Indigenous knowledge of wild plants collected in Darfur, Sudan

Ahmad K. Hegazy, Hasnaa A. Hosni, Lesley Lovett-Doust, Hanan F. Kabiel, El-Shafie M. Badawy and Edward N. Mwavu

Research

Abstract

Background: The lives of the "Fur", indigenous people of Darfur, Sudan are intimately connected to local wild plants, but the traditional uses of these plants are, so far, poorly documented. Many species are indigenous to the region, but others are introduced, and have naturalized over millennia.

Methods: For a month each summer from 2014-2016, using questionnaire interviews, direct observation of practices, and a literature review, 58 species were identified. An "importance value" for each was determined, based on the intensity and season(s) of use, in eight use categories. For each species, a "concordance ratio" characterized the degree of agreement between indigenous knowledge and our current "scientific understanding" of their value.

Results: All species were multi-use; animal forage, "other functional uses", traditional medicine, and construction predominated. Some species are declining due to overharvesting by the growing local population, exacerbated by conflict and refugee encampments. Most of the species are used in traditional medicines, but active ingredients have been scientifically confirmed for only half of them. Surprisingly, several species with known medicinal ingredients are not used locally.

Conclusions: The "Fur" people have long combined agriculture with pastoralism and wildcrafting. For this to be sustainable, it is critical to understand cultural contexts and recognize multi-use species. This can help identify new medicines, and guide sustainable development of local resources, adapted to local conditions. Naturalized wild fruit trees may have evolved drought resistance in this increasingly dry savanna climate; such genes might usefully be incorporated in crop strains elsewhere as climate change proceeds.

Key words: Ethnobotany, Multipurpose-Use Plants, Importance Value, Indigenous Knowledge Index, Scientific Knowledge Index, Concordance Value, Plant Diversity, Climate Change

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المستخلص

الخلفية: ترتبط حياة السكان الأصليون في دارفور بالسودان ارتباطًا وثيقًا بالنباتات البرية المحلية. وبالرغم من ذلك، فإن الاستخدامات التقليدية لهذه النباتات، حتى الآن، غير موثقة جيدًا. يوجد العديد من الأنواع النباتية المحلية المتأصلة في المنطقة، بالأضافة الي انواع اخري دخيلة استوطنت على مدى مئات السنين.

طرائق الدراسة: أجريت هذة الدراسة لمدة شهر من كل صيف في الأعوام 2014-2016. وتم جمع المعلومات من خلال مقابلات مع السكان المحليين، وطرح اسئلة استبيان معد لذلك أوالملاحظة المباشرة لممارسات السكان ومراجعة الأدبيات والمراجع المتاحة. تم التعرف علي عدد 58 نوعًا

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نباتيا وحساب "درجة الأهمية" لكل منها، بناءً على كثافة وموسم (أو مواسم) الاستخدام، في ثماني فئات للاستخدام بالنسبة لكل نوع. وبحساب "نسبة التوافق" بين المعارف الأصلية والمعارف العلمية أتضحت المفاهيم بقيمة التنوع النباتي في هذة المنطقة.

النتائج: أتضح ان جميع الأنواع قيد الدراسة متعددة الاستخدامات. وقد سادت استخدامات النباتات كأعلاف للحيوانات، الاستخدامات الوظيفية، الطب التقليدي ومواد البناء علي باقي الأستخدامات. وقد انخفض استخدام بعض الأنواع بسبب الحصاد المفرط والمتزايد من قبل السكان المحليين، والذي تفاقم بسبب النزاع القائم في المنطقة وما يصاحبها من اقامة مخيمات اللاجئين. ويتم استخدام معظم الأنواع في الأدوية التقليدية، وذلك بالرغم من التأكيد العلمي للمكونات النشطة فيما لا يزيد عن نصف النباتات المستخدمة طبيا. والمثير للدهشة أن العديد من الأنواع المعروف مكوناتها الطبية لا يتم استخدامها محليًا.

الاستنتاجات: لقد جمع السكان المحليين منذ زمن طويل بين الزراعة، الرعي والحرف البرية. وضمانا لأستدامة هذة الحرف، كان لازاما فهم الأنماط الثقافية والتعرف على الأنواع متعددة الاستخدامات. حيث يمكن أن يساعد ذلك في التعرف علي الأدوية الجديدة، وتوجيه التنمية المستدامة نحو استخدام الموارد المحلية، المتكيفة مع الظروف المحلية. وتعتبر النباتات البرية المحلية المثمرة مقاومة للجفاف لوجودها في مناخ السافانا الجاف؛ ولذلك يمكن الأستفادة منها بنقل هذه الجينات الي سلالات المحاصيل المحلية او المنزرعة في أماكن آخري خاصة مع استمرار تغير المناخ.

الكلمات الدالة: علم النبات العرقي ، النباتات متعددة الأستخدام ، درجة الأهمية ، مؤشر المعارف الأصلية ، مؤشر المعارف العلمية ، درجة التوافق ، التنوع النباتي

Background

The diverse climate, topography and soils of Darfur, Sudan generate a relatively rich flora, with vegetation types matching the mosaic of topography and soils (Hegazy *et al.* 2018a,b). The region benefits from accessible surface water, due to orographic rainfall in summer, as moist air rises and cools over the mountain massif (El-Tom 1972). This supported the early development of agriculture and settlements in the lowlands and pastoralism on the slopes of Jebel Marra (see Figure 1).

Engagement with local communities can help support conservation efforts; sharing knowledge also helps communities to re-connect with traditional resource uses and celebrate the long-standing relationship between communities and the environment (Martin 1995, Choudhary *et al.* 2008, Dapar *et al*. 2020). In building support for conservation, it is often helpful to recognize "nature's services", both in terms of direct material benefit (medicines, food, fodder, etc.,) and in terms of other, less obvious benefits such as soil retention, maintenance of soil fertility, filtration of wastewater, etc. (Daily 1997, Tukur *et al.* 2013, Hegazy *et al*. 2014). In Darfur, there is an ancient tradition of harvesting and processing of wild plants; however, the current prolonged warfare, famine and disturbance endanger retention and transmission of traditional knowledge and connection with the land, and the pressures of famine promote overharvesting of wild plant resources.

An appreciation of plant resources sometimes correlates with factors like ethnicity, gender, age, education, social and economic status, roles and responsibilities in the family and community, profession, aptitude and educational attainment, and ownership/control of natural resources (Holt, 2005, Ayantunde *et al.* 2008). Wild plants may be valued in many ways; they may be primarily sources of goods and services, providing a return on capital or labor investments in terms of grazing, timber, food, honey production, etc., or they may support leisure and enjoyment (Sen 2005, Anonymous 2010). Scientists may see wild plants as potential sources of new medicines and disease-resistance genes for related cultivars, or as research and teaching material, and anthropologists may see vegetation as a context within which distinct human cultures evolve, with plants contributing to language and culture. Artists may view them as subjects, with some species being iconic symbols of the desert, or savanna, etc., and religions may use plants in a narrative that often builds on an ancient secular appreciation and veneration of nature (Hegazy *et al.* 2014).

Plants may have a single use, or be multi-use species that play key economic, environmental, industrial, historical, esthetic and spiritual roles in sustaining indigenous peoples (Hegazy *et al.* 2014). They also support the functional and ecological stability of ecosystems (Von Carlwolitz 1984). However, today, many plants of high economic importance are over-exploited, and at risk of extinction (Tukur *et al.* 2013).

Traditional Ecological Knowledge (TEK), or Indigenous Knowledge (IK) represents "The body of knowledge, practice and beliefs evolved from adaptive processes that is unique to a given culture or society, existing within, or acquired by, local people over time through accumulation of experiences, society-nature relationships, community practices and institutions, and by passing it down through generations" (Fernando 2003, Sillitoe 2000). This knowledge is characteristically local, holistic, integrative and rooted in cultural traditions (Mearns *et al.* 2006). It is reinforced through experience, trial and error, and learned through traditions and repetition rather than being theoretical; this supports its retention, and essentially provides a "screening procedure" for any given use. Since IK is constantly evolving, being produced, discovered, lost, rediscovered and tested in an ongoing way, it tends to be shared more than are other forms of knowledge.

Some dismiss IK as "merely" a question of trial and error whereas modern knowledge is science-based, characterized by hypothesis testing and the experimental method, but over 80% of "modern" medicines are, or were originally, derived from wild plants and microorganisms, where most were first identified and used in traditional medicine by indigenous peoples in various parts of the world (Vasisht & Kumar 2006). Indeed, humans have often learned about medicinal plants by watching, and then mimicking their consumption by other animals – a concept known as "zoopharmacognosy" (Shurkin 2014). As we encounter new strains of drug-resistant pathogens and the emergence of new diseases, scientists have recognized the value of exploring TEK uses of wild plants, in the quest for new medicines and other plant products. More recently, scientists have acknowledged the value of blending respect for IK practices with "scientific" knowledge and practices, some proposing assignment of "patent" rights to indigenous users and recognizing that IK practices are often superior as sustainable approaches to resource development and conservation (World Bank 1998, Sillitoe 1998, Dekens 2007, Mercer *et al.* 2009, Darwish & Aburjai 2010, Hegazy *et al.* 2014). For example, traditional nomadic pastoralism (e.g. *"hema"* in the Arabian Peninsula) better preserves biodiversity in rangeland than does "settled" agriculture with conversion to pasture or grain cultivation for animal feed (Hegazy & Lovett-Doust 2016). Meaningful engagement with IK requires the respectful collaboration of scientists with local knowledge stakeholders to develop appropriate strategies for sustainable use (Rai *et al.* 2000, Cork *et al.* 2002, Cordell & Colvard 2005, Alzweiri *et al.* 2011, Siew & Doll 2012).

Formal "quantitative ethnobotany" has progressed significantly in recent decades (Pardo-de-Santayana *et al.* 2010). Earlier studies measured the value of plant species by developing indices that did not distinguish cultural, practical and economic dimensions. In the present study, the cultural dimension was estimated as a function of the potential uses and number of people reporting the plant use, while the practical dimension considered the number of observed uses and number of times the species was used (Hegazy *et al.* 2014). For materials collected for sale, such as the high-value material, "Gum Arabic", tapped from *Senegalia senegal*, an additional "economic" dimension could be estimated in terms of the number of times the plant was used and the market price of the species (Phillips & Gentry 1993a,b, Reyes-Garcia *et al.* 2006, Theilade *et al.* 2007).

There are no previous published ethnobotanical studies of the montane and surrounding savanna ecosystems in West Darfur, so our objectives were to document, from the perspective of indigenous people, the major uses of wild plants, identify which species are used for each purpose, and assess the relative importance attached to different categories of plant use. A better understanding of local knowledge of native plant species could inform the identification of research priorities for improved, sustainable management of natural resources and conservation of the region's diverse flora, which is already showing detrimental effects from increased aridity and overharvesting, with a switch from the dominance of phanerophytes (shrubs and trees) in the canopy to a more sparse savanna where more than 50% of the vegetation cover is therophytes (annuals and ephemerals) (Hegazy *et al*. 2020). The region has suffered decades of political and social instability; these pressures, combined with a young and expanding local population, endanger the region's plant resources. The objectives of this study, then, are to assess current indigenous knowledge of wild plants (both indigenous and naturalized species), to categorize current uses, and to identify any gaps in terms of medicinal plants used locally that merit scientific investigation. Finally, this is a region that has been severely disturbed over millennia, by various waves of invaders, with the current situation being one of widespread famine. It is important to identify any medicinal plants known to science, that are not being used as medicines locally. This would support the proposition that the current level of disruption, associated with an extended period of over-harvesting, and declines in many of the heavily-used species, is causing some indigenous knowledge to be lost.

Material and Methods

Study Area

The Jebel Marra study area is located between 11°32′20″ to 13°00′ N and 23°24′ to 24°10′ E in the western part of the middle of Darfur state, Sudan (Figure 1). The mountainous topography drains westward into Lake Chad. The region is characterized by a descending escarpment, and flat plains at lower elevations. A detailed description of the study area, habitat types, altitudinal belts and climate is found in Hegazy *et al*. (2018a, b).

Plant Identification

The identification of plant specimens was confirmed using published keys (Wickens 1967, FTEA 1952–1978, Andrews 1950, 1952, 1956, Oliver *et al.* 1979, Hutchinson & Dalziel 1954-1958, Täckholm 1974 and Boulos 1999, 2000, 2002, 2005), and by comparing specimens with those in "virtual herbaria", available online: (http://apps.kew.org), African Plant Database www.tropicos.org and the JSTOR global plants database. The specimens were also compared and checked against specimens housed at the herbarium of Cairo University (CAI), in addition to consultation with experts. Voucher specimens have been deposited at Cairo University Herbarium (CAI) and Al Fashir University, Darfur, Sudan. The affiliation of taxa to families followed the approach of the Angiosperm Phylogeny Group (Stevens 2001 onwards), authors of taxa are in accord with the African Plant Database (Tropicos).

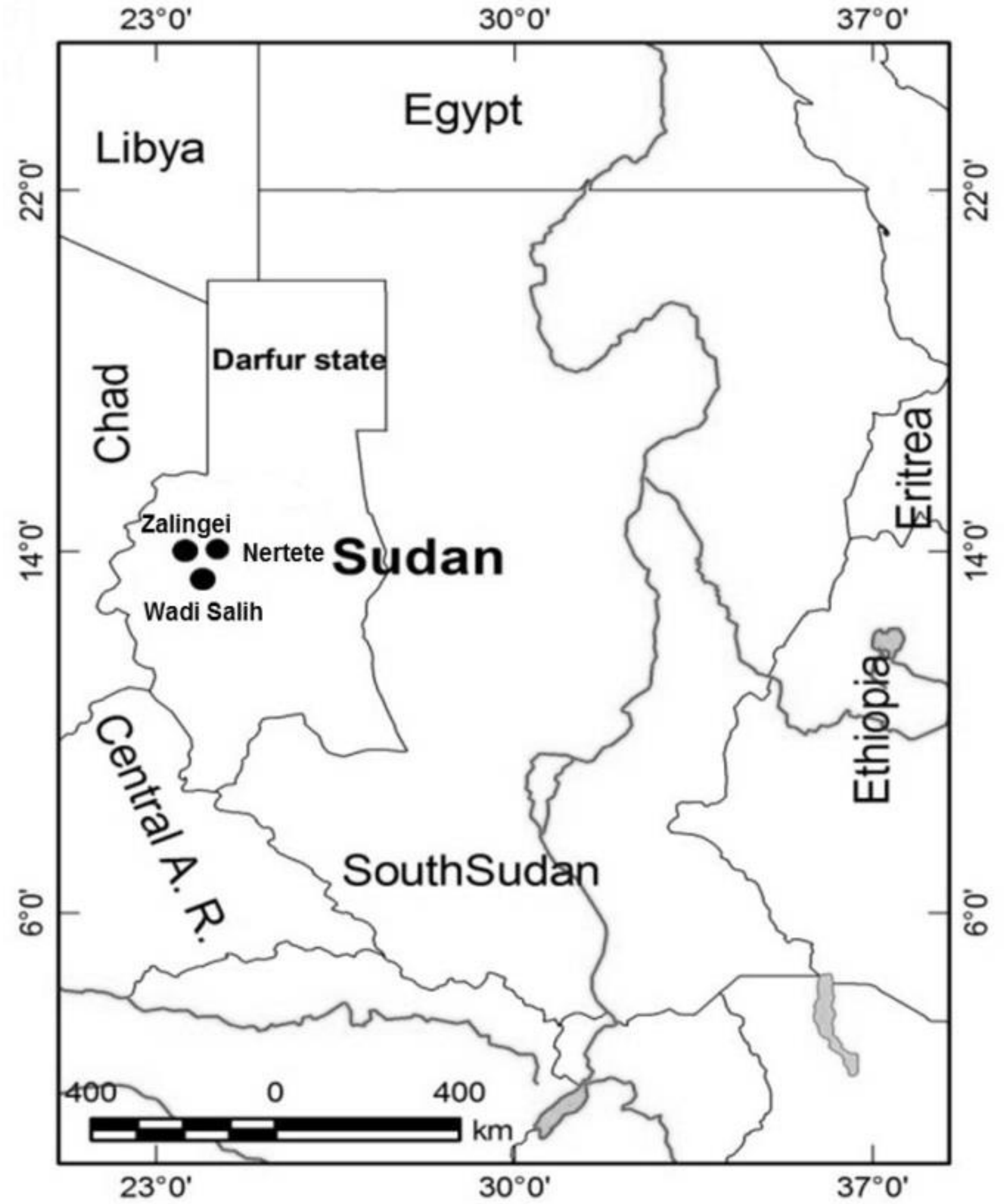

Figure 1. Map of the Study Area, Darfur. Interviews were carried out in the three towns indicated (Zalingei, Nertete and Wadi Salih), and in the surrounding countryside.

Study Population

The study population represented a sample of indigenous families identifying as "Fur" in Darfur. The Fur are settled farmers, with a black African identity, who today generally practice Islam. Families typically have a permanent home in the mountains; some also have a second residence in one of the three nearby towns, Zalingei, Wadi Saleh and Nerttiti, in western Jebel Marra (see Figure 1). One hundred and fifty (150) respondents were interviewed; 93 males (aged 30-65) and 57 females (aged 27-71). This age range was selected based on the expectation that adults would be more aware of plant resources and uses. We used participatory rural appraisal techniques (Briggs *et al.* 1993) supported by a questionnaire and direct interviews. Interviews and discussions were based on previously identified sets of points and questions on different uses of plant resources.

Respondents were also asked to react to a list of regularly-used plants in terms of stating what they were used for, and whether that use was seasonal or year-round. They were shown herbarium samples of the plants in question.

Assessing "Importance Value"

The "importance value" of each plant species for local people was calculated. A three-part approach was used (*cf.* Hegazy *et al.* 2014). Eight common categories of use were identified, namely: medicine, (animal) forage, (human) food, firewood, research/education, construction, beekeeping, and "other functions" (these would include specific industrial or craft uses of plant extracts, fibers, etc., or use of live plants to provide, for example, soil stabilization, shade and hedges, or use as ornamental plants). The Importance Value (IV) of each role was estimated for each plant species based on these eight use categories (Table 1). For each species, zero indicates it is not currently used for that purpose. A score of 4 would suggest limited use, while a score of 8 denotes the highest level of year-round use. The sum of IVs for all uses, for each species, is expressed as a relative percentage of the maximum score available (which would be 8 x 8 = 64). This percentage represents a species' total importance value (TIV), with larger values indicating more uses and/or intensity of year-round use. For other examples of calculations see Hegazy *et al*. (2014).

Table 1. Factors used to estimate a score for "Importance Value" for each species, and for each use. Where a species is not used for a given purpose it receives a score of zero for that use. The maximum possible score for a species for a given use is therefore eight. Plants were all collected in the Jebel Marra mountains and surrounding area in West Darfur.

Criterion	Category	Score
Availability	Limited to seasonal Year-round	1 2
Species abundance	Rare Abundant	1 2
Species use	Only mentioned in literature Cited, known by local people	1 2
Intensity of use	Low High	1 2
Maximum Points Available		8

Indigenous Knowledge

The cultural value (CV) of a species can be calculated (Reyes-Garcia *et al.* 2006) using the formula:

$$CV = Uc \times Ic \times \Sigma IUc$$

Where CV= cultural value of a species. Uc = total number of uses reported for the species divided by the eight potential uses considered in this study. Ic = number of informants who recorded the species as useful divided by the total number of people participating in the survey. IUc = the number of informants who mentioned each of the eight uses of the species divided by the total number of participants. The value, an indigenous knowledge index, ranges from zero to one (*cf.* Hegazy *et al.* 2014).

Scientific Knowledge

We estimated the current (medical) scientific knowledge index (SKI) according to the formula:

$$SKI = MP/TC$$

Where MP is the total number of compounds with medicinal and pharmacological applications, and TC represents the total number of (known) active chemical constituents in each species. The index value ranges from zero to one.

Concordance Ratio

To assess the level of agreement (concordance) in terms of scientific "confirmation" of TEK, the concordance ratio is calculated as indigenous knowledge index /scientific knowledge index:

$$\text{Concordance ratio} = IKI/SKI$$

If all indigenous uses of the species are supported by current scientific evidence (i.e. the known scientific applications match all indigenous uses) the concordance ratio would = 1. Ratios >1 imply there are still gaps in terms of the scientific study of the species, and that at least some of the indigenous uses of the species merit scientific inquiry. When the ratio is <1, this suggests that scientific knowledge of the species' use exceeds the indigenous knowledge, implying these species could be even better used and developed to benefit the local community (Hegazy *et al.* 2014).

Results

Uses for the study species, in terms of the eight use categories, are summarized in Figure 2, with species-by-species details in Table 2. All species were multi-use, with the number of use categories ranging from 2 - 8. Seventeen species fulfilled all 8 uses, another 17 had 7 uses (the "missing" use was usually as (human) food, the remaining 3 instances involved species used as firewood). The most important use was as livestock forage (for all but two of the species surveyed), followed by use in "other roles" (all but 3 species), then medicine (all but 5 species), and construction (all but 9 species). Only 27 of the 58 species (47%), served as human food (Table 2). The most heavily used species in terms of "TIV%", or total importance value were *Ziziphus spina-christi* (81%) and *Cordia africana* (80%), both used "year-round" in all 8 use categories. Only occasionally did a species earn the maximum importance value of "8" in a use category; 4 were for medicines, 2 for forage, 4 for human food, 3 for firewood, and one for each of construction and beekeeping (Table 2). Over 65% of the study species have a TIV% higher than 50%.

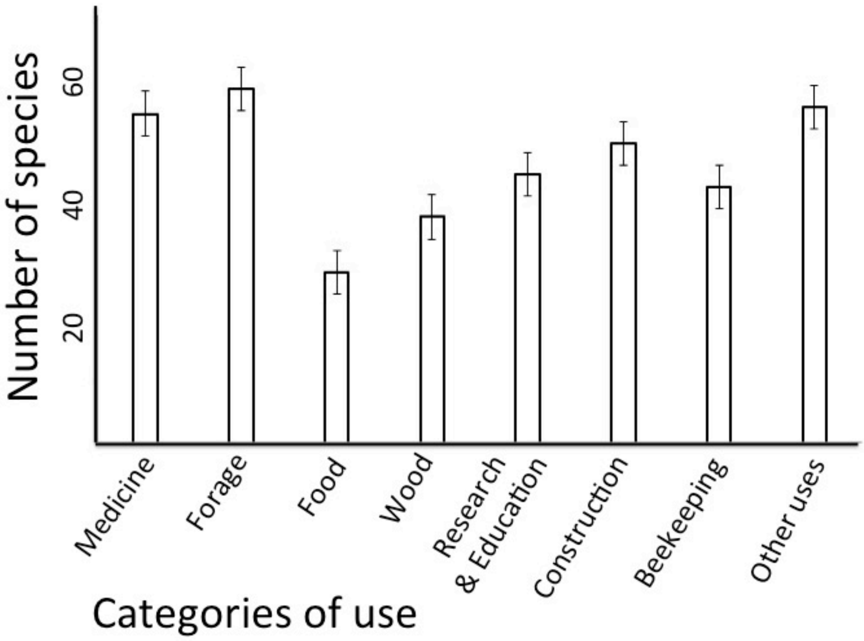

Figure 2. Number of species appearing in each category of "use".

Forage

Accessible forage is used directly by grazers; livestock species differ in their grazing selectivity (in terms of preferred species); they also graze in different ways (removing whole shoots, or nibbling only leaves, etc.). Grasses, fodder trees and water sources along Wadis (valleys) are critical resources during the dry season (December-April) for animals herded by pastoralists. In addition, branches and leaves may be collected to supplement the food supply for livestock. The most heavily used species were *Faidherbia albida* and *Acacia seyal*, with scores of "8"; *Bauhinia rufescens*, preferred mostly by camels and goats, has a score of "7" (Table 2). Dried and pressed *Acacia seyal* seeds and *Acacia sieberiana* fruits are collected and used as supplemental fodder and leaves of *Boscia senegalensis* and *Capparis sepiaria* are also harvested when pastures are overgrazed. These activities support local food security, providing protein in the form of milk and meat products either for personal use or for sale. Plants in the Fabaceae (legumes), with their higher protein content, are particularly important.

Medicinal Plants

Of the fifty-eight species studied, fifty-three were used locally as medicines (Table 2). Some are still common in the region (shaded species in column 1 of Table 2), but others have declined in abundance due to over-harvesting, *e.g.*, *Commiphora africana* (African myrrh) and *Terminalia brownii*. Medicines are made from extracts of fresh or dry plant parts, liquid exudates, latex, and gums (Table 3). Some species (*Adansonia digitata, Khaya senegalensis, Tamarindus indica* and *Acacia nilotica)* earned the highest medicinal importance value (8). Only five species (*Aeschynomene uniflora, Albizia antunesiana, Azanza grackeana, Desmodium ospriostreblum,* and *Vangueria venosa)* had no reported medicinal use; of these five, only one, *Azanza grackeana* was used as a human food, but all five were used as animal forage. Leaves were the most frequently used tissues, followed by roots, fruits, bark and seeds (Figure 3), and they were used to treat a variety of ailments (Figure 4).

Table 2. Importance value of the study species in terms of eight different plant uses. The maximum score available for a species is 64. TIV= Total importance value assessed as (the sum of scores/maximum score available) * 100. In the far-left column, species shaded in grey are among the dominant species in the eight vegetation types recognized in Jebel Marra (see Hegazy *et al.,* 2020). For any given use, instances where a species earned a score of 8 for that use are shaded in grey. The number of uses that each species fulfilled is also indicated, with species fulfilling all 8 uses (under the header "Total Number of Uses") shaded in grey. Finally, in the column headed "TIV %", values of 70% and above are shaded grey to denote the species that are most heavily used, overall.

Species & [Family]	**Medicine**	**Forage**	**Food**	**Wood**	**Research & Education**	**Construction**	**Bee-keeping**	**Other functions**	**Total # uses**	**%TIV**
Acacia mellifera (M.Vahl) Benth. [Fabaceae]	4	4	-	5	6	5	4	6	7	53
Acacia nilotica (L.) Delile [Fabaceae]	8	6	-	7	6	7	6	7	7	73
Acacia polyacantha Willd. [Fabaceae]	4	4	-	6	4	5	6	6	7	55
Acacia senegal (L.) Willd. [Fabaceae]	6	5	5	6	7	5	6	6	8	72
Acacia seyal Delile [Fabaceae]	4	8	-	6	4	6	5	5	7	59
Acacia sieberiana DC. [Fabaceae]	5	6	-	6	6	5	5	4	7	59
Acacia tortilis (Forssk.) Hayne [Fabaceae]	4	4	-	5	4	5	5	6	7	52
Adansonia digitata L. [Malvaceae]	8	4	6	5	7	4	6	7	8	73
Aeschynomene uniflora E.Mey. [Fabaceae]	-	4	-	-	4	-	-	5	3	20
Ailanthus excelsa Roxb. [Simaroubaceae]	6	-	-	4	4	6	-	4	5	38
Albizia antunesiana Harms [Fabaceae]	-	4	-	4	4	5	6	4	6	42
Albizia amara (Roxb.) B.Boivin [Fabaceae]	4	6	4	7	5	7	6	6	8	70
Anogeissus leiocarpus (DC.) Guill. & Perr. [Combretaceae]	6	5	4	8	7	7	6	5	8	75
Asparagus africanus Lam. [Asparagaceae]	5	5	-	-	-	-	-	4	3	22
Azanza grackeana (E.Hoffman) Exell. & Hillc. [Malvaceae]	-	6	7	-	4	5	7	4	6	52
Balanites aegyptiaca (L.)Delile [Zygophyllaceae]	5	7	6	6	5	6	4	6	8	70
Bauhinia rufescens Lam. [Fabaceae]	4	7	-	4	-	6	5	5	6	48
Bauhinia thonningii Schum. [Fabaceae]	5	6	4	7	6	7	6	6	8	73
Boscia senegalensis Lam. [Capparaceae]	4	5	4	-	-	6	-	4	5	36
Cadaba farinosa Fossk. [Capparaceae]	5	4	-	-	5	4	4	5	6	42
Capparis sepiaria L. [Capparaceae]	6	4	-	-	-	5	4	5	5	38
Carica papaya L. [Caricaceae]	4	4	7	-	-	-	7	6	5	44
Combretum glutinosum Perr. ex DC. [Combretaceae]	6	4	-	7	-	6	5	6	6	53
Combretum molle R.Br. ex G.Don [Combretaceae]	5	4	-	6	-	4	5	5	6	45
Commiphora africana (A.Rich.) Endl. [Burseraceae]	4	4	5	7	4	6	6	5	8	64
Cordia africana Lam. [Boraginaceae]	5	6	7	8	6	6	7	6	8	80

Dalbergia melanoxylon Guill. & Perr. [Fabaceae]	4	5	-	6	5	4	6	5	7	55
Dalbergia sissoo DC. [Fabaceae]	4	4	-	6	-	6	-	7	5	42
Desmodium ospriostreblum Chiov. [Fabaceae]	-	4	-	-	-	-	-	5	2	14
Dichrostachys cinerea (L.) Wight & Arn. [Fabaceae]	5	6	5	7	6	7	-	5	7	64
Diospyros mespiliformis Hochst. ex A. DC. [Ebenaceae]	6	5	4	6	4	5	7	6	8	67
Eucalyptus camaldulensis Dehnh. [Myrtaceae]	5	4	-	7	6	7	6	5	7	63
Euphorbia tircucalli L. [Euphorbiaceae]	5	4	-	-	-	-	-	5	3	22
Faidherbia albida (Delile)A.C [Fabaceae]	5	8	4	4	6	7	8	7	8	77
Ficus salicifolia Vahl [Moraceae]	4	5	-	6	5	4	5	4	7	52
Ficus sycomorus L. [Moraceae]	6	4	5	5	6	5	5	6	8	66
Gardenia ternifolia Schumach. & Thorne [Rubiaceae]	5	6	-	4	4	5	5	5	7	53
Grewia damine Gaertn. [Malvaceae]	5	6	5	-	5	4	6	4	7	55
Grewia flavescens Juss. [Malvaceae]	6	5	6	-	4	4	6	5	7	56
Grewia villosa Willd. [Malvaceae]	4	5	5	-	4	4	5	5	7	50
Hibiscus cannabinus L. [Malvaceae]	5	6	5	-	-	-	6	5	5	42
Ipomoea carnea Jacq. [Convolvulaceae]	5	4	-	-	-	-	-	4	3	20
Khaya senegalensis (Desv.) A.Juss. [Meliaceae]	8	4	-	8	7	8	5	6	7	72
Lannea fruticosa (Hochst. ex A.Rich.)Engl. [Anacardiaceae]	6	5	-	6	7	7	5	6	7	66
Malus silvestris (L.) Mill. [Rosaceae]	7	5	8	-	-	4	4	4	6	50
Mangifera indica L. [Anacardiaceae]	5	4	8	5	6	4	7	6	8	70
Psidium guajava L. [Myrtaceae]	7	5	8	5	6	4	6	6	8	73
Pavetta gardeniifolia Hochst. ex A.Rich. [Rubiaceae]	5	5	-	-	-	4	4	-	4	28
Phyllanthus maderaspatensis L. [Phyllanthaceae]	4	5	-	-	-	-	-	-	2	14
Punica granatum L. [Punicaceae]	7	4	8	5	4	-	-	4	6	50
Ricinus communis L. [Euphorbiaceae]	7	6	-	-	-	4	-	4	4	33
Sclerocarya birrea (A.Rich.)Hochst. [Anacardiaceae]	7	5	7	6	6	7	5	6	8	77
Senna alexandrina Mill. [Fabaceae]	6	-	-	-	-	6	-	5	3	27
Tamarindus indica L. [Fabaceae]	8	6	6	6	5	5	6	7	8	77
Terminalia brownii Fresen. [Combretaceae]	6	5	-	7	6	6	6	5	8	64
Vangueria venosa (Hochst.)Sond. [Rubiaceae]	-	6	-	-	5	5	-	-	3	25
Ziziphus abyssinica Hochst. ex A.Rich. [Rhamnaceae]	4	4	5	6	5	6	4	4	8	59
Ziziphus spina-christi (L.) Desf. [Rhamnaceae]	6	6	7	7	6	7	7	6	8	81
Total # species used for each purpose	53	56	27	38	41	49	44	55		

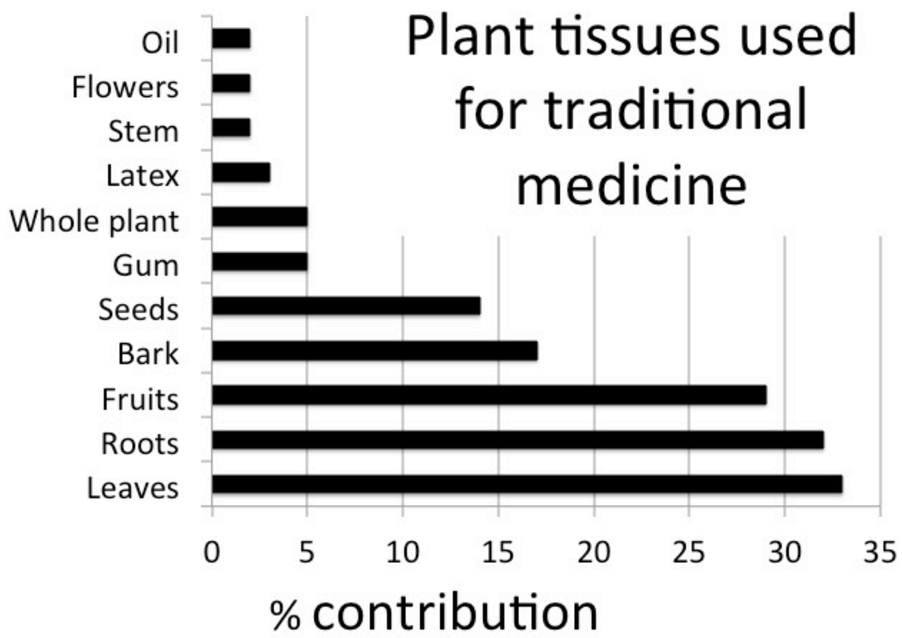

Figure 3. Relative frequency of use of each plant tissue for traditional medicine in West Darfur.

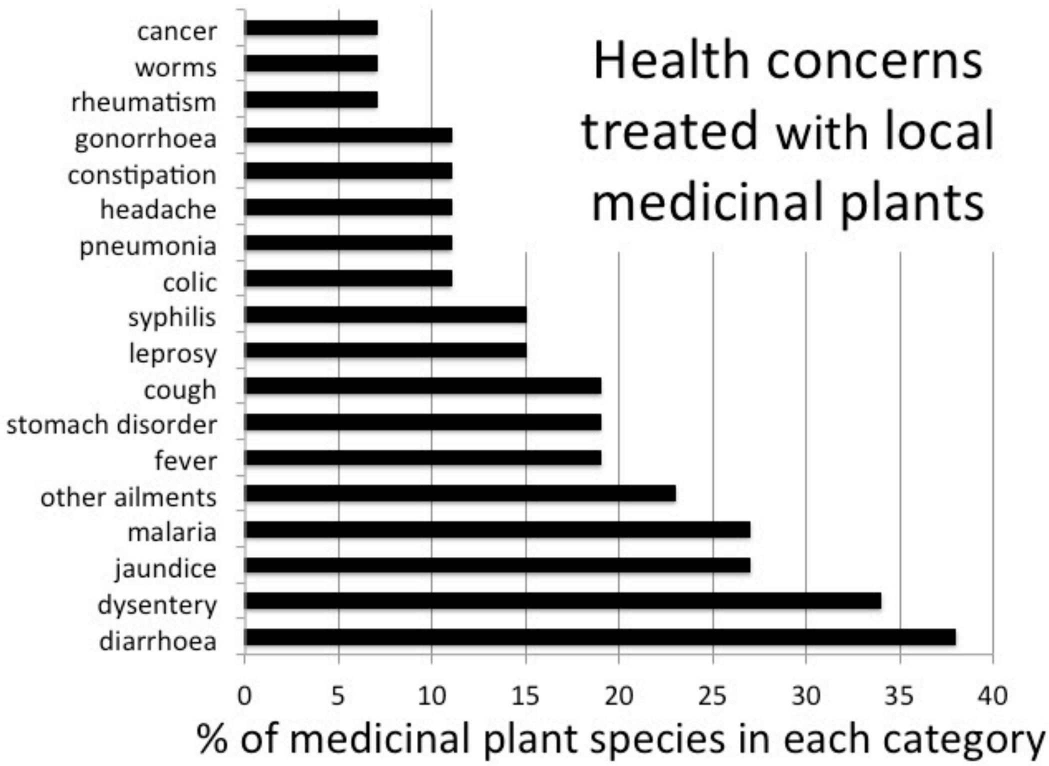

Figure 4. Major ailments that medicinal plants are used to treat in West Darfur.

Table 3. Plant materials used as medicines

Plant tissue or material	Species
Stem extracts	**Khaya senegalensis, Ailanthus excelsa*
Latex	*Lannea fruticosa, Euphorbia tircucalli*
Chewing of fresh leaves	*Azanza grackeana, Bauhinia thonningii, Ficus sycomorus*
Preparations and extracts	**Acacia nilotica, *Adansonia digitata, Anogeissus leiocarpus, Sclerocarya birrea, Gardenia ternifolia, Terminalia brownii, Senna alexandrina* and *Tamarindus indica*
*These three species have the highest score available of "8" for their Total Importance Value (TIV) as medicines.	

Food Plants

Only 47% of the species studied were used as human food. The most heavily used species, scoring "8", are all introduced, naturalized fruit-bearing species: *Malus sylvestris* (the European crab-apple), *Mangifera indica* (mango), *Psidium guajava* (guava) and *Punica granatum* (pomegranate); these are regularly collected from the wild –their use is not restricted to times of famine. Tissues used include leaves, fruits and seeds, in fresh, dried or cooked forms. People also consume ripe, fresh fruits of *Ziziphus spina-christi, Azana grackeana, Ficus sycomorus, Sclerocarya birrea, Grewia flavescens, Commiphora africana, Tamarindus indica and Balanites aegyptiaca.* Leaves and mature and immature fruits of *Azana garckeana* (Jagjag) are cooked and eaten, serving as an important food in the region (Table 2). Fruits of *Tamarindus indica* (aradeib)*, Adansonia digitata* (gongoleis), *Grewia spp.* (gudeim) and *Commiphora africana (*gimbeel) are used in soft drinks. Latex (gum) harvested from *Acacia senegal, Acacia seyal,* and *Albizia amara* is chewed fresh and regarded as a good source of "energy".

Beekeeping

Beekeeping (for honey production) supports both home consumption and generates income. Several species serve as key nectar sources (Table 2). The most important of these (IV = 8), is *Faidherbia albida*. Other important species, with IV scores of 7, are: *Azanza grackeana, Carica papaya, Cordia Africana, Diospyros mespiliformis, Mangifera indica,* and *Ziziphus spina-christi.* Beekeepers also use wood from *Faidherbia albida*, *Sclerocarya birrea* and *Ficus sycomorus* to build hives. The best sites for apiaries offer nectar- and pollen-producing plants year-round, and hives are often placed to ensure that.

Research and Education

No species studied scored an "8" in this category; indeed 28% (17 out of 58 species) had a score of zero (Table 2). Indigenous knowledge can be fragile in times of stress and conflict, which puts that knowledge at risk. Many of the indigenous medicines (and other plant products) could benefit communities far beyond Jebel Marra, so it is important to support research and education to assess and "validate" TEK. Uses by pastoral communities are especially at risk since the present conflict seriously restricts normal movements across the terrain and knowledge may be rapidly lost. This is particularly pressing since wild plants in Jebel Marra are not well-studied.

Wood (For Firewood and Construction)

Wood is an important forest product in Sudan, and especially in Darfur. Trees and shrubs provide wood that provides, for example, poles for building traditional huts and fences, and roofing materials for mud houses that are replaced every couple of years, in addition to serving as fuel (Table 2). Generally, species that are heavily used as firewood are also much used in construction (showing scores of 7-8 under the headings "Firewood" and "Construction" in Table 2). For example, *Terminalia brownii* is recognized for its strength, durability and termite-resistance, and is used in all types of construction, and, under "other roles" for handles of tools and kitchen utensils, and mortars and pestles for grinding. As fuels, wood from *Acacia* spp. and related members of the Fabaceae generate more heat and burn more slowly than other woody plants. Species like *Commiphora africana* (Gimbeel or "African myrrh") and *Khaya senegalensis* (Mahogani, or "African mahogany") are the major species used for furniture, crafts, and related purposes due to the high quality of their grain, conferring strength; these products are for both domestic use and for sale. As a result, they are heavily and intensively harvested, especially in areas close to settlements. *Khaya senegalensis* (IV=8), and ten more species (with IV=7), play major roles in construction (see Table 2). The grass-and wood-thatched roofs of huts in the area are replaced about every two years; the top conical part of the hut is built separately, and then raised above the lower, circular base. Timber is also used to build small beds, saddles and agricultural tools as well as furniture, crafts, etc., some of which are sold.

Other Uses

Besides the major, obvious uses described above, some multi-use plants are also planted to provide protection from sun and wind as shade hedges and windbreaks (e.g. *Ailanthus excelsa, Albizia amara, Anogeissus leiocarpus, Ziziphus spina-christi* and *Azana garkeana),* and for soil erosion control (*Ipomoea carnea*). Many herbaceous (ground cover) plants benefit from the shade provided by a canopy of trees and shrubs, especially Fabaceae, with nitrogen-fixing *Rhizobium* symbionts that boost available nitrates in the soil and develop extensive root systems that support soil retention. Plantings also support recreation, environmental protection, and cultural and aesthetic values.

Plants may also serve as a source of cosmetics and photoprotective creams (sunscreens). Tannins from fruits of *Acacia nilotica* are used in the leather industry (Table 2), and oil from the bark of *Balanites aegyptiaca* is used to make household soap. Many trees provide fibers, used in "cottage industries" to produce ropes, baskets, woven mats and platters (e.g., *Acacia tortilis, Acacia seyal, Bauhinia rufescens*, and *Grewia flavescens*). Charcoal, for cooking, is made from *Albizia amara* and *Balanites aegyptiaca*, while *Acacia nilotica, Acacia seyal, Combretum glutinosum and Combretum molle* are sources of incense. Three types of gum are also harvested; Gum Arabic from *Acacia senegal* is used as a binder and emulsifying agent; it increases the viscosity of pharmaceuticals and cosmetics, and is added to soft drink syrups, gummy candies and other confectioneries, artists' paints, and frankincense. The other two types of gum that are collected are *Acacia seyal* (Talh), (often mixed with pulp from the fruit of *Balanites aegyptiaca* to counter the acid taste and produce a syrup) and *Boswellia papyrifera* (gafal), or frankincense (which grows wild in the region, but was not reported in the present study).

Total Importance Value

The total importance value (TIV) of the species studied ranges from 14% for *Phyllanthus maderaspatensis* and *Desmodium ospriostreblum,* each with only two categories of use, to 81% for *Ziziphus spina-christi,* which fulfils all eight use categories, with scores of 6 and 7. (Table 2).

Knowledge Indices

The indigenous knowledge index (IKI) was heavily influenced by the number of uses for a species (see Table 2); the highest indices were seen in the species with diverse uses (Table 4). Values of IKI ranged from scores of 0.01 (for *Desmodium ospriostreblum,* which had only two uses, as animal fodder, and in "other roles") to 0.72 (out of a maximum of 1.0) for *Cordia africana*, used in all eight categories, with a TIV of 80%.

The scientific knowledge index (SKI) characterizes the degree to which modern science has confirmed the presence of recognized active medicinal or other useful constituents in each plant species; the SKI can range from 0-1 (Table 4). For the species studied, the SKI value ranged from 0.03 in *Asparagus africanus* to 0.86 in *Anogeissus leiocarpus*. Generally, species with 7 or 8 recognized uses also had higher SKI values. An exception was *Hibiscus cannabinus* (Kenaf) which was listed for only 5 (out of 8) uses, but since all 5 uses had importance values of 5–6, this generated a high SKI of 0.72.

The level of agreement between IK and SK was evaluated as the IKI:SKI ratio (Table 4). A total of 28 species have an IKI/SK ratio >1, and *Dalbergia melanoxylon* had the highest ratio, at 1.96; *Desmodium ospriostreblum* has the lowest ratio, at 0.01.

Discussion

People of the Darfur region are generally well-informed about the uses and value of wild plants, viewing them as part of a valuable cultural heritage, central to supporting local cultural identities and traditions. Awareness of the actual and/or potential use(s) of the species differed among the eight use categories. Respondents were more likely to know of uses as animal fodder, traditional medicine, construction materials and various functional uses, but less likely to be aware of use as human food, firewood, use in research/education and beekeeping. This is likely because "famine foods" are only used under extreme conditions when the harvest has failed, and many of these species require careful treatment to remove toxins, based on relatively specialized knowledge. Regarding firewood, this use is less a function of the species, and more related to availability and ease of collection; the actual species collected as dead branches, etc. may be less important or obvious.

Beekeeping is a specialized skill, so the relative importance of various nectar- and pollen-producing plants is known by only a subset of the local population. Honey production provides a valued commodity that is both consumed and offered for sale in the region. The montane landscape of Western Darfur, with a range of altitude, exposure/aspect, soils and slopes, offers adjacent, but diverse "phenological niches" for plants, and supports high biodiversity (Hegazy *et al.* 2018a). As a result, experienced beekeepers can place apiaries strategically, to access different nectar-producing species, and populations of the same species with different flowering times, ensuring a steady supply of nectar for much of the year.

Table 4. IKI is calculated as equivalent to "Cultural Value" as: U_c x I_c x$\sum IU_c$ where U_c = total number of uses of the species/total potential uses (8). I_c = the number of informants reporting the species as useful/total number of participants. IU_c = the number of informants. SKI is calculated specifically in relation to medicinal uses; it is calculated as MP/TC where MP represents the total number of compounds having recognized medicinal or pharmacological applications, and TC represents the total number of active chemical constituents in the species. Both index values range from 0-1. The concordance ratio assesses the level of agreement between these two metrics, calculated as the IKI/SKI. Where the concordance ratio is >1, there is a need for more scientific investigation of the indigenous medicines; where it is ≈1, there is alignment of scientific and traditional knowledge, and when the value is <1, scientific knowledge has identified potential medicinal uses of a species that are not presently recognized by the local community. Where possible, the local name for a species is also given.

Species and [Family]	**Local name**	**IKI**	**SKI**	**IKI/ SKI ratio**
Acacia mellifera (M.Vahl) Benth. [Fabaceae]	Khashab	0.50	0.47	1.06
Acacia nilotica (L.) Delile [Fabaceae]	Gorta	0.50	0.37	1.34
Acacia polyacantha Willd. [Fabaceae]	Um Seneina	0.24	0.30	0.79
Acacia senegal (L.) Willd. [Fabaceae]	Hashab	0.69	0.57	1.21
Acacia seyal Delile [Fabaceae]	Sayaal	0.25	0.20	1.26
Acacia sieberiana DC. [Fabaceae]	Kook	0.15	0.67	0.22
Acacia tortilis (Forssk.) Hayne [Fabaceae]	Taleh	0.24	0.45	0.54
Adansonia digitata L. [Malvaceae]		0.61	0.64	0.95
Aeschynomene uniflora E.Mey. [Fabaceae]	Tebeldi, homeira	0.02	0.03	0.63
Ailanthus excelsa Roxb. [Simaroubaceae]		0.09	0.44	0.19
Albizia antunesiana Harms [Fabaceae]		0.07	0.57	0.13
Albizia amara (Roxb.) B.Boivin [Fabaceae]	Arad	0.39	0.27	1.42
Anogeissus leiocarpus (DC.) Guill. & Perr. [Combretaceae]		0.45	0.86	0.53
Asparagus africanus Lam. [Asparagaceae]	Shouk	0.01	0.03	0.28
Azanza grackeana (E.Hoffman) Exell. & Hillc. [Malvaceae]		0.28	0.23	1.20
Balanites aegyptiaca (L.) Delile [Zygophyllaceae]	Heglig, Laloba	0.49	0.35	1.42
Bauhinia rufescens Lam. [Fabaceae]	El Begeili	0.10	0.36	0.28
Bauhinia thonningii Schum. [Fabaceae]		0.50	0.27	1.83
Boscia senegalensis Lam. [Capparaceae]	Mekheit	0.08	0.05	1.62
Cadaba farinosa Fossk. [Capparaceae]	Qadab, Rayaad	0.21	0.44	0.49
Capparis sepiaria L. [Capparaceae]		0.04	0.13	0.29
Carica papaya L. [Caricaceae]	Papaz	0.21	0.23	0.93
Combretum glutinosum Perr. ex DC. [Combretaceae]	Habei	0.23	0.43	0.53
Combretum molle R.Br. ex G. Don [Combretaceae]		0.12	0.75	0.16
Commiphora africana (A.Rich.)Endl. [Burseraceae]	Doweinaat	0.34	0.22	1.55
Cordia africana Lam. [Boraginaceae]		0.72	0.54	1.33
Dalbergia melanoxylon Guill. & Perr. [Fabaceae]		0.44	0.22	1.96
Dalbergia sissoo DC. [Fabaceae]	Sarsoo	0.10	0.18	0.57
Desmodium ospriostreblum Chiov. [Fabaceae]		0.01	0.06	0.01
Dichrostachys cinerea (L.) Wight & Arn. [Fabaceae]		0.24	0.22	1.07
Diospyros mespiliformis Hochst. ex A. DC. [Ebenaceae]		0.41	0.38	1.10
Eucalyptus camaldulensis Dehnh. [Myrtaceae]	Kafour	0.34	0.21	1.60
Euphorbia tircucalli L. [Euphorbiaceae]	Malbina	0.03	0.47	0.07
Faidherbia albida (Delile)A.C [Fabaceae]	Haraz	0.65	0.35	1.86
Ficus salicifolia Vahl [Moraceae]	Teen	0.10	0.21	0.50
Ficus sycomorus L. [Moraceae]	Teen, gemeiz	0.50	0.53	0.94
Gardenia ternifolia Schumach. & Thorne [Rubiaceae]	Abu Gawi	0.16	0.27	0.60
Grewia damine Gaertn. [Malvaceae]		0.24	0.22	1.08
Grewia flavescens Juss. [Malvaceae]	Abu Halaf	0.25	0.16	1.57
Grewia villosa Willd. [Malvaceae]	Diwal, Katat	0.17	0.12	1.49
Hibiscus cannabinus L. [Malvaceae]	Jute	0.15	0.72	0.21
Ipomoea carnea Jacq. [Convolvulaceae]	Aweer	0.01	0.20	0.04

Khaya senegalensis (Desv.)A.Juss. [Meliaceae]		0.32	0.34	0.94
Lannea fruticosa (Hochst. ex A.Rich.) Engl. [Anacardiaceae]		0.31	0.31	1.01
Malus silvestris (L.) Mill. [Rosaceae]		0.31	0.25	1.25
Mangifera indica L. [Anacardiaceae]	Manga	0.50	0.32	1.58
Psidium guajava L. [Myrtaceae]	Guava	0.50	0.35	1.42
Pavetta gardeniifolia Hochst. ex A.Rich. [Rubiaceae]		0.02	0.47	0.03
Phyllanthus maderaspatensis L. [Phyllanthaceae]	Ayyobeet	0.01	0.07	0.04
Punica granatum L. [Punicaceae]	Roman	0.24	0.19	1.29
Ricinus communis L. [Euphorbiaceae]	Kerwei	0.06	0.07	0.80
Sclerocarya birrea (A.Rich.)Hochst. [Anacardiaceae]		0.46	0.46	0.99
Senna alexandrina Mill. [Fabaceae]	Senna	0.05	0.25	0.18
Tamarindus indica L. [Fabaceae]	Tamr Hindi	0.67	0.53	1.26
Terminalia brownie Fresen. [Combretaceae]	Arza,sobag	0.27	0.19	1.43
Vangueria venosa (Hochst.)Sond. [Rubiaceae]		0.05	0.06	0.83
Ziziphus abyssinica Hochst. ex A.Rich. [Rhamnaceae]		0.29	0.26	1.10
Ziziphus spina-christi (L.) Desf. [Rhamnaceae]	Nabaqa, Sidr	0.54	0.33	1.66

Of the 58 species, 18 (31%) are relatively abundant, and characteristic dominants of various vegetation types in the Jebel Marra region (Hegazy *et al.* 2018b & 2020). Harvesting of tree branches as animal fodder provides a critical resource in the late dry season (April- June) when herbaceous species are already gone, and crop residues are scarce. This material can be a valuable protein supplement, particularly in the case of Fabaceae, as mentioned above; however, under severe drought conditions concentrations of toxic HCN (hydrogen cyanide) may increase in these species (Thorne *et al.* 1999). Another factor that can limit their consumption by ruminants is tannin, a “digestibility reducer” (Morrison *et al.* 1996; Barbehenn & Constabel 2011). Some trees become more important food sources for humans during drought and famine, e.g., *Boscia senegalensis* (makhait), a tree in the caper family; its seeds are soaked prior to cooking to remove potentially toxic secondary chemicals. Although our survey indicated only moderate human use of this species at present (with a score of 4 out of 8), this was the most widely consumed famine food in both Sudan and Darfur during the 1984-5 famine, and was relied on by over 94% of people in northern Darfur at that time (National Research Council, 2008).

Worldwide, traditional medicines offer a starting point for “drug discovery” efforts (Kolawole *et al.* 2011). Many plants evolved secondary compounds to protect them from herbivores, but also from microbial attack, and the antimicrobial activity of these compounds has often been confirmed, generating interest from the pharmaceutical industry, especially considering adverse side-effects of synthetic drugs and the evolution of pathogen resistance to widely-used antibiotics (Johann *et al.* 2007, Lykke *et al.* 2004). In the developing world, the high cost of industrialized medicines, and poor access to health care has also stimulated renewed interest in traditional medicines. Medicinal and aromatic plants are integral to the life and culture of the people of Sudan, for treatment of disease in both humans and livestock (Hassan *et al.* 2012, Ricker 2002, Maundu *et al.* 2001).

In the semi-arid and humid tropics, wild foods have a role in the regular diet of many households, becoming especially important in times of food shortage (Asfaw & Taddesse 2001, Harris & Mohammed 2003, Debela *et al.* 2010). Their nutritional role and health benefits are recognized worldwide (Pardo-de-Santayana *et al.* 2007), and their consumption allows survival during food shortages driven by unpredictable rains and drought (Mathys 2000, Saied *et al.* 2008). *Hibiscus cannabinus* (Kenaf) is an interesting example of a plant that has shaped human history. This diploid member of the Malvaceae was introduced to the region about 6,000 years ago as a food and fiber crop; its tetraploid relative “roselle”, *Hibiscus sabdariffa* L., is cultivated locally as a famine food in dry years; *H. sabdariffa* was also introduced to Jamaica, Mexico and the southern USA by captive African slaves (Mohamed *et al.* 2012). The dried flowers are popular today for brewing “hibiscus tea”, viewed as rich in “anti-oxidants”.

In the Jebel Marra region, traditional uses of plants persist alongside their “modern” counterparts; industrialized medicine coexists with traditional medicine, wooden huts and thatched roofs coexist with concrete walls for dwellings, shade trees with patios, and wood and charcoal-burning stoves with electrified kitchens. This reinforces the need for active conservation and sustainable use of plant resources in the region, and the protection and retention of TEK (Alzweiri *et al.* 2011, Hegazy *et al.* 2014).

The profiles of plant species with high “importance values” or “use values” support Feeny’s “apparency hypothesis” (Feeny 1976), which proposes that plants that are dominant in a community are more likely to require defense against herbivores and microbial pathogens, and therefore contain more bio-active secondary compounds. This principle is combined with the fact that humans are most likely to notice, and use, Keystone species (*sensu* Hegazy *et al.* 2018b); that is, that woody plants that are dominant in a region are more likely to be used than species that are less apparent (e.g. herbaceous species with short life cycles, present only during the summer rainy season). Similar results were seen in the West African Sahel (Diop *et al.* 2005, Lykke *et al.* 2004, Nikiema 2005), where multiple uses were more likely for woody plants than for other plant life forms. Unfortunately, high-use values can reflect overuse; this is seen for species that have high TIV values but that have lost their status as canopy dominants. In this study, several species fell into this category, e.g., *Adansonia digitata, Faidherbia albida, Khaya senegalensis, Mangifera indica, Psidium guajava, Bauhinia thonningii, Sclerocarya birrea* and *Tamarindus indica.* These species should be prioritized in terms of targeted conservation measures, and the promotion of sustainable practices and levels of harvesting (Hegazy *et al.* 2014, Hegazy *et al.* 2018b). In a study of a semi-arid region of the state of Paraíba, in Northeastern Brazil, apparency explained the local importance of plants used in construction, technology, and as fuel, but the same did not hold for species used as medicines (Ribiero *et al.* 2014). However, that Brazilian study encountered few multi-use species compared to our study.

Concordance between indigenous and scientific knowledge offers a valuable metric to guide better conservation, “drug discovery” and formal acknowledgement of IK. Where IK and uses exceed the current state of scientific knowledge, we should focus inquiry into the effects and efficacy of these plants’ secondary compounds for medicine and other potential applications. On the other hand, in the cases where SK has already identified interesting or promising chemical ingredients that are not presently used by local communities, and the IKI/SKI ratio is very low (for example nine species have ratios that are below 0.20) it may be worthwhile to collect, assess, and market such extracts, to the benefit of local communities. For example, although no medicinal uses were reported for *Azanza grackeana,* Maroyi (2017) reviewed secondary compounds in the species and confirmed that it contained many bioactive compounds including alkaloids, amino acids, ascorbic acid, carotenoids, cyanogenic glucosides, flavonoids, lipids, phenols, saponins and tannins. Pharmacological studies confirmed antibacterial, antifungal, anti-hyperglycemic, antimalarial and antioxidant effects, as well as enhancing iron uptake in rats (Ahmed *et al.* 2016), so this local species may have medicinal value that is no longer recognized by local traditional practitioners. Frankincense (*Boswellia papyrifera)*, is an ancient commodity which some argue could be marketed as a “fair trade” product in the West (e.g. see http://fairtradefrankincense.com/tag/ethical-harvesting/). Frankincense grows on upper slopes of the massif, typically at 1170-1830 m.a.s.l., and is harvested through coppicing, a practice that must be carefully managed and limited, to ensure the recovery of re-growing shoots (Adam & Osman 2008).

Acknowledgement and protection of IK have obvious socio-cultural and ecological value. At the same time, wildcrafting must be carefully managed to ensure sustainable harvesting of such “shared” community resources. As IK and SK become more aligned, we gain a better understanding of potential new sources of medicines and other useful plant secondary products as well as sources of fiber, and other natural services such as soil protection, shade and windbreaks. This, in turn, should enhance our awareness of “nature’s services” and appreciation, in both scientific and indigenous communities, of the value of supporting research into plant resource conservation, with the goal of maximizing benefits to local communities in terms of ecosystem goods and services (Sen 2005, Reyes-Garcia *et al.* 2006, Siew & Doll 2012,Hegazy *et al.* 2014). Sustainable use of wild plants is best achieved by building on the priorities of local people, then creating a technological base that includes both traditional and modern approaches to problem-solving (IUCN, UNEP & WWF 1991, Johnson 1992, Labatut & Akhtar 1992, Icamina 1993). Traditional patterns of resource use often include practices that inherently support sustainable development; these should be incorporated in planning and implementing socio-economic development programs (Mitchell 1997, Reed 1990, Neis 1992).

West Darfur is often cited as a classic case where human conflict is driven by the pressures of drought and climate change (e.g. Sachs 2006, Mohammed 2000). However, there is no simple, short-term, “cause-and-effect” relationship between rainfall and recurrent conflict in the region (Kevane & Gray 2008). Bromwich (2015) argues that the key issue is a convergence of limited water, food and energy resources that could be addressed through good governance. However, Darfur is not a “steady-state system”; the number of people drawing on limited regional resources is swollen by the presence of many camps for “Internally Displaced Persons” (IDP), from other parts of Sudan, camps for refugees from adjacent Chad, and a rapidly growing local population, where more than 40% are under 14 years of age (CIA World Factbook 2019). Clearly, these pressures impact wild plant resources, particularly in terms of their use as “famine food” and as animal fodder, firewood, and construction wood (e.g. see Spröhnlea *et al.* 2016). In addition, nomadic pastoralists and the *Fur* farmers in West Darfur, today represented by distinct political groups, may place different priorities on each of the species we surveyed; our study focused on assessments by indigenous *Fur* farmers, who make up over 75% of the rural population, and who use both established farmland, and upland pastures for seasonal pastoralism. In future studies it would be interesting to interview the nomadic pastoralists and people living in the IDP and refugee camps, who collect plants in the vicinity of their camps, to discover whether their identification of species and uses differs from that of the *Fur* farmers.

There is growing evidence of localized depletion of species with high TIV values, particularly around IDP camps (Spröhnlea *et al.* 2016). The urgency of this situation suggests that scientists and local communities should collaborate to track the use, and abundance of each of these multi-use species. We also advocate evaluation of potential medicinal uses of secondary plant compounds, especially for the many species that have not yet been assessed “scientifically”. The naturalized fruit trees that feature as “human food” have been growing in the region for millennia, and therefore may have evolved and/or acclimatized to the region’s increasingly dry savanna climate. They may, therefore, be a valuable source of genes that could be incorporated in crop strains elsewhere, where drought resistance would be advantageous in the face of climate change. Other pro-active initiatives might include deliberate propagation and planting of these species to restore sustainable wild populations with stable age-structures (Hegazy *et al.* 2014). Human pressures on the region’s resources are already intense, and increasing, and the multi-use profile of these species mean that, as supplies dwindle, it may be necessary to prioritize each of their individual beneficial uses, and promote their “non-lethal” use to provide soil stability, shade, medicines and gums, rather than “consumptive” use as firewood or construction materials.

In our related study of vegetation types in Darfur, a distinctive vegetation group was found in the heavily overgrazed clay plains (Hegazy *et al.* 2020). The study indicated that human agricultural activities and disturbance have influenced vegetation in the region for millennia, as agriculture and pastoralism developed in Darfur over 7,000 years ago (Ahmed 1982). This vegetation type was dominated by weedy and invasive species, naturalized cultivars, and species associated with overgrazing by herbivores, such as *Acacia nilotica*, the “gum arabic tree”. This species is sometimes viewed as a “nurse tree” (see Hegazy & Lovett-Doust 2016), as the clay soil and accumulating organic matter and shade under the canopy retain moisture, while the bacterial rhizosphere symbiont, *Rhizobium*, fixes nitrogen, enhancing nitrate levels and providing a microsite favoring seed germination and seedling growth. Other naturalized species in this “disturbed” vegetation were several that were not reported in the present study as being collected from the wild for medicinal, food or other purposes; possibly because they were growing on land thought of as “farmland” rather than being collected “from the wild”. For example, there were two other Fabaceae (*Zornia glochidiata*, used as a food and medicine, and *Senna occidentalis*, “coffee senna”, a species introduced from the Americas that is often used as a coffee substitute), as well as *Sesamum angustifolium*, a relative of pearl millet, introduced originally from Kenya. Seeds and leaves of *S. angustifolium* are used as food, and as a source of medicines.

In several cases, scientific knowledge is well aligned with indigenous knowledge of the uses for a species, giving a concordance value close to 1.0 (e.g. for *Acacia mellifera, Adansonia digitata, Carica papaya, Ficus sycomorus, Grewia damine, Khaya senegalensis, Lannea fruticosa, Sclerocarya birrea,* and *Ziziphus abyssinica).* Low values, close to zero, would suggest science has recognized medicinal ingredients in a plant that are not recognized (or are no longer recognized) by the indigenous population, implying that local use is not as high as it might be (e.g. in the cases of *Phyllanthus maderaspatensis*, *Pavetta gardeniifolia*, *Ipomea carnea* and *Desmodium ospriostreblum).* Thirteen species (22.5%), have IKI:SKI ratios below 0.30, indicating that they have uses or active medicinal ingredients that are recognized by western science, but that are no longer widely recognized by the indigenous community. In contrast, high ratios, above 1.0 identify species for which the scientific knowledge lags far behind the level of indigenous use, e.g. *Dalbergia melanoxylon, Faidherbia albida* and *Bauhinia thonningii*. Of the 58 species studied, about half (28) have concordance values above 1.0, suggesting they merit more focused study to better understand, and potentially benefit from, active ingredients that led to their indigenous use.

Conclusions

In conclusion, the wild plants collected in the Jebel Marra region of Sudan, are typically multi-use, and they continue to be an important resource for rural communities. The species with most diverse uses and high TIV values are clearly the most important economic species in the study area. The concordance ratios suggest nearly half of the species surveyed merit additional scientific assessment in terms of their potential medicinal value. It is interesting that many of the recognized famine foods (e.g. *Boscia senegalensis*) are not, otherwise, heavily used. However, some species are at special risk, as they are both in high demand (used for all 8 categories of use, and with high TIV values, more than 70%) and they have lost their role as dominant species in the recognized vegetation communities when we compare their relative abundance today (Hegazy *et al.* 2020), with their relative abundance in the 1970s (Wickens 1976). This is the case for *Faidherbia albida,* for example, which is especially important for animal forage and beekeeping, and holds a TIV of 77%. Other species in this more vulnerable situation include *Adansonia digitata* (73%) and *Tamarindus indica* (77%), both important medicines; as well as *Mangifera indica* (70%) and *Psidium guajava* (73%)*,* both important as human foods.

Declarations

List of Abbreviations: CV: Cultural Value**;** HCN: Hydrogen cyanide**;** IDP: Internally Displaced Persons (refugee camp)**;** IK: Indigenous Knowledge; IKI: Indigenous Knowledge Index**;** m.a.s.l.: metres above sea level (altitude); SK: Scientific Knowledge**;** SKI: Scientific Knowledge Index**;** TEK: Traditional Ecological Knowledge**;** TIV: Total Importance Value

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