.) Pichon 2741	Wêdga (M), Zaban(D)	1,3,5	Li	NI	L	Decoction	Wound healing, stomachache	Drink, enema	50	Two hands-circumference of leafy stem	50
Cynanchum viminale (L.) L. 2016	Wobsaré (M)	3,5	Li/La	NI	Sb, Sa	Trituration	Eye infection	Instillation, application	50	Two hands-circumference of leafy stem	100
Leptadenia hastata (Pers.) Decne. 2060	Lelungo (M)	3	Li/la	NI	L, Sb	Decoction	Malaria , jaundice, sexual impotence	Drink	7	One hand-circumference of leafy stem	50
Asteraceae											
Chrysanthellum americanum (L.) Vatke 5464	Waltuko (M)	1	H	NI	L, Sb, R	Decoction, infusion	Liver diseases	Drink	7	One hand-circumference of the plant	50-200
Bombacaceae											
Adansonia digitata L. 2038	Toêga (M)	6	Li	NI	L	Decoction	Dysentery	Drink	3	Two hands-circumference of leaf	50
Boraginaceae											
Heliotropium indicum L. 3070	Nonsikou (D)	2	H	NI	L, Sb	Decoction	Diarrhea, hypertension	Drink	3	One hand-circumference of plant	50
Burseraceae				NI							
Boswellia dalzielii Hutch. 8103	Gondreyongo (M)	1	Li	NI	L	Decoction	Wound healing, stomachache	Enema	10	One hand-circumference of leafy stem	50
Celastraceae											
Maytenus senegalensis (Lam.) Exell 2247	Tovougri (M), Barkawouli (Gsi)	1,3,6	Li	NI	L, R	Decoction	Malaria, diarrhea, dental pain, headache	Bath, gargle	50	One hand-circumference of leafy stem	50
Hippocratea africana (Willd.) Loes. 2446	Zibri (M)	3	Li	NI	Sb	Decoction	Sickle-cell disease	Bath	3	Two hands-circumference of leaf	50

Cochlospermaceae											
Cochlospermum planchonii Hook.f. 8437	Sons-raaga (M)	5	Li	Li	R	Decoction	Malaria	Drink, bath	17	One hand-circumference of the root	50
Cochlospermum tinctorium Perrier ex A. Rich. 3430	N'dribala (D)	2	Li	NI	L,R	Decoction	Malaria, ulcer	Drink, bath	17	Two hands-circumference of leafy stem	100
Combretaceae											
Anogeissus leiocarpa (DC.) Guill. & Perr. 5799	Siiga (M)	2	Li	NI	Sb	Decoction	Respiratory diseases	Drink	33	Two hands-circumference of stem bark	50
Combretum aculeatum Vent. 1904	Guitga (M)	1,4,6	Li	NI	L	Decoction	Dental pain	Gargle	50	Two hands-circumference of leaf	50
Combretum adenogonium Steud. ex A. Rich. 2244	Dayigoubwala (Gsi),Kwigenga (M)	5,6	Li	NI	L, Sb	Decoction	Dysentery	Drink	3	Two hands-circumference of leaf	50
Combretum glutinosum Perr. ex DC. 2263	Kuenga (M), Lifapelu(G)	4	Li	NI	L	Decoction	Stomachache, liver trouble	Drink	3	Two hands-circumference of leaf	50
Combretum micranthum G. Don 346	Raandga (M)	2,3,4	Li	NI	L	Decoction	Malaria	Drink	50	Two hands-circumference of leaf	50
Combretum paniculatum Vent. 2250	Kudgunlungu (M)	3	Li	NI	L	Decoction, maceration	Hemorrhoids	Drink	7	Two hands-circumference of leaf	50
Combretum sericeum G. Don 340	Vopopwao (Gsi)	6	Li	NI	L, Sb	Decoction	General fatigue	Bath	3	Two hands-circumference of leaf	50
Guiera senegalensis J.F. Gmel. 1921	Wilim-wiiga (M)	1,2,3	Li	NI	L, Sb	Decoction	Malaria, diarrhea, cold, sinusitis	Drink, bath	50	Two hands-circumference of leaf	50
Pteleopsis suberosa Engl. & Diels 1876	Guirga (M), Gnonlifou (D)	1,2,4,5	Li	NI	L, Sb	Decoction, maceration	Dysentery, stomachache, cough, hemorrhoids	Drink	67	Two hands-circumference of leaf	50
Terminalia avicennioïdes Guill. & Perr. 2091	Kondré (M)	2	Li	NI	L, Sb, R	Decoction	Liver trouble, heartache, diarrhea	Drink	50	Two hands-circumference of leaf	50

Terminalia macroptera Guill. & Perr. 2007	Koond-poko (M)	1	Li	NI	R	Decoction	Hemorrhoids	Enema	3	One hands-circumference of root	50
Ebenaceae											
Diospyros mespiliformis Hochst. ex A. DC. 4637	Gaaka (M)	1,4	Li	Li	L, Sb, R	Decoction	Wound healing, sexual impotence, parasite infections	Drink, bath	17	Two hands-circumference of leaf	50
Euphorbiaceae											
Euphorbia hirta L. 468	Wal-biisum (M)	1	H	NI	L, Sb, R	Maceration, decoction	Dysentery, respiratory diseases	Drink	7	One hand-circumference of plant	50
Fabaceae				NI							
Afzelia africana Smith ex Pers. 2414	Kankalga (M), Tiégué (Gsi)	6	NI	Li	Sb, R	Decoction	Stomachache	Drink	3	One hand-circumference of stem bark	50
Alysicarpus glumaceus (Vahl) DC. 2402	Rabgo (M)	5	Hs	NI	L	Decoction	Diarrhea	Drink	3	One hand-circumference of the plant	50
Bauhinia rufescens Lam. 6045	Tipohèga (M)	1,2	Li/He	NI	L, Sb, R, Fr	Trituration	Cold, sinusitis, tonic	Fumigation, bath	50	One hand-circumference of leaf	50
Burkea africana Hook. 1994	Kasi-sané (M)	6	Li	Li	Sb	Decoction, infusion	Cough, heart diseases	Drink	3	One hand-circumference of stem bark	50
Cassia alata L. 220	Colbata (D)	2	Li	NI	L	Decoction, trituration	Skin disorders, liver diseases	Drink, application	3	One hand-circumference of leafy stem	50
Cassia italica (Mill.) Lam. ex F.W. Andrews 232	Panedmantiiga (M), Bali bali (D)	1	Li	NI	L	Decoction	Stomachache, skin disorders	Drink, bath	17	One hand-circumference of leafy stem	50
Cassia nigricans Vahl 2223	Zander-kuka (M)	1	Li	NI	L	Decoction, trituration	Wound healing, stomachache	Enema, application	10	One hand-circumference of leafy stem	50
Cassia occidentalis L. 5375	Balambala (D)	5	Li	NI	L, Sb	Decoction	Tonic, stomachache	Bath	13	One hand-circumference of leafy stem	50

Cassia sieberiana DC. 5895	Samdiani (G), Kumbr-saka (M)	1,3,4	Li	NI	L, Sb, Root	Decoction, trituration	Stomachache, malaria, kidney diseases, sexual impotence	Drink	50	One hand-circumference of leafy stem	50-100
Cassia singueana Del. 3113	Djélponsré (M)	1	Li	NI	L, R	Decoction	Stomachache	Drink	10	One hand-circumference of leafy stem	50
Detarium microcarpum Guill. & Perr. 2948	Kadga (M)	4	Li	Li	L, Sb	Decoction	Headache, stomachache	Drink	3	One hand-circumference of leafy stem	50
Dichrostachys cinerea (L.) Wight & Arn. 2678	Susutga (M)	6	Li	NI	R	Decoction	Respiratory diseases	Drink	3	One hand-circumference of stem bark	50
Entada africana Guill. & Perr. 2993	Sennogo (M)	2	NI	Li	Sb	Decoction, maceration	Cold, sinusitis, cough	Drink	3	Two hands-circumference of stem bark	50
Faidherbia albida (Del.) A. Chev. 420	Zaanga (M)	1,2,3	Li	NI	L	Decoction	Kidney diseases, malaria	Drink	3	One hand-circumference of leafy stem	50
Senegalia macrostachya (Rchb. ex DC.) Kyal & Boatwr. 52	Zamenega (M)	1	Li	NI	Le	Decoction	Headache	Drink, bath	3	Two hands-circumference of leafy stem	50
Senegalia senegal (L.) Britton 8609	Gompèlga (M)	1	Li	NI	L, Sb	Decoction	Diarrhea, hemorrhoids	Drink	3	Two hands-circumference of leafy stem	50
Vachellia nilotica (L.) P.J.H. Hurter & Mabb. 680	Pegengá (M)	1,3,6	Li	NI	Fr, Fr, Sb	Decoction	Stomachache, hemorrhoids, cough	Drink, bath, gargle	50	Two hands-circumference of leafy stem	50
Parkia biglobosa (Jacq.) R. Br. ex G. Don 669	Rondo (M)	1,3	Li	NI	Sb, Fr	Decoction, calcination, trituration	Wound healing, hemorrhoids	Drink	27	Two hands-circumference of stem bark	100
Piliostigma reticulatum (DC.) Hochst. 5329	Bâguendé (M)	1,2,3,4	Li	NI	L	Decoction, infusion	Cold, sinusitis	Inhalation, enema	50	Two hands-circumference of leafy stem	50
Piliostigma thonningii (Schum.) Milne-Redh. 2210	Bag gnanga (M), Nabali (G)	4	Li	NI	L	Decoction	Diarrhea, dysentery	Drink, bath	40	Two hands-circumference of leafy stem	50
Pterocarpus erinaceus Poir. 540	Noèka (M)	1	Li	NI	Re, R	Decoction	Diarrhea	Drink, bath	13	One hand-circumference of stem bark	50

Tamarindus indica L. 5326	Pousga (M)	1,2,3,5	Li	NI	Sb, S	Decoction	Stomachache, wound healing	Drink, bath	33	One hand-circumference of seed	50
Tephrosia bracteolata Guill. & Perr. 2352	Sanri (M)	1	H	NI	L	Decoction	Dental pain, headache	Bath	3	One hand-circumference of the plant	50
Lamiaceae											
Hyptis specigera Lam. 2232	Rounroungu (M)	1	H	NI	L	Decoction	Malaria, dental pain	Bath, gargle, enema	10	One hand-circumference of the plant	50
Leonotis nepetaefolia (L.) R.Br. 145	Barakourouni (M)	5	H	NI	I	Decoction	Cold, sinusitis	Bath	20	One hand-circumference of the plant	50
Ocimum americanum L. 145	Yulu-yuga (M)	1,2	H	NI	L, Sb, Fl	Decoction, infusion	Indigestion, diarrhea, rheumatism	Bath, inhalation	40	One hand-circumference of the plant	50
Ocimum basilicum L. 779	Yulin-gnuuga (M)	1,2	H	NI	L	Decoction	Children fears	Bath	33	One hand-circumference of the plant	50
Vitex cuneata Schumach. & Thonn. 6190	Andga (M)	1	Li	NI	L	Decoction	Diarrhea	Drink	3	Two hands-circumference of leafy stem	50
Vitex doniana Sweet 6189	Koto (D), Anda (M)	2	Li	NI	L	Decoction	Hypertension	Drink	3	Two hands-circumference of leafy	50
Lauraceae											
Cassytha filiformis L. 586	Naam-kaboul (M), Sanguidjo (D)	1,2,6	H/La	NI	L, Sb	Decoction, infusion	Stomachache	Drink, bath	50	One hand-circumference of the plant	50
Loranthaceae											
Tapinanthus globiferus (A. Rich.) Van Tiegh 2875	Soto (Fu)	6	Li, Pp	NI	L, Sb	Decoction	Diarrhea	Bath	7	One hand-circumference of leafy stem	50
Lythraceae											
Lawsonia inermis L. 3012	Lallé (M)	1,2,3,6	Li	NI	Sb	Decoction	Kidney	Purgative	3	One hand-circumference of leafy stem	50
Malvaceae											
Grewia mollis Juss. 287	Mounou mouka(M)	3	Li	NI	Sb	Decoction	Growth retardation	Drink, purgative	3	One hand-circumference of leafy stem	50

Waltheria indica L. 5910	Yaryâamdém (M)	1,3,5	H	NI	L, R	Decoction, trituration	Growth retardation	Bath, application	50	One hand-circumference of the plant	50
Sida alba L. 5878	Zoaaga (M)	3	H	NI	L	Decoction	Pitting edema	Enema	7	One hand-circumference of plant	50
Wissadula amplissima (L.) R. E. Fries. var. *rostrata* (Sch. & Th.) R.E. Fries. 47	Gomtilaon-go (M)	1,3	H	NI	R	Decoction	Cold, sinusitis	Bath	13	One hand-circumference of the plant	50
Meliaceae											
Khaya senegalensis (Desr.) A. Juss. 303	Kuka (M)	3	Li	NI	L, Sb	Decoction, maceration	Malaria	Drink, bath	10	One hand-circumference of leafy stem	50
Pseudocedrela kotschyi (Schweinf.) Harms 72	Sigdre (M)	2,3	Li	Li	L, R	Decoction, calcination	Hemorrhoids, tiredness, tooth pain	Drink, massage, brush	40	One hand-circumference of leafy stem	50
Trichilia emetica Vahl 2577	Sula fĩzân (D), Kinkirs-taanga (M)	2,6	Li	NI	L, Sb	Decoction, trituration	Hemorrhoids, malaria	Drink	10	Two hand-circumference of leafy stem	100
Moraceae											
Ficus gnaphalocarpa (Miq.) Steud. ex A. Rich. 5584	Kamsogo (M), Kankoabou(G)	2,4	Li	Li	L	Decoction	Malaria	Bath	3	Two hands-circumference of leaf	100
Ficus platyphylla Del. 8283	Kansaogo (M), Kankanga (M)	3	Li	NI	L	Decoction	Stomachache, malaria	Drink, bath	3	Two hands-circumference of leaf	100
Moringaceae											
Moringa oleïfera Lam. 7071	Arzan tiiga (M)	2	Li/Ga	NI	L, R, Sb, G	Decoction, infusion, trituration	Dysentery, malaria, stomachache, general fatigue, hypertension	Drink	7	Two hands-circumference of leaf	100
Ochnaceae											
Lophira lanceolata Van Tiegh. ex Keay 738	Mana (D), Malanga (Fu)	6	Li	NI	L	Trituration	Skin disorders	Application	3	Two hands-circumference of stem bark	50

Olacaceae											
Ximenia americana L. 8203N360	Lenga (M)	2,3	Li	Nl	Sb	Trituration	Stomachache, wound healing	Drink, bath	10	One hand-circumference of stem bark	50
Phyllantaceae											
Phyllanthus amarus Schum. & Thonn. 6134	Woompon-ré (M)	1	H	Nl	L, Sb R	Decoction, Cataplasm, infusion	Hemorrhoids, diarrhea, gout, stomachache, liver diseases	Drink, bath, purgative	17	One hand-circumference of the plant	50
Plantaginaceae											
Scoparia dulcis L. 3163	Tim tim (D), Kafré-mandé (M)	2,5	H	Nl	L, Sb, R	Decoction	Cough, hemorrhoid, syphilis	Drink	17	One hand-circumference of the plant	50
Poaceae											
Andropogon gayanus Kunth 20	Pittou (M), Waga ou Karsabiin (D)	2	H /F	Nl	L	Decoction	Cough, malaria	Drink	10	One hand-circumference of the plant	100
Bambusa vulgaris Schrad.ex J.C. Wendl. 3025	Nasar-tanwiiga (M)	2	H	Nl	L	Decoction	Malaria	Bath	3	One hand-circumference of stem bark	50
Cymbopogon citratus (DC.) Stapf 3011	Citronnelle (Fu)	4	H/Ga	Nl	L	Decoction	Cold, sinusitis, general fatigue	Drink	3	One hand-circumference of the plant	50
Cymbopogon giganteus Chiov. 8377	Kuwere (M)	2	H	Nl	L, R	Decoction	Prostate diseases	Drink	3	One hand-circumference of the plant	50
Cymbopogon schoenanthus (L.) Spreng. 5969	Saabi (D)	2	H	Nl	L, Sb, R	Trituration	Skin disorders	Application	3	One hand-circumference of the plant	50
Polygalaceae											
Securidaca longipedunculata Fres. 862	Pelga (M)	2,3	Li	Nl	R	Infusion	Ulcer, liver diseases, respiratory diseases	Enema, inhalation	10	One hand-circumference of root	300
Rubiaceae											
Crossopteryx febrifuga (Afzel. ex G. Don) Benth. 15	Kumbr-wâaga (M)	4	Li	Li	L, Sb Fr	Decoction	Tonic	Drink	3	One hand-circumference of leafy stem	50

Fadogia agrestis Schweinf. ex Hiern 286	Bit koon-bré (M)	1	Li	NI	L, Sb	Decoction	Rheumatism	Bath	17	One hand-circumference of stem bark	50
Feretia apodenthera Del. 5374	Mounouna (M)	3,5	Li	NI	L	Decoction	Stomachache	Drink	3	Two hands-circumference of leafy stem	50
Gardenia erubescens Stapf & Hutch. 2	Susuba (M)	4	Li	NI	L, Sb	Decoction	Healing of umbilical cord wounds	Enema	7	One hand-circumference of leafy stem	50
Gardenia sokotensis Stapf & Hutch. 8211N360	Tang-ra-kwenga (M), Toukôrôgoulé (D)	1,3,5	Li	NI	L	Decoction	Tonic, malaria, wound healing, stomachache	Drink, bath	67	One hand-circumference of leafy stem	50
Gardenia ternifolia Schum. & Thonn. 2018	Râmbrezûnga (M)	1	Li	NI	Fr	Decoction	Tonic	Bath	10	One hand-circumference of fruit	50
Mitragyna inermis (Willd.) Kuntze 823	Yilga (M)	2,3	Li/ Cw	Li /Cw	L, Sb	Decoction, infusion	Malaria, tiredness, hypertension	Drink	50	Two hand-circumference of fruit	50
Nauclea latifolia Smith 2858	Gouinga (M)	2	Li	NI	L,R	Decoction, infusion	Wound healing, stomachache	Drink, bath	40	Two hand-circumference of fruit	100
Sarcocephalus latifolius (Smith) Bruce 2059	Goinga(M)	1	Li	NI	Sb	Decoction	Wound healing, stomachache	Drink, bath	50	One hand-circumference of stem bark	50
Rutaceae											
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler 3061	Rapèka (M)	1	Li	NI	Sb, R	Decoction	Stomachache, dental pain, sickle-cell disease	Drink, bath, toothbrush	17	One hand-circumference of root bark	200
Sapindaceae											
Paullinia pinnata L. 2118	Nusanu (M), Brodinburu (D)	1,2,5,6	Li	Li	L, Sb, R	Decoction	malaria, general fatigue, stomachache	Drink, bath	67	One hand-circumference of leafy stem	200
Sapotaceae											
Vitellaria paradoxa Gaertn. f. 4683	Taanga (M)	1,2,3	Li	NI	Sb	Decoction, trituration	Cold, sinusitis, wound healing, stomachache hemorrhoids	Drink, bath, inhalation	67	One hand-circumference of stem bark	50

Solanaceae											
Physalis angulata L. 642	Poapoa raaga (M)	1	H	NI	L	Trituration	Skin disorders	Application	3	One hand-circumference of the plant	50
Verbenaceae											
Lantana camara L. 2096	Nasar luili sibi (M)	1,2	H	NI	L, Sb, R	Decoction, infusion	Hypertension	Drink	3	One hand-circumference of the plant	50
Tectonia grandis L.f. 3023	Teck (F)	1	NI	Li	L	Decoction, maceration	Ulcer	Drink	3	Two hands-circumference of leaf	50
Vitaceae											
Cissus quadrangularius L. 4132A	Kilounoarou (G)	4	Li/La	NI	Sb	Cataplasm	Tiredness	Massage	3	One hand-circumference of stem bark	50
Zygophyllaceae											
Balanites aegyptiaca (L.) Del. 5208	Kyegelega (M)	1	Li	NI	Fr, Sb	Decoction	Stomachache, hemorrhoids	Drink	33	One hand-circumference of leafy stem	50

Legend:

Local name: D Dioula, G Gourmantché, Gsi Gourounsi, F French, M Mooré, Fu Fulfudé.

Provenance: Li ligneous, H Herbaceous, La Liana, Pp Parasitic plant, F Field, Ga Garden, He Hedgerow, Cw Coast watercourse, NI: No Information.

Part used: L Leaf, Sb Stem bark, B Bark, R Root, S Seed, G Gum, Fr Fruit, I Inflorescence, Sa Sap, Re Resin, Fl Flora

City: Ouagadougou (1), Bobo Dioulasso (2), Ouahigoua (3), Fada (4), Dedougou (5), Léo (6).

Table 2. Plant parts sold in the market for ailment treatment

Plant part used	No. of plants parts (n = 162)	% of plant parts
Leaves	76	47.0
Stem bark	55	34.0
Root	28	17.2
Inflorescence	1	0.6
Gum	1	0.6
Seed	1	0.6

The total number of species for calculation of percentages was 162

Table 3. Source of medicinal plants

Habitat	No. of species	% of species
Savanna	101	86.3
Forest	3	2.6
Savanna and forest	9	7.7
Savanna and field	1	0.9
Savanna and garden	3	2.6

The total number of species for calculation of percentages was 117

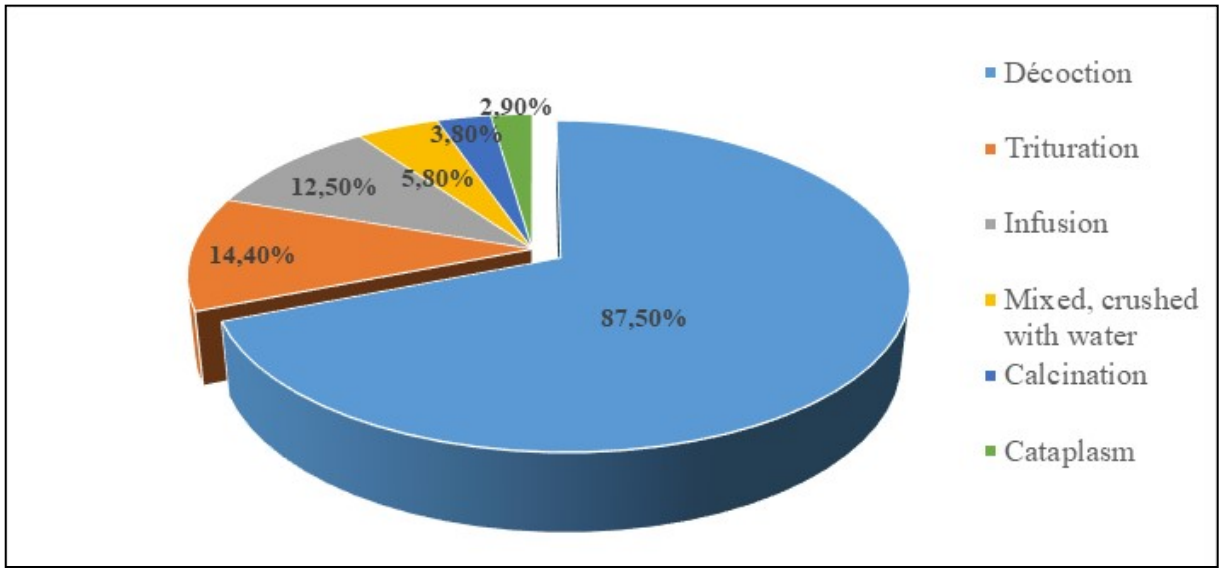

Figure 3. Percentage of species used for various recipe preparations. The total number of species for calculation of percentages was 104. Some species were used for multiple recipe preparations.

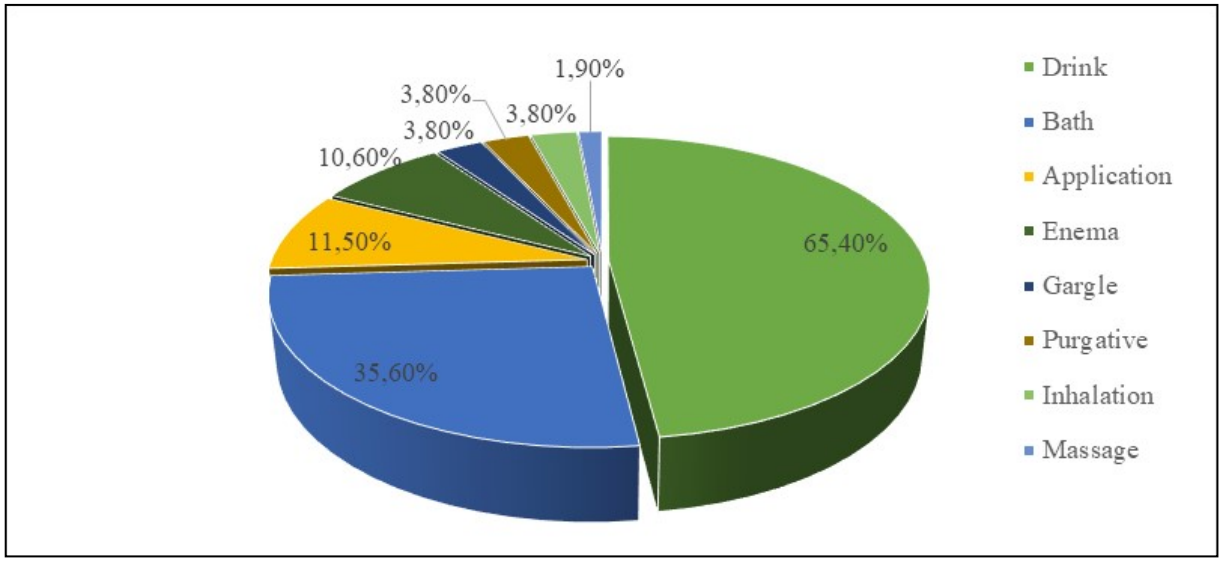

Figure 4. Percentage of species used for various administration modes. The total number of species for calculation of percentages was 104. Some species were used for multiple administration modes.

Table 4. Ailment categories (some species were used to treat multiple conditions)

Ailment categories	Specific condition	No. of plants species (n = 104)	% of total species
Gastrointestinal diseases	Dysentery, ulcer, diarrhea, stomachache	*Adansonia digitata (1), Afzelia africana (2), Alysicarpus glumaceus (3), Annona senegalensis (4), Baissea multiflora (5), Balanites aegyptiaca (6), Boswellia dalzielii (7), Cassia italica (8),Cassia nigricans (9), Cassia occidentalis (10), Cassia sieberiana (11), Cassia singueana (12), Cassytha filiformis (13), Cochlospermum tinctorium (14), Combretum adenogonium (15), Combretum glutinosum (16), Detarium microcarpum (17), Diospyros mespiliformis (18), Euphorbia hirta (19), Ficus platyphylla (20), Feretia apodenthera (21), Gardenia sokotensis (22), Guiera senegalensis* (23)*, Heliotropium indicum (24), Lannea acida (25), Lepidagathis anobrya (26), Maytenus senegalensis (27), Moringa oleïfera (28), Nauclea latifolia (29), Ocimum americanum (30), Paullinia pinnata (31), Phyllanthus amarus (32), Piliostigma thonningii (33), Pteleopsis suberosa (34), Pterocarpus erinaceus (35), Pupalia lappacea (36), Saba senegalensis (37), Sarcocephalus latifolius (38), Sclerocarya birrea (39), Securidaca longipedunculata (40), Senegalia* senegal *(41), Tamarindus indica (42), Tapinanthus globiferus (43), Tectonia grandis (44), Terminalia avicennioïdes (45), Vachellia nilotica* (46)*, Vitellaria paradoxa (47), Vitex cuneata (48), Ximenia Americana (49), Zanthoxylum zanthoxyloides (50)*	48.1
Malaria	-	*Andropogon gayanus (1)* , *Annona senegalensis (2), Bambusa vulgaris (3), Cochlospermum planchonii (4), Cochlospermum tinctorium (5), Combretum micranthum (6), Gardenia sokotensis (7), Guiera senegalensis (8), Cassia sieberiana (9), Faidherbia albida (10)*, *Ficus gnaphalocarpa (11)*, *Ficus platyphylla (12)*, *Hyptis specigera (13)*, *Khaya senegalensis (14)*, *Leptadenia hastate (15), Maytenus senegalensis (16), Mitragyna inermis (17)*, *Moringa oleïfera (18), Paullinia pinnata (19)*, *Trichilia emetica (20)*	19.2
General pathology symptoms	Headache, tiredness, cold, insomnia, fatigue	*Annona senegalensis (1), Bauhinia rufescens (2), Cissus quadrangularius (3)*, *Combretum sericeum (4), Cymbopogon citratus (5)*, *Detarium microcarpum (6), Entada africana (7)*, *Guiera senegalensis (8), Leonotis nepetaefolia (9), Maytenus senegalensis (10), Mitragyna inermis (11), Moringa oleïfera (12)*, *Paullinia pinnata (13)*, *Piliostigma reticulatum (14), Pseudocedrela kotschyi (15)*, *Senegalia macrostachya (16), Tephrosia bracteolate (17), Vitellaria paradoxa (18), Wissadula amplissima (19)*	18.3
Dermatosis	Skin disorders, wound healing	*Annona senegalensis (1), Boswellia dalzielii* (2), *Cassia alata (3), Cassia italica(4), Cassia nigricans* (5), *Diospyros mespiliformis* (6), *Gardenia sokotensis (7)*, *Lophira lanceolata (8), Cymbopogon schoenanthus (9), Nauclea latifolia (10), Parkia biglobosa (11), Physalis angulata (12), Pupalia lappacea* (13), *Saba senegalensis (14)*, *Sarcocephalus latifolius (15)*, *Vitellaria paradoxa (16), Tamarindus indica (17), Ximenia americana (18)*	17.3
Respiratory diseases	Respiratory disorder, sinusitis, cough	*Andropogon gayanus (1)*, *Anogeissus leiocarpa (2)*, *Bauhinia rufescens (3), Burkea africana (4), Cymbopogon citratus (5), Dichrostachys cinerea (6), Entada africana (7), Guiera senegalensis (8), Euphorbia hirta (9)*, *Hygrophila auriculata (10)*, *Leonotis nepetaefolia (11)*, *Piliostigma reticulatum (12)*,	17.3

		Pteleopsis suberosa (13), *Scoparia dulcis (14)*, *Securidaca longipedunculata (15), Vachellia nilotica (16)*, *Vitellaria paradoxa (17), Wissadula amplissima (18)*	
Hemorrhoids	-	*Balanites aegyptiaca (1), Combretum paniculatum (2)*, *Parkia biglobosa (3), Phyllanthus amarus (4), Pseudocedrela kotschyi (5)*, *Pteleopsis suberosa (6)*, *Scoparia dulcis (7), Senegalia* Senegal *(8)*, *Terminalia macroptera (9), Trichilia emetica (10), Vachellia nilotica (11), Vitellaria paradoxa (12)*	11.5
Internal organ diseases	Liver diseases, kidney diseases	*Cassia alata (1), Cassia sieberiana (2), Chrysanthellum americanum (3), Combretum glutinosum* (4), *Faidherbia albida (5)*, *Lawsonia inermis (6)*, *Securidaca longipedunculata (7), Phyllanthus amarus (8), Terminalia avicennioïdes (9)*	8.7
Cardiovascular diseases	Heart aches, control of heartbeat, hypertension	*Anacardium occidentale* (1), *Burkea africana (2), Heliotropium indicum (3)*, *Lantana camara (4)*, *Mitragyna inermis (5)*, *Moringa oleïfera* (6),*Terminalia avicennioïdes (7), Vitex doniana (8)*	7.7
Infections (excl. malaria)	Dental infections, eye infections	*Combretum aculeatum (1), Cynanchum viminale (2), Maytenus senegalensis (3), Tephrosia bracteolata (4), Hyptis specigera (5), Hyptis specigera (6)*	5.8
Child diseases	Umbilical cord treatment, children fears, growth retardation	*Alternanthera nodiflora (1)*, *Gardenia erubescens (2), Grewia mollis (3), Lepidagathis anobrya* (4), *Ocimum basilicum (5), Waltheria indica (6)*	5.8
Urogenital diseases	Syphilis, prostate, sexual impotence	*Cassia sieberiana (1), Cymbopogon giganteus (2)*, *Diospyros mespiliformis (3)*, *Leptadenia hastate* (4), *Scoparia dulcis (5)*	4.8
Arthritis	Rheumatism and gout	*Fadogia agrestis (1), Phyllanthus amarus (2), Ocimum americanum (3)*	2.9
Blood diseases	Sickle cell disease, anemia	*Hippocratea africana (1)*, *Zanthoxylum zanthoxyloides (2)*	1.9

Fidelity Levels (FL) of plant species

The FL values reflect the concordance between informants in using a particular plant species for treating of a specific disease in relation to the total numbers of use reports of that particular species for treating any disease. The highest fidelity level of all plant species was attributed to *Gardenia sokotensis* Stapf & Hutch. (FL=80%) used for treatment of malaria (Table 7). This was followed by *B. rufescens* for usage as tonic and *Pteleopsis suberosa* Engl. & Diels for treatment of stomachache (FL=77% for both species). Two other species, *C. micranthum* and *Maytensus senegalensis* (Lam.) Exell exhibited also rather high-fidelity levels in treatment of malaria (FL=75% for both species).

Presence of species in the markets and prices demanded

The species most frequently offered in the stalls (present in ≥67% of all stalls) were *Annona senegalensis* Pers., *G. sokotensis, Paullinia pinnata* L.*, P. suberosa* and *V. paradoxa* (Table 8). As prices of the medicinal plants varied somehow from one market to market, we give an average price estimate in Table 1 for a one hand-circumference quantity. For the majority of species prices were 50 FCFA for a bundle of one hand-circumference. Higher prices were demanded for some species which were rarely commercialized, like *Chrysanthellum americanum* (L.) Vatke, *Securidaca longipedunculata* Fres.*,* and *Zanthoxylum zanthoxyloide*s (Lam.) Zepern. & Timler (up to 300 FCFA for a one hand-circumference bundle). However, rarity is not the only condition for being a highly valued species, as found for *P. pinnata* which was offered in 67% of the markets and priced for 200 FCFA per bundle.

Conservation status of species encountered in the markets

For only 19% of the species encountered in the markets an estimation of the IUCN conservation status is available (IUCN 2018). Within the 20 most frequently commercialized species nine are qualified in the category Data Deficient, as there are currently not sufficient data for a precise evaluation of the extinction risk. Ten species have a stable population status and one (*V. paradoxa*) is assessed by IUCN as vulnerable (Table 8). Three additional species found in the markets have a vulnerable status: *Afzelia africana* Smith ex Pers.*, Khaya senegalensis* (Desr.) A. Juss. and *Tapianthus globiferus* (A.Rich.)

Van Tiegh. These species were rarely present in the stalls (frequency of citation ≤10%).

Table 5. Informant consensus factor (FIC) about ailment treatment by medicinal plants

Ailment category	N_{ur}	N	FIC
Child diseases	48	6	0.9
Cardiovascular diseases	38	8	0.8
Respiratory diseases	68	19	0.7
Infectious diseases (excl. malaria)	21	7	0.7
General pathology symptoms	71	21	0.7
Arthritis	8	3	0.7
Dermatosis	52	21	0.6
Malaria	45	19	0.6
Gastrointestinal disease	125	50	0.6
Hemorrhoids	26	11	0.6
Blood diseases	3	2	0.5
Urogenital diseases	8	5	0.4
Internal organ diseases	12	9	0.3

N_{ur} = Number of use reports by category from vendors in the markets. N = Number of species listed in each category from all vendors. FIC= Informant Consensus Factor

Table 6. Rank value assigned by key informants for the 10 preferred medicinal plants

Medicinal plant species	Part used	Ailment / Symptoms treated	Key informants (n=9)									Value / 90	Rank
			A	B	C	D	E	F	G	H	I		
Combretum micranthum	Leaf	Malaria	10	8	9	10	8	10	8	9	10	82	1st
Vitellaria paradoxa	Stem bark	Cold, sinusitis, wound healing, hemorrhoids	10	8	10	8	9	10	8	8	6	77	2nd
Vachelia nilotica	Fruit, stem bark	Stomachache, hemorrhoids, cough	9	8	6	10	9	10	10	8	7	77	3rd
Gardenia sokotensis	Leaf	Tonic, malaria, wound healing, stomachache	8	10	8	10	8	6	8	10	6	74	4th
Maytenus senegalensis	Leaf, root	Malaria, diarrhea, dental pain, headache	10	8	10	7	9	8	5	6	10	73	5th
Lepidagathis anobrya	Leaf	Growth retardation, stomachache	8	9	10	6	8	7	10	5	6	69	6th
Pteleopsis suberosa	Leaf, stem bark	Dysentery, stomachache, cough, hemorrhoids	7	8	10	8	8	7	6	5	8	67	7th
Paullinia pinnata	Leaf, stem bark, root	Malaria, general fatigue, stomachache	8	6	8	9	7	5	7	8	7	65	8th
Bauhinia rufescens	Leaf, stem	Cold, sinusitis, tonic	8	10	9	5	6	5	8	7	6	64	9th

	bark, root,fruit												
Annona senegalensis	Leaf, stem bark, root	Wound healing, stomachache, somniferous malaria	8	6	4	6	6	4	10	4	6	50	10th

Ranks given to a medicinal plant are based on its efficacy in treating a special ailment according to the informant. Highest number (10) for a medicinal plant is given when informants considered the plant being most effective in healing an ailment and lowest (1) for the least effective.

Table 7. Fidelity levels of most common species used

Medicinal plant species	Therapeutic use	I_P	I_U	FL[%]
Gardenia sokotensis	Malaria	16	20	80
Bauhinia rufescens	Tonic	20	26	77
Pteleopsis suberosa	Stomachache	10	13	77
Combretum micranthum	Malaria	15	20	75
Maytenus senegalensis	Malaria	18	24	75
Vitellaria paradoxa	Sinusitis	15	20	75
Vachellia nilotica	Stomachache	18	25	72
Lepidagathis anobrya	Growth retardation	11	16	69
Paullinia pinnata	Stomachache	10	20	50
Annona senegalensis	Stomachache	10	20	50

Ip = Number of informants who suggested the use of a species for the same major ailment; Iu = Total number of informants who mentioned the species for any use

Discussion

Informant characteristics

Women by far prevailed in the trade of medicinal plants in the studied markets in Burkina Faso. In Africa, this trade is commonly dominated by women (Van Andel *et al.* 2012). The average age of vendors of medicinal plants was about 54 years. This relatively high age may be attributed to two reasons: In Africa herbalists of higher age (>50) are commonly estimated to have acquired more knowledge in the area of medicinal plants (Tugume *et al.* 2016). Until recently this knowledge has traditionally been passed to the young generation by oral communication, but nowadays younger people have little interest in learning and practicing this activity.

Most of the traditional healers were affiliated with an association in the field of medicinal plants. These associations possess a formal authorization from the government to exercise this activity.

Diversity of medicinal plant species and plant parts used

The high number of species recorded (104) proves that Burkina Faso has a diverse flora used as remedies against ailments and rich traditional knowledge on medicinal plants is still present in the community. In a similar investigation performed in another country of the Sahel zone, North Sudan, only 44 plant species could be identified for medicinal uses (Suleiman 2015). The most represented plant families in our study were Fabaceae, Combretaceae, and Rubiaceae. A high rate of utilization of these plant families has also been reported in other studies on medicinal plant use in Burkina Faso (Zerbo *et al.* 2011; Ky *et al.* 2009). Fabaceae was also the most represented plant family in an ethnobotanical study in Togo which highlights the importance of this family in traditional medicine (Agbodeka *et al.* 2015). The plant parts preferably used for medicinal recipes were leaves followed by barks and roots. In previous investigations in other regions of Burkina Faso (province of Kadiogo and Kouritenga), leaves were also the predominant plant parts collected (Tapsoba and Deschamps 2006; Nadembega *et al.* 2011). The high utilization rate of leaves could be attributed to the ease with which they can be obtained in large quantities compared to other plant parts and the abundance of bioactive compounds usually found in leaves (Tugume *et al.* 2016; Nadembega *et al.* 2011). Large quantities of roots and barks were also collected for recipe preparations. If not properly controlled, this destructive harvesting practice certainly threatens the survival of numerous medicinal plant species in the long term (Bhattarai 1997).

Table 8. Frequency of citation of medicinal plant species most commonly encountered on market stalls and corresponding conservation status according to the IUCN Red List

N°	Medicinal plant species	Frequency of citation (%)	IUCN Conservation status
1	*Annona senegalensis*	67	LC
2	*Gardenia sokotensis*	67	DD
3	*Paullinia pinnata*	67	DD
4	*Pteleopsis suberosa*	67	LC
5	*Vitellaria paradoxa*	67	VU
6	*Bauhinia rufescens*	50	LC
7	*Cassia sieberiana*	50	LC
8	*Cassytha filiformis*	50	DD
9	*Combretum aculeatum*	50	LC
10	*Combretum micranthum*	50	LC
11	*Guiera senegalensis*	50	LC
12	*Lepidagathis anobrya*	50	DD
13	*Maytenus senegalensis*	50	DD
14	*Mitragyna inermis*	50	DD
15	*Piliostigma reticulatum*	50	LC
16	*Saba senegalensis*	50	LC
17	*Sclerocarya birrea*	50	DD
18	*Terminalia avicennoïdes*	50	DD
19	*Vachellia nilotica var. adansonii*	50	LC
20	*Waltheria indica*	50	DD

DD data deficient; LC least concern; VU vulnerable

As can be expected the most varied range of species was offered in the two largest cities of Burkina Faso, Ouagadougou and Bobo Dioulasso. Most of the species were found in at least two markets. The most unique medicinal plant panels with numerous plants not found in other markets were offered in the cities Fada N'Gourma and Léo. Whether this reflects specific cultural or social differences linked to these regions is beyond the scope of this study.

Herbal medicine preparation and administration

Decoction is by far the most common method of preparation, as already described in previous ethnobotanical studies in Burkina Faso (Zerbo *et al*. 2011; Tapsoba and Deschamps 2006). Water is the cheapest and the most available solvent for rapid extraction of active ingredients, but some of the active metabolites of plants can be degraded by extraction performed at high temperatures (Kasali *et al.* 2014). Decoction by boiling or shaking herbals uses large quantities of plant material and may thus contribute to overexploitation of species (Tugume *et al.* 2016). Drinking was the main route of administration, which is common practice for treatment of ailments in families (Togola *et al.* 2005).

Quantitative analysis of the field study for highlighting the most important plants

One of the objectives of this investigation was to identify plants that are of particular importance for the treatment of certain diseases. For this, a set of ethnobotanical indices was used for quantitative analysis of the results of the structured interviews performed with the herbalists.

The factor of informant consensus (FIC value) is particularly useful for selecting the categories of diseases for which medicinal plants are traditionally used. By applying this tool, researchers can identify the main diseases in a community grouped by the categories for which medicinal plants are used. The highest FIC value was found for childhood illnesses, followed by cardiovascular diseases. The most cited species for the treatment of childhood diseases was the herbaceous plant, *Lepidagathis anobrya* (Acanthaceae). This species is particularly used for the cure of growth retardation and stomach pain in children. *Ocimum basilicum* (Lamiaceae), a globally estimated herb, was also often cited by the vendors for the treatment of children fears. Cardiovascular diseases come in second in the disease ranking. As a remedy against this ailment, the vendors particularly mentioned *Mitragyna inermis* as being highly effective against hypertension. These results are in line with those of Konkon *et al.* (2008) who demonstrated that the anti-hypertensive activity of *M. inermis* is due to the presence of triterpenes.

In addition to the factor of informant consensus, the fidelity level was applied to the data of our field study for selecting important individual plants. Using this

tool, the species *Gardenia sokotensis, Combretum micranthum* and *Maytenus senegalensis* ranked as the best candidates for treatment of malaria. These three species were also among the favorites when we asked vendors to perform a preference ranking of the ten most valued plants in terms of frequency of use and effectiveness against malaria.

Thus, the combination of fidelity level and preference ranking highlights *G. sokotensis*, *C. micranthum* and *M. senegalensis* as particularly important species for treatment of malaria. *G. sokotensis* is described as containing multiple chemical compounds including saponosides, alkaloids, triterpens and sterols (Ouédraogo 1998). Previous studies have already described the anti-plasmodial efficacy of *G. sokotensis* and *M. senegalensis* (Ouédraogo 1998; Willcox *et al.* 2011). Extracts from *C. micranthum* have already been tested clinically and have demonstrated partial parasite clearance and very efficient fever clearance after seven days of treatment (Willcox *et al.* 2011). The high frequency of citation of these three species also demonstrates the high prevalence of malaria in Burkina Faso. According to WHO (2009) and several other studies (Ky *et al.* 2009; Zizka *et al.* 2015), malaria is a major threat to the population of Burkina Faso, with 3.5 million recorded cases in 2008 (thereof 50% of the children under 5 years).

The results of our field study highlight the value of traditional knowledge in detecting plant species containing pharmacological effective substances with potential to treat this important disease. We thus strongly encourage the development of plant material derived from *G. sokotensis, C. micranthum* and *M. senegalensis* into standardized phytotherapeutical drugs. This can be done quickly and cheaply and ensures the access to complementary medicine for the poorest people in remote areas. The use of alternative active substances might also delay the development of resistance to current standard drugs. As all three plants have a long tradition in the treatment of malaria by traditional healers in Burkina Faso and Mali (Zizka *et al.* 2015; Haidara *et al.* 2016), severe toxicological and safety issues are not to be expected.

In the present survey, combinations of plants for the treatment of diseases were not reported by the vendors. In contrast, treatment of several diseases with a single plant seems to be common practice. For example, *Hippocratea africana* (Wild.) Loes. or *Vitex doniana* Sweet were used to treat sickle-cell disease and hypertension, while *Euphorbia hirta* L. was used for the treatment of dysentery and respiratory troubles. Some medicinal plants were used to treat three or more types of diseases. An example for this is *Mitragyna inermis*, which by the informants was mainly mentioned for hypertension treatment but was also recorded to treat malaria, wounds and stomach aches. This is substantiated by several studies that have reported positive effects of *M. inermis* against stomachache, malaria, diabetes, dysentery, venereal diseases and mental disorders (Sourabie *et al.* 2013). According to Tugume *et al*. (2016), the use of a plant to treat several ailments is probably attributed to the presence of many metabolites in this plant and also to the observation that the same molecule can be active against different pathologies.

Conservational aspects

In Burkina Faso, most of the plants sold in the markets are collected in the savanna by traditional health practitioners, sellers or collectors. Whereas the traditional health practitioners are instructed to collect herbal material in a sustainable manner by government, numerous uncontrolled collectors represent a serious risk for medicinal plant species (Nadembega *et al*. 2011). This risk is also increased by the fact that most plant parts are collected from ligneous species in the savannas (Kristensen *et al.* 2003; Moyo *et al.* 2015). Savanna trees are often overexploited because of their multiple usages, not only for medicine products, but also for domestic energy, timber for construction, seeds for food preparation or fodder for animals. The V*itellaria paradoxa* tree is such a multi-purpose species that was among the most cited species encountered in the markets and plant material was sold in large quantities in nearly 70% of the stalls at a relatively low price (one hand-circumference of stem bark for 50 FCFA). Unsustainable collection of the stem bark of this tree by local drug collectors could lead to the disappearance of this species in the savanna. In addition to the bark collected for preparation of remedies, the nuts of this tree are also intensively collected by local women to obtain oil used for food and for preparation of cosmetics products. This impacts the reproduction of the tree populations from seeds and thus further increases the extinction pressure on this species. It is classified by the IUCN as a vulnerable species. According to forest villagers and our own observations in the field, *V. paradoxa* is now in fact a very rare plant found in the savanna area. Some other species as *Securidaca longipedunculata* and *Zanthoxylum zanthoxyloides* are already diminished in their native environment (own observations). They were rarely offered in the stalls and their prices greatly exceeded the ones for readily available species converting them into a highly profitable natural resource. Three additional tree species which are assessed as vulnerable by IUCN (*Afzelia africana*, *Tapianthus globiferus, Khaya*

senegalens) were sold at low prices, nevertheless they were quite rarely found in the markets. The stem bark and roots of *A. africana* are used in phytomedicine, a practice that particularly endangers this species. From *T. globiferus* and *K. senegalensis* leaves or stem bark are used for the preparation of extracts. The vulnerable status of *Tapinanthus globiferus* could be explained by the fact that it parasitizes on *V. paradoxa* (Ahamidé et al. 2017). For many other species, like *Annona senegalensis*, *Bauhinia rufescens* or *Cassia occidentalis* L. (for further species see Table 1), the stem bark, the roots and the leaves have been cited as a remedy for the same ailment. Sustainability of these species would be secured if harvesting of bark and root is avoided and instead harvesting of leaves would be promoted.

Unfortunately, medicinal plants are cultivated only in rare cases in home gardens, as hedges or in nurseries in Burkina Faso. This is underlined by our survey as we found very rarely cultivated plants in the stalls of the vendors. There are several reasons for this. Firstly, institutional support for the production and dissemination of approved plant material for cultivation is very limited (Cunningham 1997). Secondly, there is a common belief that cultivated plants do not contain the same composition and quantities of active ingredients as plants grown in their native environments. The rapid urbanization currently in progress in Burkina Faso will inevitably lead to an excessive harvest of medicinal plants in the savannas and forests surrounding large cities. There is thus an urgent need to cultivate medicinal plants in order to conserve biodiversity and protect threatened species (Joshi and Joshi 2014). Population selection in nurseries accompanied by quality control of active ingredient composition could help to identify accessions that can be grown *ex situ*, thus contributing to the sustainable utilization of medicinal plant species. This is of particular relevance for herbaceous species that are frequently uprooted in the wild, a practice that often results in the extinction of natural populations.

Our study also demonstrates that many wild plants heavily exploited as medicinal remedies in Burkina Faso are not yet finally assessed in their conservation status by IUCN (2018) due to a lack of data. There is an urgent need for assessing the threat status of natural populations of medicinal plants and to strengthen conservation work in order to preserve this cultural heritage for future generations.

Conclusions

Our study on medicinal plants traded in various regions of Burkina Faso demonstrates that a high diversity of species is used as remedies for many ailments. This complementary medicine is particularly useful for people who cannot afford or do not have access to modern medicinal care. Savanna trees are the most widely used source of medicinal plants. Increased efforts are therefore necessary to preserve the integrity of natural populations of these species regarding their low conservation status. One remedy could be the cultivation of these species in home gardens or nurseries. Our field study could help to focus future conservation efforts and to identify promising candidates for further experimental and clinical research with the objective for developing these plants into standardized drugs.

Declarations

List of abbreviations: AN: Assemblée Nationale**;** HNBU: Herbier National du Burkina Faso**;** IUCN: International Union for Conservation of Nature**;** MAHRH: Ministère de l'Agriculture de l'Hydraulique et des Ressources Halieutiques**;** WHO: World Health Organization

Ethics approval and consent to participate: All participants were asked for their free prior informed consent before interviews were conducted.

Consent for publication: Not applicable.

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Authors' contributions: LO designed and performed the field study and together with JE wrote the paper. PAEDS and HS contributed to the drafting of the paper. MK reviewed the final version of the manuscript.

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