



# Diversity and socio-cultural importance of wild food herbs and cyanobacteria in the Lake Chad Basin (Niger)

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## Research

### Abstract

*Background:* Wild herbaceous food species are declining throughout the Sahel region, particularly in the south-eastern corner of Niger, where settlements of thousands of refugees from Boko Haram, in addition to the native people, generate high pressure on the herbaceous food species. The objective of this study is to assess the use of wild herbaceous food plants in two departments in the Lake Chad Basin.

*Methods:* Ethnobotanical surveys were conducted with 270 informants asked about their use of these plants for food including parts consumed, food categories, economic value and impact of exploitation.

*Results:* A total of 32 wild herbaceous species, mainly from the family Poaceae (21.8%) and dominated by the life form Therophytes (43.7%), were cited. According to the respondents, the most consumed parts were the leaves with 51.2% and 41.3% of the citations in Mainé Soroa and N'Guigmi, respectively. Seeds were cited by 26.8% of the informants in Mainé Soroa and 30.7% in N'Guigmi. Fruits were cited by 19.2% and 26.2% in Mainé Soroa and N'Guigmi, respectively. The least consumed parts were roots and flowers. The species preference depends on the ethnic group. Refugees who had recently settled in the area stood out with a consumption of other species than the native people. Informants from Mainé Soroa and N'Guigmi stated that 52% and 44% of the species, respectively, were becoming increasingly scarce. The main causes of the degradation of these resources were agriculture, drought and overexploitation.

*Conclusions:* In general wild herbaceous food resources play a very important role in the Lake Chad Basin, where people live insecure lives.

*Keywords:* Herbaceous food plants, indigenous plants, local knowledge, Lake Chad Basin, Niger.

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## Background

In sub-Saharan Africa, native plant resources provide food, income and other services to rural populations (Bassene *et al.* 2020). Yet, a large number of species, especially the herbaceous species, remain unrecognized or neglected by research and development (Malela *et al.* 2016, Adjahossou, *et al.* 2018, Kamal *et al.* 2019), despite the fact that they make vital contributions, especially in times of drought and by providing essential nutrients to the diet (Djaha *et al.* 2014, Camarda *et al.* 2017, Gnido *et al.* 2017, Garba *et al.* 2020, Lykke 2021). Their importance is particularly vital in the driest parts of sub-Saharan Africa (Wédjangnon *et al.* 2016, Betti *et al.* 2020, Abdoulaye *et al.* 2017).

Especially the leaves and fruits, are used for self-consumption, sale on local markets and export from Niger to Nigeria and Algeria (Boudi *et al.* 2016, Betti *et al.* 2020, Ursule *et al.* 2020). A wide range of native species are gathered, mainly by women and children. In Niger, the exploitation of plant resources constitutes not only a source of food, but also of income for about 84% of the people (CDB 2014). Similarly, in Madagascar 74% of the people lives in rural areas, where 78% are considered poor and mostly depend on the direct exploitation of natural resources (fields, water, forests) for their livelihoods (Andriamparany *et al.* 2014).

Since 2013, the security situation in the Lake Chad Basin in south-eastern Niger has been precarious because of Boko-Haram related conflicts. This has resulted in displacement of over 69,664 households, 263,013 people, from Nigeria to other countries in the Lake Chad Basin (OCHA 2020). This is in addition to 700,000 local people already living there (CDB 2014). This has caused immense humanitarian needs in a region already facing poverty and environmental degradation.

It is important to document the knowledge of rural communities about native species in order to guide priority interventions for sustainable conservation and domestication. The objective of this study is to assess the knowledge of rural communities on the use of wild herbaceous food plants in the Lake Chad Basin and to determine people's preferences, plant parts consumed as well as the economic value, availability and observed causes of degradation.

## Materials and Methods

### Study areas

The study was conducted in the departments of Mainé-Soroa and N'Guigmi in Lake Chad Basin in south-eastern Niger (Figure 1). Both localities belong to the Diffa region. Since 2013, the region has been affected by the Boko Haram crisis, which forced people to abandon their fields and other properties to move to places where attacks were less frequent. However, this area is now affected by desertification and facing challenges related to malnutrition and food insecurity (OCHA 2020).

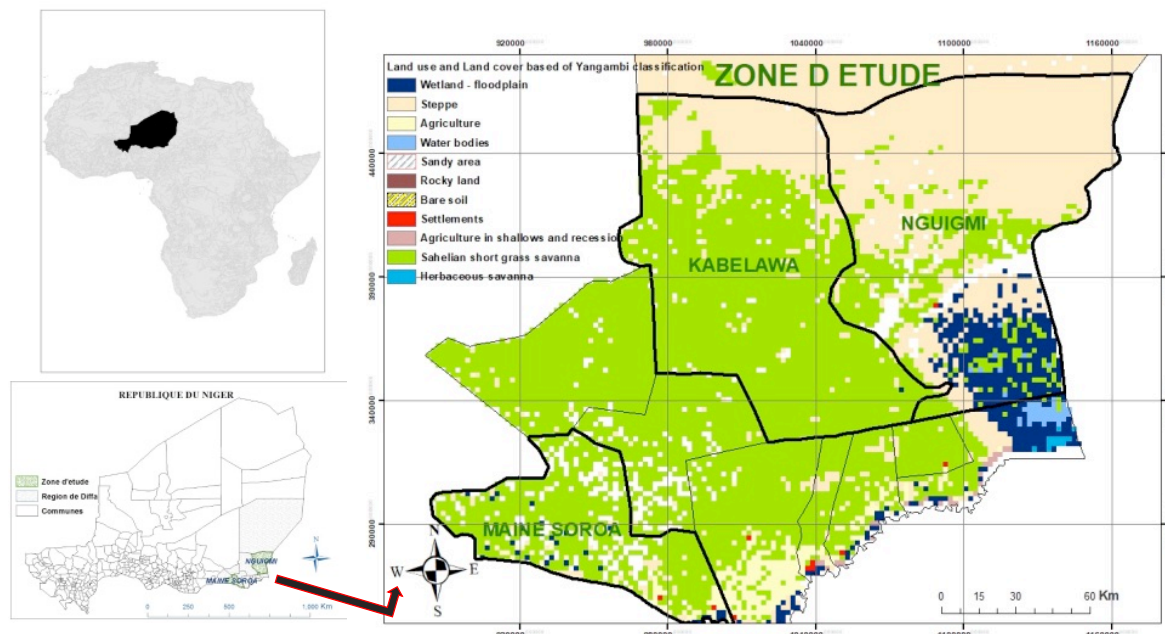


Figure 1. Location of the study area.

The department of Mainé-Soroa is 70 km south-west of Diffa (1300 km from Niamey, the capital of Niger). It covers an area of 15,000 km<sup>2</sup> or about 9.5% of the Diffa region. The average annual rainfall was 399 mm/year over a period of 30 years. The average daily temperature during the warm period (April to June) ranges between 29° C and 43° C. and during the cold period (December to February) between 10° C and 23° C. However, the temperature can reach a maximum of 45° during the hot period and a minimum of 8° during the cold period. The southern part of the department is bordering Komadougou Yobe River which forms the natural border with Nigeria. The vegetation is typically made up of dry savanna characterized by a strong presence of *Acacia tortilis*, *Balanites aegyptiaca*, *Leptadenia pyrotechnica*, *Aristida* spp. and *Schoenefeldia gracilis*.

The department of N'Guigmi is 140 km northeast of Diffa (1500 km from Niamey). It covers an area of about 39,200 km<sup>2</sup> or about 22.5% of the Diffa region. The average annual rainfall was 341 mm/year over a period of 30 years (Figure 2). The highest temperatures were observed during the hot period (April to June) and varied from 36 to 47°C and the lowest temperatures were observed during the cold period (December to February) and varied from 6 to 19°C. The south-east of the department borders Lake Chad, which forms the natural border with Chad and Nigeria. The vegetation is made up of shrub savanna dominated by a stand of *Salvadora persica*, *Acacia tortilis*, *Balanites aegyptiaca*, *Commiphora africana* and a herbaceous cover mainly composed of *Cenchrus biflorus*, *Eragrotis tremula*, *Panicum* spp. and *Cyperus conglomeratus* in the south and of *Panicum turgidium* and *Stipagrostis pungens* in the north. Exotic species such as *Prosopis juliflora* form dense thickets in lowlands.

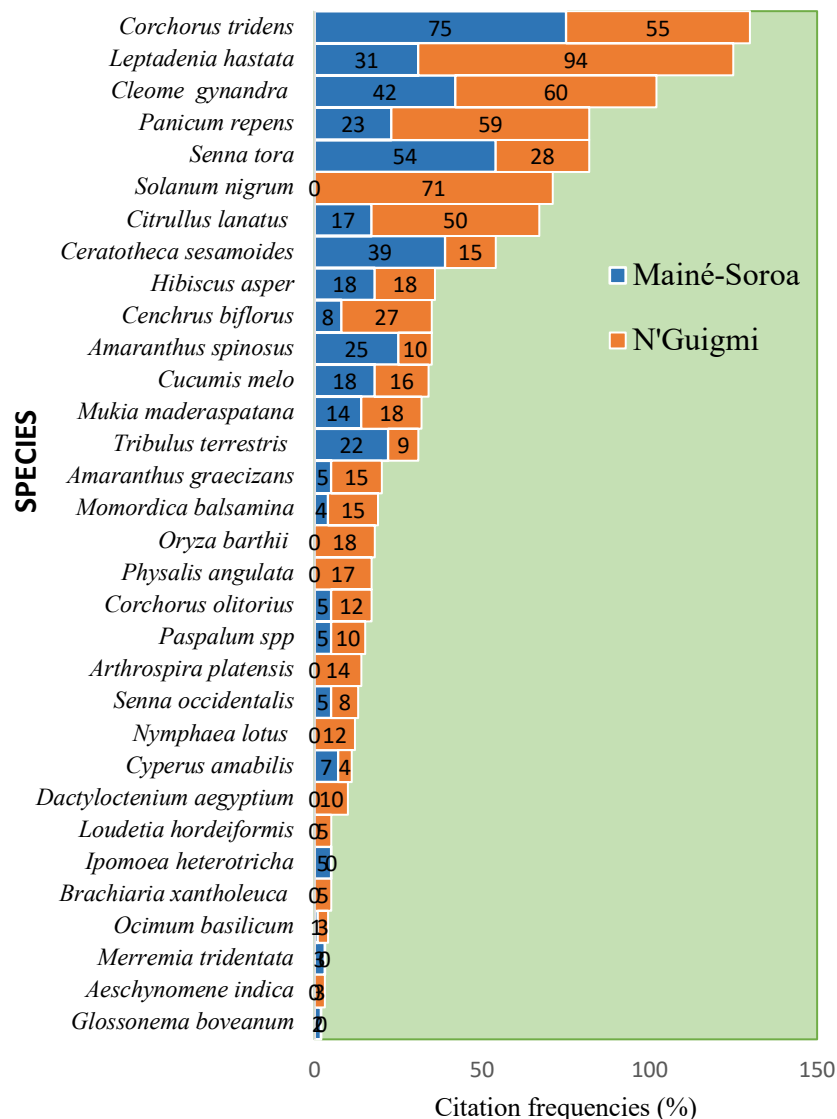


Figure 2. Ranking of species based on relative citation frequency in the two departments. The number of citations is given for each department.

### Sampling

Surveys were conducted in a randomly selected sample of 10 villages spread over two departments. An exploratory survey of 40 people per department was used to determine the proportion ( $p$ ) of informants who were aware of the usefulness of wild herbaceous food species. It was found that 60% and 70% of the informants in Mainé-Soroa and N'Guigmi, respectively, were aware of the usefulness of wild herbaceous food species.

The number  $n$  of persons to be surveyed per department was estimated using the formula of Dagnelie (1998) and Levy and Lemeshow (2008).

$$n = \frac{U_{1-\alpha/2}^2 \times p(1-p)}{d^2}$$

$n$  is the critical minimum value of the number of people to be interviewed per department and  $U_{1-\alpha/2}$  is the value of the normal distribution statistic at probability value  $1-\alpha/2$  with  $\alpha=5\%$ , equal to 1.96;  $p$  is the percentage of informants in each department, who knows the usefulness of native food species;  $d$  is the margin of error of the estimate set at a value of 8%. Based on this the sample size corresponds to 144 and 126 people to be surveyed in Mainé-Soroa and N'Guigmi departments, respectively. These individuals were randomly selected from a list of people living in the study localities (established with the village chiefs and/or key informants identified by the village chiefs). Gender, age (youth under 30 years, adults 30-45 years, and people over 45 years), ethnic group and origin were considered. A total of 270 people were surveyed: 75 refugees and 195 natives, 159 women and 111 men.

### Data collection

Surveys based on direct questioning on the uses of wild herbaceous plants in human nutrition were conducted during the months of July, August and September, corresponding to the rainy season, when the products are consumed. Informants were selected from five native and refugee socio-cultural groups (Boudouma, Haoussa, Kanouri, Fulani and Toubou) and from different gender and age groups. People were asked about: (i) plant parts consumed, (ii) food categories, (iii) economic value asking respondents to rank plants in order of economic importance, (iv) availability of the resource, and (v) causes of resource degradation. We noted the local names of the species cited by informants and following went to the natural habitat for direct observation. A herbarium sample was taken and the scientific names of the species collected were determined in the laboratory of Botany Garba Mounkaila of the Biology Department at the Abdou Moumouni University of Niamey. The collected species were and compared to the specimen of the species of the Herbarium of Niger at the same Laboratory.

### Data analysis

The collected data were used to calculate frequencies of species citation per department:

$$F = (\text{Nec}/N) \times 100.$$

Nec is the number of people who cited a species and  $N$  is the total number of informants per department (Tiétiambou *et al.* 2016).

In order to analyze the relationships between ethnic groups and the diversity of herbaceous plants consumed, a principal component analysis (PCA) based on correlation analysis was performed using Minitab 16 software.

The life-forms inspired by Raunkiær (1934) (Therophytes, Therophytic Lianas, Nanophanerophytes, Hydrophytes, Rhizome Geophytes, Chamephytes and Tuber Geophytes) were used to characterize the different life forms of the plants consumed. These are the forms of adaptation that allow plants to endure seasonal climate variation.

## Results

### Socio-economic characteristics of informants

The 270 informants belonged to five ethnic groups, Kanouri (45.9%), Fulani (28.1%), Haoussa (11.9%), Boudouma (7.8%) and Toubou (6.3%) (Table 1). The native and the refugees belonged to some of the same ethnic groups, Boudouma, Haoussa and Fulani.

Table 1. Number of informants by department and according to socio-economic characteristics.

Socioeconomic characteristics		N'Guigmi	Mainé-Soroa	Total	Proportion (%)
Sex	Female	67	92	159	58.9
	Male	59	52	111	41.1
Age	< 30 years	13	20	33	12.2
	30 to 45 years old	43	42	85	31.5
	> 45 years old	70	82	152	56.3
Ethnic group	Boudouma	21	0	21	7.8
	Haoussa	14	18	32	11.9
	Kanouri	68	56	124	45.9
	Fulani	17	59	76	28.1
	Toubou	6	11	17	6.3
Origin	Native	93	102	195	72.2
	Refugee	33	42	75	27.8

### Botanical diversity

A total of 31 wild herbaceous food species and one cyanobacterium species were cited by the 270 informants. Of the 32 species recorded, 20 were common to both sites. They were, in order of importance, *Corchorus tridens*, *Leptadenia hastata*, *Cleome gynandra*, *Panicum repens*, *Cassia tora*, *Citrullus lanatus*, *Ceratotherca sesamoides*, *Hibiscus asper*, *Cenchrus biflorus*, *Amaranthus spinosus*, *Cucumis melo*, *Mukia maderaspatana*, *Tribulus terrestris*, *Amaranthus graecizans*, *Momordica bealsamina*, *Corchorus olitorius*, *Paspalum spp*, *Cassia occidentalis*, *Cyperus esculentus* and *Ocimum basilicum* (Figure 2).

Of the remaining 12 species, 3 were found only in Mainé Soroa and 9 only in N'Guigmi. These were, in order of importance, *Glossonema boveanum*, *Merremia tridentata* and *Ipomoea heterotracha* in Mainé Soroa and *Solanum nigrum*, *Oryza barthii*, *Physalis angulata*, *Arthrospira platensis*, *Nymphaea lotus*, *Dactyloctenium aegyptium*, *Brachiaria xantholeuca*, *Loudetia hordeiformis* and *Aeschynomene indica* in N'Guigmi.

It should be noted that *Amaranthus graecizans*, *Glossonema boveanum*, *Merremia tridentata* and *Ocimum basilicum* were cited only by refugees in Mainé Soroa and *Aeschynomene indica*, *Amaranthus spinosus*, *Loudetia hordeiformis* and *Ocimum basilicum* in N'Guigmi.

### Parts uses and forms of use

According to the respondents, the most consumed parts were the leaves with 51.2% and 41.3% respectively in Mainé Soroa and N'Guigmi. Seeds were cited by 26.8% of respondents in Mainé Soroa and 30.7% in N'Guigmi. Fruits were cited by 19.2% and 26.2% in Mainé Soroa and N'Guigmi respectively. The least consumed parts were flowers (2.7% in Mainé Soroa and 1.4 in N'Guigmi) and roots (0.4% in N'Guigmi) (Figure 3A).

The majority of respondents in Mainé-Soroa (50%) and only 12.5% in N'Guigmi stated that these plants were used in the preparation of the sauce. A similar pattern was found for the use as spinach used by 25% and 15% of respondents in Mainé-Soroa and N'Guigmi, respectively. The forms of use were, in order of importance, cooked spinach, drinks, raw, couscous and dough (Figure 3B).

### Economic value

Around one third of the informants found the economic value of herbaceous plants medium, 35.4% in Mainé-Soroa and 42.5% in N'Guigmi. The value was considered high by 27% in Mainé-Soroa and 36% in N'Guigmi (36.4%) (Figure 3C). The informants cited *Corchoris tridens*, *Leptadenia hastata*, *Cleome gynandra*, *Senna tora*, *Ceratotherca sesamoides*, *Physalis angulata* and *Amaranthus spinosus* as the species with the highest economic value.

### Abundance

Most informants considered the wild herbaceous plant resources rare, 51.9% in Mainé-Soroa and 44.1% in N'Guigmi, whereas it was considered abundant by 8% in Mainé-Soroa and 17% in N'Guigmi (Figure 3D). Some species, such as *Arthrospira platensis*, had disappeared according to some informants in N'Guigmi (3.3%). The species cited as rare resources were *Senna tora*, *Cleome gynandra*, *Ceratotherca sesamoides*, *Amaranthus graecizans*, *Senna occidentalis*, *Cucumis melo*, *Mukia maderaspatana*, *Momordica balsamina*, *Corchorus olitorius*, *Paspalum scrobiculatum*, *Cyperus amabilis*, *Ocimum basilicum*, *Hibiscus asper*, *Aeschynomene indica*, *Oryza spp*, *Loudetia hordeiformis* and *Arthrospira platensis*.

The main causes of degradation were found to be drought, agriculture and overexploitation. However, these causes vary from one department to another. Thus, in Mainé-Soroa, the causes related to agriculture (33%), drought (30%) and overexploitation (29%) were the most cited. On the other hand, in N'Guigmi the most cited causes were drought (42%), agriculture (40%) and finally overexploitation (18%) (Figure 3E).

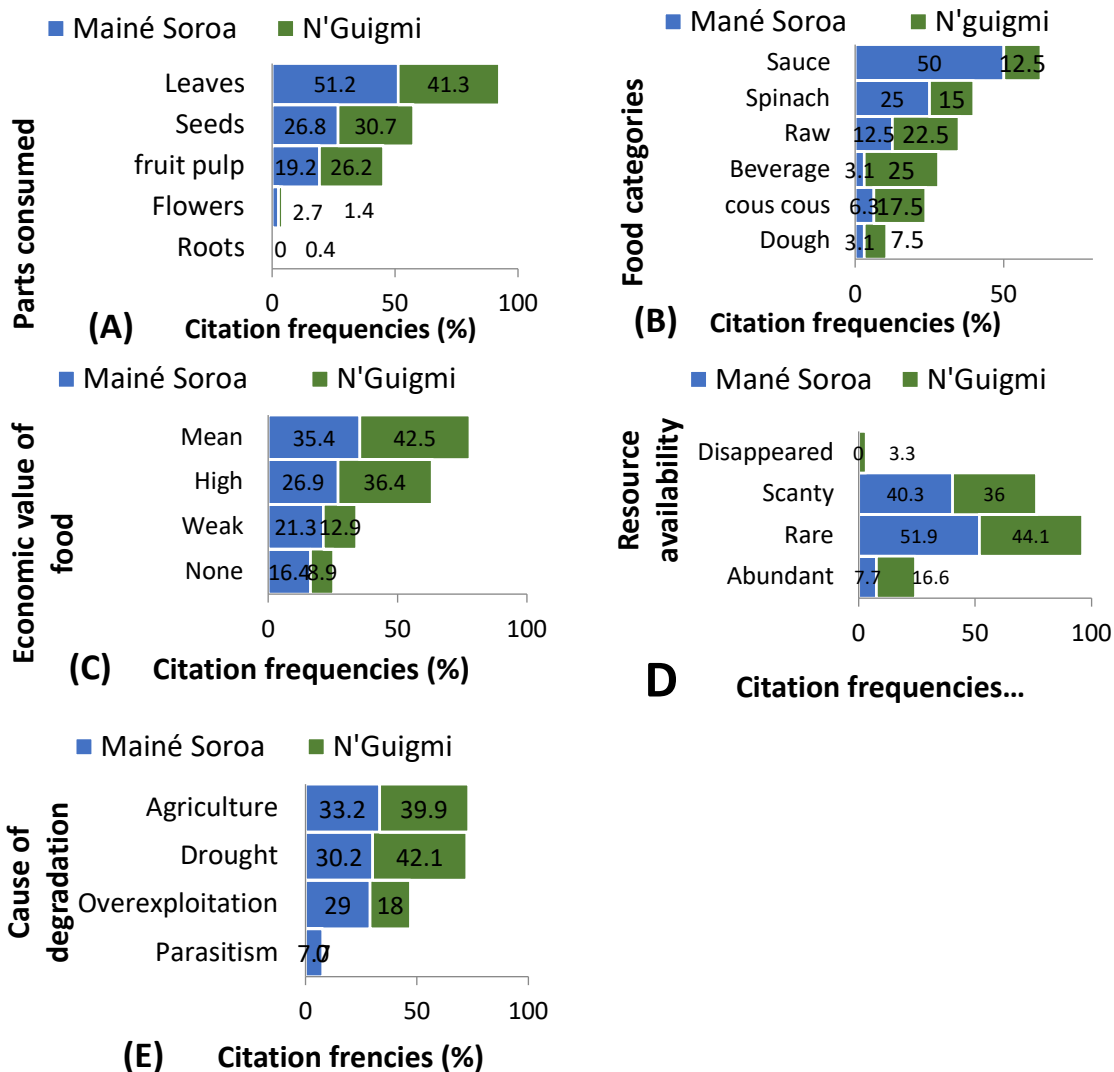


Figure 3. Citation frequencies. (A) Parts consumed; (B) Food categories; (C) Economic values; (D) Resource availability; (E) Cause of degradation.

### Knowledge and distribution of ethnic groups

The principal component analysis (PCA) showed clear patterns in the knowledge of native food plants according to ethnic groups and origin of informants (Figure 4). The first two axes explained 68.2% of the information. The Toubou cited a limited number of species and more or less different from those cited by the other groups. The species most cited by the Toubou were *Cucumis melo*, *Mukia maderaspatana*, *Amaranthus graecizans*, *Ocimum basilicum* and *Citrullus lanatus*. The Fulani mentioned species similar to those mentioned by the refugees. These were *Cleome gynandra*, *Tribulus terrestris* and *Corchorus tridens*. The species most cited by the refugees were *Amaranthus spinosus*, *Ceratotheca sesamoides*, *Senna occidentalis* and *Senna tora*. The Boudouma and Haoussa cited fairly similar species. These were *Nymphaea lotus*, *Aechynomene indica*, *Corchorus olitorius*, *Oryza* spp. *Loudoutia hordeiformis* and *Arthrospira platensis*. The Kanuri cited a fairly extensive list consisting of almost all wild herbaceous food species.

A principal component analysis (PCA) based on socioeconomic groups and plant parts used showed that fruits and seeds were cited more by the Hausa, while leaves are cited much more by the Toubou and Fulani and flowers and roots are particularly cited by the refugees. In total 94% of variation was explained (Figure 5).

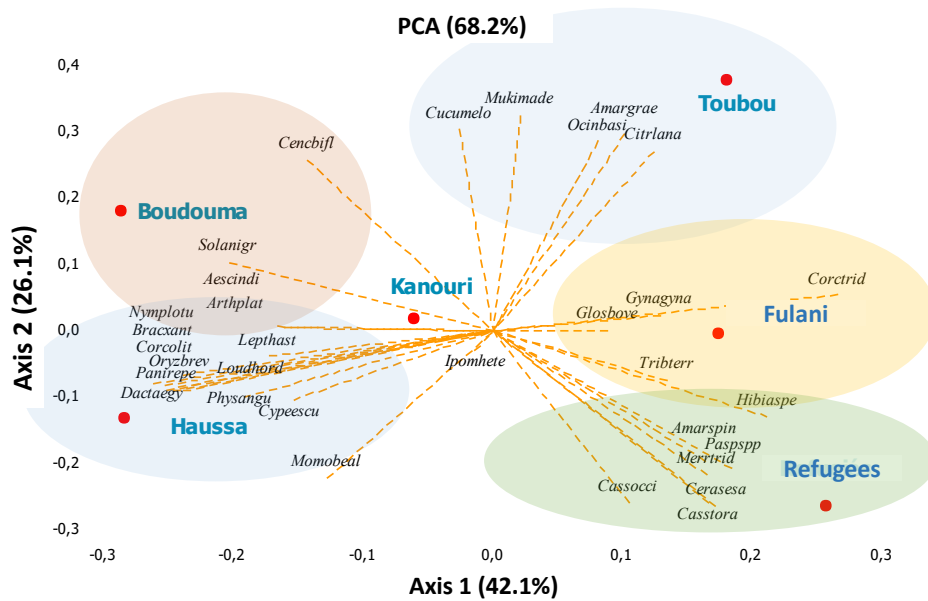


Figure 4. Principal component analysis showing socio-economic groups according to their knowledge on wild herbaceous foods. Species names are shown as the first four letters in the genus name and the first four letters of the species epithet.

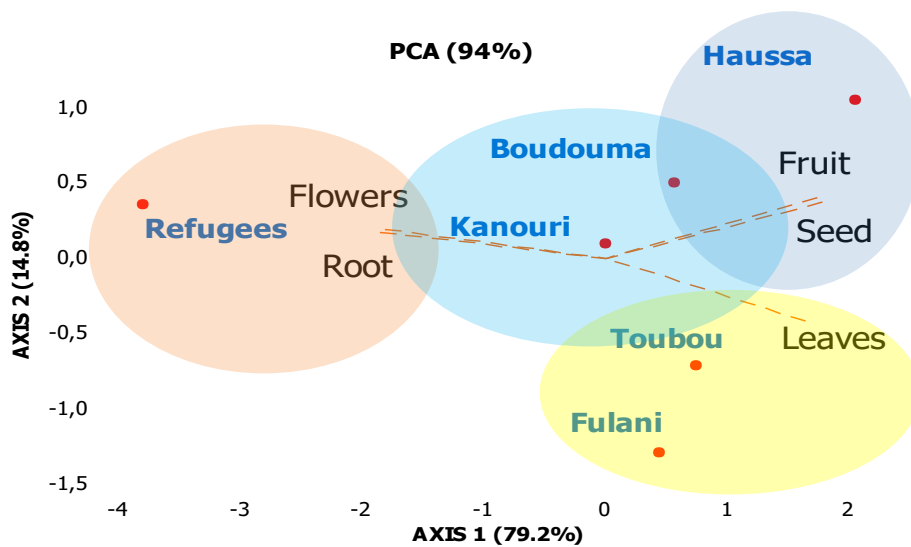


Figure 5. Principal component analysis showing the relationship between sociolinguistic groups and the parts of plants consumed.

**Use of plant part according to group**

The species cited were mainly therophytes (44%), followed by therophytic lianas (19%), hydrophytes (16%) and nanophanerophytes (9%) (Table 2). The other life forms covered 13%.

Table 2. Use of different parts of wild herbaceous and a cyanobacterium food by natives and refugees in two communities in Niger. Lifeform abbreviations: T = Therophytes, Lt = Therophytes Lianas, Np = Nanophanerophytes, Hy = Hydrophytes, Gr = Rhizome Geophytes, Ch = Chamephytes and Gr = Root Geophytes

Species	Life-form	Families	Mainé Soroa (%)		N'Guigmi (%)	
			Native (N=102)	Refugee (N=42)	Native (N=93)	Refugee (N=33)
<i>Aeschynomene indica</i> L.	Hy	Fabaceae	-	-	-	Root (14.2%)
<i>Amaranthus graecizans</i> L.	T	Amaranthaceae	-	Leaf (9.1%)	Leaf (11.3%)	Leaf (28.5%)
<i>Amaranthus spinosus</i> L.	T	Amaranthaceae	Leaf (22.3%)	Leaf (30.3%)	-	Leaf (47.6%)
<i>Arthrospira platensis</i> Gomont (cyanobacterium)	Hy	Phormidiaceae	-	-	Leaf (17.7%)	-
<i>Brachiaria xantholeuca</i> (Schinz.) Stapf.	T	Poaceae	-	-	Root (1.3%)	Root (19.0%)
<i>Senna occidentalis</i> (L.) Link	Np	Caesalpiniaceae	Seed (14.9%)	Leaf (15.1), Seed (15.1%)	Seed (13.9%)	Leaf (33.3%), Seed (53.5%)
<i>Senna obtusifolia</i> (L.) H.S.Irwin & Barneby	T	Caesalpiniaceae	Leaf (50.7%)	Leaf (60.6%)	Leaf (25.3%)	Leaf (30.1%)
<i>Cenchrus biflorus</i> Roxb.	T	Poaceae	Seed (5.9%)	Seed (12.2%)	Seed (25.3%)	Seed (3.3%)
<i>Ceratothera sesamoides</i> Endl.	T	Pedaliaceae	Leaf (29.1%)	Leaf (48.4%)	Leaf (11.4%)	Leaf (28.5%)
<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai	Lt	Cucurbitaceae	Fruit (19.4%)	Fruit (18.1%)	Fruit (49.3%)	Fruit (85.7%), Seed (76.1%)
<i>Corchorus olitorius</i> L.	T	Tiliaceae	Leaf (29.1%)	Leaf (28.2%)	Leaf (11.4%)	Leaf (14.3%)
<i>Corchorus tridens</i> L.	T	Tiliaceae	Leaf (62.6%)	Sheet (100%)	Leaf (51.9%)	Sheet (100%)
<i>Cucumis melo</i> Naud.	Lt	Cucurbitaceae	Fruit (14.9%)	Fruit (24.2%)	Fruit (12.7%)	Fruit (28.6%)
<i>Cyperus amabilis</i> Vahl	Gr	Cyperaceae	Seed (5.9%)	Seed (9.0%)	Seed (1.3%)	Seed (14.3%)
<i>Dactyloctenium aegyptium</i> (L.) Willd.	T	Poaceae	-	-	Seed (7.6%)	Seed (14.3%)
<i>Glossonema boveanum</i> (Decne.) Decne.	Ch	Apocynaceae	-	Fruit (6.1%)	-	-
<i>Cleome gynandra</i> L.	T	Capparaceae	Leaf (35.8%)	Leaf (54.5%)	Leaf (50.6%)	Leaf (60.6%)
<i>Hibiscus asper</i> Hook.f.	T	Malvaceae	Leaf (12.6%) Flower (12.6%)	Leaf (24.2%), Seed (24.2%)	Leaf (14.9%)	Leaf (38.1%)
<i>Ipomoea bonariensis</i> Hook.	Lt	Convolvulaceae	Leaf (4.4%)	Leaf (6.1%)	-	-
<i>Leptadenia hastata</i> (Schumach. & Thonn.) Decne.	Lmp	Asclepiadaceae	Leaf (41.7%)	Leaf (69.6%), Fruit (69.6%), Flower (69.6%)	Leaf (84.61%)	Leaf (100%), Flower (100%), Fruit (100%)
<i>Loudetia hordeiformis</i> (Stapf.) CE.Hubb.	T	Poaceae	-	-	-	Leaf (23.8%)
<i>Merremia tridentata</i> (L.) Hallier. f.	Lt	Convolvulaceae	-	Leaf (9.0%), Flower (9.1%), Fruit (6%), Seed (3.03%)	-	-
<i>Momordica balsamina</i> L.	Lt	Cucurbitaceae	-	Leaf (12.1%), Seed (6.1%)	Fruit (12.6%)	Fruit (23.8%)
<i>Mukia maderaspatana</i> (L.) M.Roem.	Lt	Cucurbitaceae	Leaf (11.9%)	Leaf (18.8%), Seed (12.1%)	Leaf (12.6%), Seed (5.8%)	Leaf (38.1%), Fruit (38.09%)



## Ethnobotany Research and Applications

Species	Life-form	Families	Mainé Soroa (%)		N'Guigmi (%)	
			Native (N=102)	Refugee (N=42)	Native (N=93)	Refugee (N=33)
<i>Nymphaea lotus</i> L.	Hy	Nymphaeaceae	-	-	Seed (18.5%)	Seed (33.3%), Flower (28.5%)
<i>Ocimum basilicum</i> L.	Np	Lamiaceae	-	Flower (14,2%)	-	Leaf (14.3%), Flower (14.3%)
<i>Oryza barthii</i> A.Chev.	Hy	Poaceae	-	-	Seed (47.6%)	Seed (19.0%)
<i>Panicum repens</i> L.		Poaceae	Seed (19%)	Seed (30.3%)	Seed (50,6%)	Seed (90.4%)
<i>Paspalum scrobiculatum</i> L.	Hy	Poaceae	Seed (4.4%)	Seed (6.1%), Leaf (6.1%)	Seed (6.3%)	Seed (23.8%)
<i>Physalis angulata</i> L.	T	Solanaceae	-	-	Fruit (37.3%)	Fruit (76.1%)
<i>Solanum nigrum</i> L.	Np	Solanaceae	-	-	Fruit (63.2%)	Fruit (100%)
<i>Tribulus terrestris</i> L.	T	Tribulaceae	Leaf (17.9%)	Leaf (30.3%), Seed (24.2%)	Leaf (2.5%)	Leaf (33.3%), Seed (23.8%)

For the most part, the list is dominated by species of the Poaceae family (21.8%) followed by the Cucurbitaceae (12.5%) (Table 2). In Mainé-Soroa, in addition to the 19 species commonly used by both native and refugees, the latter cited five other species that the native did not mention. These were *Amaranthus graecizans*, *Glossonema boveanum*, *Merremia tridentata*, *Momordica balassamina* and *Ocimum basilicum*. In N'Guigmi, of the 30 species cited by the population, only one was not cited by the refugees. This was *Arthrospira platensis*, which had already disappeared before the refugees settled in the area. The natives cited 26 species compared to 29 cited by the refugees. As for the parts used, in Mainé-Soroa as in N'Guigmi, the refugees use a greater number of plant parts than the natives, such as *Paspalum scrobiculatum*, whose leaves and seeds are consumed by the refugees, whereas the natives consume only the grains. *Tribulus terrestris*, whose leaves and seeds are consumed by the refugees while the natives only consume the leaves. *Senna occidentalis*, *Leptadenia hastata*, in addition to the leaves used by the natives, the refugees use the flowers and fruits of the species.



Figure 6. Marketing of *Corchorus* spp. at the Mainé-Soroa market (A) and storage in a shop (B).

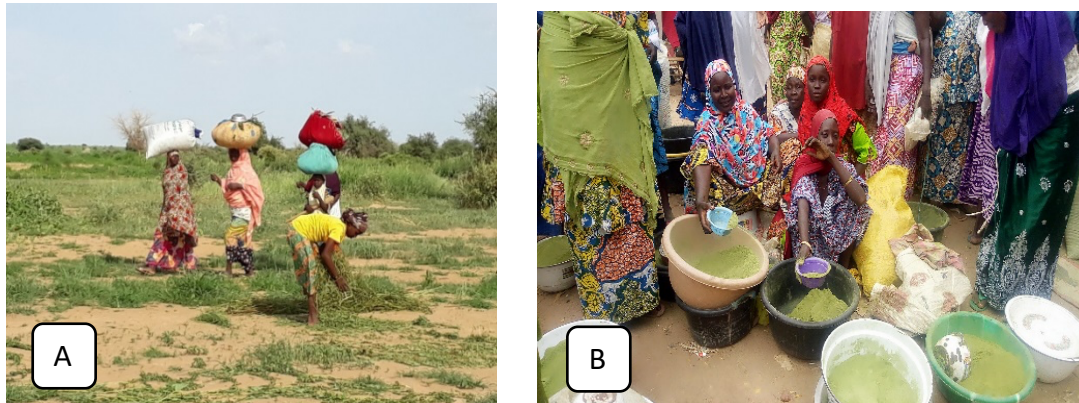


Figure 7. Harvest of *Corchorus* spp. in a fallow; Sale of *Corchorus* spp. powder at the N'Guigmi market.



Figure 8. Leaf mill of herbaceous food species.

## Discussion

### Diversity of native food grasses used

Wild herbaceous plant species are intensively exploited by the people for food (Garba *et al.* 2020). In Lake Chad Basin, 60-70% of the local people knew to use wild herbaceous plants for food. Herbaceous plants unlike woody

plants are available only in the rainy season and play a very important role in the lean season when the food stock is depleted.

Several studies have been conducted on food plants in the Sahelo-Sudanese zone of Niger (Dadjo *et al.* 2012, Dan Guimbo *et al.* 2012, Balla & Baragé 2008, Douma *et al.* 2009), but only 13 herbaceous species out of the 32 were recorded by the previous studies, the other 19 species were not revealed in other studies in Niger. These are *Aeschynomene indica*, *Arthrospira platensis*, *Brachiaria xantholeuca*, *Senna occidentalis*, *Cucumis melo*, *Cyperus amabilis*, *Dactyloctenium aegyptium*, *Ipomoea heterotricha*, *Loudetia hordeiformis*, *Merremia tridentata*, *Mukia maderaspatana*, *Ocimum basilicum*, *Oryza brevigulata*, *Panicum repens*, *Paspalum scrobiculatum*, *Physalis angulata* and *Solanum nigrum*. This can be explained by the lack of studies on food plants in the Lake Chad basin. Indeed, this study is one of the few studies conducted in the extreme eastern part of Niger. Additionally, the study included species that were mainly consumed among the refugees.

A species such as *Arthrospira platensis* (spirulina) has long been used as a traditional food by the Kanembou ethnic group around Lake Chad (Cruchot 2008). *Arthrospira platensis*, *Nymphaea lotus* and *Oryza brevigulata* are aquatic species cited only in N'Guigmi. It is also important to note that in the area, plant resources are facing strong human pressure especially with a large influx of refugees. Moreover, it is observed that the population of this area is beginning to expand its food habit by integrating consumption of new species such as *Merremia tridentata* and *Momordica balsamina*.

### Socio-economic importance of native forbs

People use food plants in many forms, e.g. in sauce, raw or cooked as spinach, in the form of couscous, drinks, porridge.. as well as seasoning, acidifier and odorant. These same uses have been reported in work in other regions of Niger (Dan Guimbo *et al.* 2012). Leaves were the most consumed parts in the two departments of the present study. In contrast, studies conducted by Kouamé *et al.* (2008) on woody species showed that fruits are the most used parts at more than 50% of the people. Some species serve for multiple uses while for others the uses are limited (Savadogo *et al.* 2017 & 2019; Ehillé *et al.* 2019). Thus, *Hibiscus asper* is used by the populations both as a spice, leaf vegetable, spinach or acidifier. Its seeds are used in sauce, its fruits are used to make drinks that are sold all over the country. On the other hand, *Ceratotheca sesamoides* and *Corchorus* spp. are used as leafy vegetables in sauce. *Ocimum basilicum*, on the other hand, has only a fragrant role and is used to season the sauce and juice. The leaves of *Senna tora*, a neglected species in the past (Joy *et al.* 2018), were used only as fodder given to animals in the past, are currently used for the preparation of couscous or spinach seasoned with groundnut paste and even sold in large urban centres. The same observation was made for *Cleome gynandra* and *Amaranthus spinosus*.

The native species of great importance are those with high economic value. These are, in order of importance, *Corchorus* spp., *Leptadenia hastata*, *Cleome gynandra*, *Senna tora* and *Ceratotheca sesamoides*. The leaves of the latter species are dried and stored in bags for use during the low production period (dry period). These products are sold on local markets and even exported to Maghreb countries and Saudi Arabia. The same observation was made by Garba *et al.* (2020) who reported that the marketing of harvested products generates substantial income for farmers and also provides a living for many small intermediate traders. This difference in economic value between these species could be explained by the food habit of the population on the one hand and on the other hand the demand for the types of products of the species in the market. Another important factor to be notified is that these products are exploited in natural conditions whose production is devoid of the use of any other forms of chemicals. Human consumption of some species of lesser economic value such as *Cenchrus biflorus*, *Dactyloctenium aegyptium* and *Loudetia hordeiformis* could be justified by the recurrent food insecurity in the Sahelian zone. They are generally consumed during periods of severe famine in the Sahel. The reserves of native food products are very important for a vulnerable population where the rainy season is very short, and the lean season is quite long. These observations are widely documented by several studies in Africa (Aboubacar *et al.* 2019, Boudraa, *et al.* 2010, Yves *et al.* 2016). Native grasses contribute to the well-being of populations located at the desert gateway where woody species that are much more sensitive to climatic variations are lacking. Most native food plant species are freely exploited. This creates negative consequences on the availability of these resources (Akpavi *et al.* 2012, Adjahossou, *et al.* 2019, Lawin *et al.* 2019) In addition to overexploitation, native food forbs face other natural and anthropogenic threats such as drought and agriculture.

The informants, specifically women, stated that harvesting products generates income throughout the year and especially during the lean season or dearth period. Women are much more involved in the marketing of non-timber forest products (NTFPs), unlike cash crops, which are prone to pests and are seasonal, requiring a large workforce

and high maintenance costs. The latter are unanimous that since agricultural production has become uncertain, men have also used this channel, especially for the most prized products.

## Conclusion

The Diffa region faces challenges related to malnutrition, food insecurity, desertification, the drying up of Lake Chad as well as displacement of populations from Nigeria. In this context, herbaceous plants play a very important role in the lean season when food stocks are depleted. In this unstable and fragile desert environment of Niger, 31 wild herbaceous food species and one cyanobacterium were cited as important by the local people. Leaves and fruits of these species play an important role in daily life, both in times of food sufficiency and shortage. However, these species are becoming increasingly rare. The study showed that the consumption of species and their parts depends on sociolinguistic groups. It can also be noted that the influx of refugees from Nigeria has contributed to the enrichment in use of native food herbs in the study area. Efforts must be made to protect and enrich ecosystems with native species of high socio-economic value in order to reconcile their conservation and use, and domestication is recommended for *Corchorus* spp., *Senna tora*, *Cleome gynandra*, *Amaranthus spinosus* and *Ceratotheca sesamoides*. The local knowledge related to the consumption of these plants has cultural value and can be a keystone in the fight against hunger and desertification.

## Declarations

**List of abbreviations.** CDB = Convention on Biological Diversity; OCHA = Office for the Coordination of Humanitarian Affairs; NTFPs = non-timber forest products; PCA = Principal Component Analysis.

**Ethical approval and consent to participation:** The authors have requested authorization from the authorities, notably from the university, customary authorities and the populations, and all the participants have given their agreement to the publication of this article.

**Consent to publication.** The article presents photos of the actors of the local food plant production chain and they have given their consent to publication.

**Availability of data and materials.** The authors will provide the raw data without the names of the informants and the database of the collected data upon request.

**Competing interests and conflicts of interest:** The authors declare that they have no competing interests or conflicts of interest.

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