Available online at http://www.ifgdg.org

Int. J. Biol. Chem. Sci. 16(4): 1434-1447, August 2022

ISSN 1997-342X (Online), ISSN 1991-8631 (Print)

International Journal of Biological and Chemical Sciences

Original Paper http://ajol.info/index.php/ijbcs http://indexmedicus.afro.who.int

Traditional uses of *Detarium microcarpum* Guill. & Perr. (Fabaceae) and potential for its valorisation as fuelwood

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Received: 07-04-2022 Accepted: 14-08-2022 Published: 31-08-2022

ABSTRACT

Detarium microcarpum Guill. & Perr. is a common multipurpose small tree species of Sudanian and Sudano-Guinean savannahs with high potential for use as fuelwood but little valued in forestry programs. The present study aimed at assessing the current local uses of *D. microcarpum*, factors determining its use as fuelwood and determine the geographical areas with the socio-cultural groups which is most suitable for its integration into fuelwood programs. An ethnobotanical survey was conducted among 1074 people selected randomly. Factors determining *D. microcarpum* use as fuelwood were identified through a binary logistic regression. Factorial Correspondence Analysis established the relationship between socio-cultural groups and the use of *D. microcarpum* parts or organs. A total of 62.47% of respondents know and use at least part of *D. microcarpum*. The trunk and branches are the most used organs (35.12%), primarily as fuelwood. The determinants of *D. microcarpum* use as fuelwood are the phytogeographic district (a proxy for the resource availability), gender, sociolinguistic group, and educational level. *D. microcarpum* is more used as fuelwood by women. The use of *D. microcarpum* as fuelwood is more pronounced in about 63% of the national territory. This study confirms the potential of *D microcarpum* as fuelwood to be promote.

Keywords: Sweet detar, usage patterns, user acceptance, local species, valuation, Benin.

INTRODUCTION

Ethnobotanical studies are useful for understanding the uses of forest resources in a given region and informing forest policy. Indeed, peoples have always had traditionally rich ethnobotanical knowledge through the cultural and ecological diversity of the environment in which they live (Gbesso et al., 2013). This knowledge and local uses may or may not be influenced by socio-cultural

DOI: https://dx.doi.org/10.4314/ijbcs.v16i4.7

characteristics such as ethnicity, age, gender, educational level, religion, or occupation (Sop and Oldeland, 2011), and a plant perceived as highly useful by one ethnic group may be considered of little use, or even useless, by another group (Ilumbe, 2010). Also, knowledge of the use and management of species by local communities can help improve the conservation of species at local and regional levels (Kouaro et Tasso, 2010) by providing basic information for the selection of the species on which the emphasis should be put in management plans to meet not only the needs of populations but also to improve the conservation status of species (Dossou et al., 2012).

D. microcarpum, also called small detar or sweet detar, is a tree up to 10 m tall that occurs naturally in the arid regions of West and Central Africa, from Senegal and The Gambia to Sudan (Kouyaté et van Damme, 2006). It is found in shrub savannas, wooded savannas and open forests, as well as in dry forests and fallows (Arbonnier, 2002). It generally grows on marginal soils such as sandy and lateritic soils (Kouyaté, 2005), thereby involving little or no land use competition with agricultural crops. It is reproduced by rejection, suckers and spontaneously sprouted seeds (Kouyaté, 2005). This capacity suggests the possibility of vegetative propagation of *D. microcarpum* which is necessary for its domestication. Regarding the species growth, it can reach 50 cm height after a year and 120 cm after 7 years (Bastide and Ouedraogo, 2008). *D. microcarpum* is also a species that supports stress such as cutting (Batiano et al., 2001; Sawadogo et al., 2002) and could therefore be conducted in thickets. Traditionally, the entire tree is cut during the dry season (February-May) for fuelwood stocks in anticipation of the rainy season (Kouyaté, 2005).

D. microcarpum is also used for food, energy, veterinary, artisanal, industrial, and medicinal purpose. In Benin, the proportion of food uses is 26.23% against 81.18% for the wood category energy (Agbo et al., 2017). According to Kouyaté et al. (2002), women classified *D. microcarpum* (fruit, firewood), *Parkia biglobosa* (Jacq.) R. Br ex G. Don (fruit) and *Vitellaria paradoxa* CF Gaertn (fruit) as the three most important forest species in Mali. In Burkina-Faso, the wood of *D. microcarpum* is particularly valued by households as firewood because of its high calorific value about 1968 KJ/kg (Kabore, 2001), which leads also to its high exploitation (Agbo et al., 2017). In Benin, the demand of domestic source of energy situation is increasing, and it is important to identify alternative sources of energy to meet local population needs.

Assessing the knowledge diversity and usage patterns of *D. microcarpum* could help in determining sustainable management and domestication strategies of the species. The present study aimed at capitalizing the knowledge and local uses of *D. microcarpum*, in order to provide the basis for its rational and sustainable management.

MATERIALS AND METHODS

Study area

This study was conducted in ten (10) Divisions (i.e. Alibori, Borgou, Atacora, Donga, Zou, Hill, Couffo, Mono, Plateau and Atlantic) out of the twelve (12) of Benin (Figure 1). The two departments of the far south of Benin (i.e. Littoral and Ouémé) were excluded because *D. microcarpum* was not observed during the exploratory phase. In each Division, the districts were chosen based on the presence of the species for investigations. In each district, the nearby villages (distance ≤ 10 km) of *D. microcarpum* dominated plant vegetation were selected for ethnobotanical studies. Study villages are characterized by a

strong sociolinguistic and cultural diversity (Dicko et al., 2017).

Ethnobotanical surveys

Ethnobotanical surveys were conducted based on a semi-structured questionnaire administered to individuals belonging to different sociolinguistic groups. Preliminary sampling for the survey included 30 randomly selected people in each studied department. The percentage of respondents who know at least one use of *D. microcarpum* was calculated and the number of respondents (Table 1) was determined afterward using Dagnelie (1998) formula:

$N = U^2_{(1-\alpha/2)xP(1-P)} / d^2$, Where N is the sample size, U_ (1-α / 2) ^ 2 is the normal random variable value for a probability value α = 0.05; U_ (1-α / 2) = 1.96; p = the proportion of respondents who know and use parts of the species and the 8% margin of error (Assogbadjo et al., 2011; Dicko et al., 2017). The sample size calculated for each department was then divided among different sociolinguistic groups for that department (Table 1).

Statistical analysis

Determinants of D. microcarpum use as fuelwood

For identifying the socio-demographic and ecological characteristics that determine *D. microcarpum* use as fuelwood in the study area, a binary logistic regression was used under R software, version 3.4.2, with the Package MASS (Venables and Ripley, 2002). Specifically, we assessed whether the probability of a respondent using the species for fuelwood is related to certain sociodemographic and ecological characteristics. The response variable is the use of the species as fuelwood and is coded as 1 (uses the species) or 0 (does not use the species). Explanatory variables included phytogeographic district, sociolinguistic group, gender, age, marital status, religion, education level, and household size. Several models were compared using the Akaike Information Criterion (AIC) (Akaike, 1974). For the sake of parsimony, we chose the model that has the smallest value of AIC and the smallest number of terms that influence *D. microcarpum* use as fuelwood.

Relationship between sociolinguistic groups and the use of D. microcarpum organs or parts

The relationship between sociolinguistic groups and the uses of *D. microcarpum* parts or organs was described using Factorial Correspondence Analysis (FCA) was carried out under the software R (version 3.4.2) with the FactoMineR package and from a data table with socio-linguistic groups (in rows) and parts / organs of *D. microcarpum* (in columns).

Table 1: Characteristics of sociolinguistic groups surveyed on the importance of *D. microcarpum* in ten Divisions of Benin.

D	N	GS	F	M	<30	30-50	>50	Σ
Alibori	195	Ahoussa	1	2	0	3	0	3
		Bariba	19	42	11	34	16	61
		Boo	4	5	2	7	0	9
		Dendi	12	23	7	13	15	35
		Gourmatche	0	3	2	1	0	3
		Idasha	0	1	1	0	0	1
		Kotokoli	0	1	0	1	0	1
		Monkole	6	21	5	16	6	27
		Peulh	13	27	7	26	7	40
		Yoruba	1	0	1	0	0	1
		Zerma	5	9	2	10	2	14
Atlantique	34	Adja	1	0	1	0	0	1
		Aizo	2	18	4	13	3	20
		Fon	5	8	1	6	6	13
Borgou	263	Adja	1	5	0	6	0	6
		Bariba	53	101	41	80	33	154
		Biali	7	2	3	6	0	9
		Boo	2	9	0	5	6	11
		Dendi	1	0	1	0	0	1
		Ditamari	0	1	1	0	0	1
		Fon	4	5	5	4	0	9
		Foodo	0	1	0	1	0	1
		Gando	4	15	0	12	7	19
		Goun	0	1	0	1	0	1
		Idasha	0	2	0	2	0	2
		Nago	4	13	6	9	2	17
		Peulh	2	22	5	17	2	24
		Yende	0	4	2	1	1	4
		Yom	1	0	0	1	0	1
		Yoruba	0	1	0	0	1	1
		Zerma	0	2	0	2	0	2
Mono	15	Kotafon	2	13	0	9	6	15
Plateau	53	Holli	1	0	0	0	1	1
		Mahi	1	14	1	8	6	15
		Nago	7	29	1	17	18	36
		Yoruba	1	0	0	0	1	1

D	N	GS	F	M	<30	30-50	>50	Σ
Atacora	167	Bariba	6	35	10	21	10	41
		Biali	1	0	0	0	1	1
		Ditamari	9	25	8	17	9	34
		Gando	3	9	4	5	3	12
		Gourmatche	5	8	1	9	3	13
		Kotokoli	0	1	0	1	0	1
		Kounteni	1	7	4	3	1	8
		Peulh	2	9	3	8	0	11
		Waaba	15	25	6	21	13	40
		Yende	2	1	0	1	2	3
		Yom	0	3	0	2	1	3
Collines	126	Adja	1	0	0	1	0	1
		Biali	0	1	0	1	0	1
		Fon	3	3	4	0	2	6
		Idasha	17	15	7	17	8	32
		Mahi	7	9	1	8	7	16
		Nago	29	39	10	37	21	68
		Sola	1	0	0	1	0	1
		Waama	1	0	0	1	0	1
Couffo	23	Adja	3	8	1	5	5	11
		Agouna	1	10	0	5	6	11
		Fon	0	1	0	1	0	1
Donga	111	Ani	14	13	7	12	8	27
		Dendi	2	3	1	3	1	5
		Ditamari	3	3	2	3	1	6
		Kotokoli	3	10	0	8	5	13
		Lokpa	10	12	2	11	9	22
		Nago	1	1	0	2	0	2
		Peulh	3	2	1	3	1	5
		Taneka	2	5	2	1	4	7
		Yom	10	14	1	9	14	24
Zou	87	Adja	0	1	1	0	0	1
		Aizo	2	0	1	1	0	2
		Fon	45	37	19	42	21	82
		Goun	1	0	1	0	0	1
		Mina	1	0	1	0	0	1

NB: D=Phytogeographic district, N = Sample size, GS = Sociolinguistic group, F = Female, M = Male, <30 = age under 30 years,
30-50 = age between 30 and 50 years, > 50 = age over 30 years.

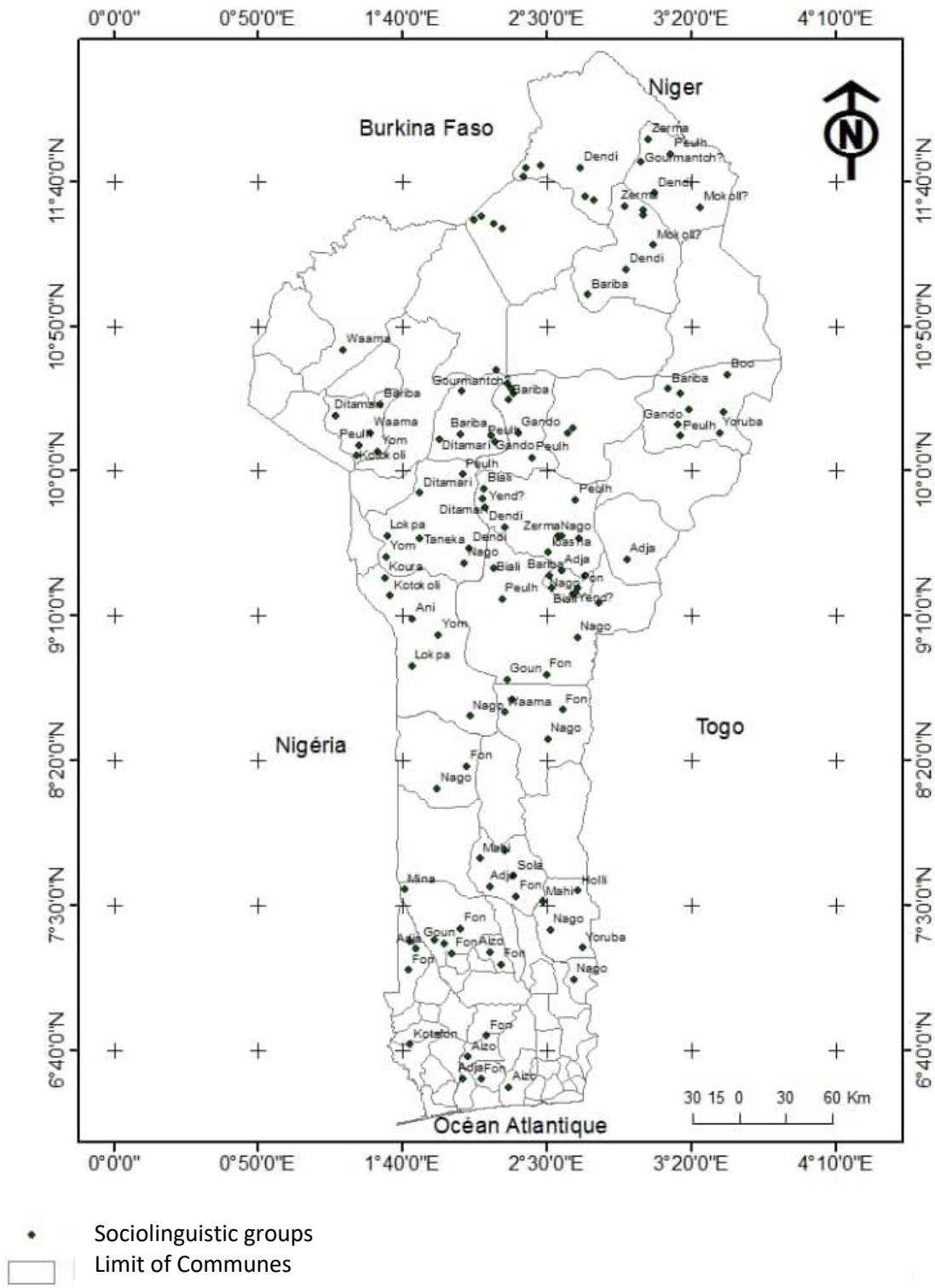


Figure 1: Study area.

RESULTS

Frequencies of opinions regarding the use of *D. microcarpum* organs / parts

Out of a total of 1074 people surveyed, 671 people know and use at least part of *D. microcarpum* (Figure 2a). The trunk and branches are the most used organs (35.12% of respondents), followed by fruits (28%), leaves (15.64%), roots (10.24%) and bark (10.14%). Sap and flower are the least used parts by the respondents (0.66% and 0.20% respectively).

Uses of *D. microcarpum*

Different uses are reported by the local populations surveyed according to *D. microcarpum* parts used. The trunk and branches of the species are more used as fuelwood (47.47% and 24.80% of uses reported by respondents (Figure 2b). Food uses represent 27.70% of all reported uses. The bark, leaves and roots are mainly used for medicinal purposes (respectively 97.94%, 84.85% and 95.83%, Figures 2c, 2d, 2g). The flowers play a magico-mystical role (66.67%, Figure 3e) while the fruits / almonds are exploited in the diet (96.91%, Figure 2f). As for the sap, it is mainly used to trap birds (54.55%, Figure 2h).

Roots are more used to treat stomach pain (2.79% of respondents). The bark is most exploited to treat malaria (2.79%), stomach pain (2.79%) and hemorrhoids (2.79%). The trunk and branches are more used as fuelwood (60.15% and 4.06% respectively). As for the leaves, they are mainly used by respondents to treat malaria (13.19%), for the vigor of children (4.82%), as a leaf vegetable (4.06%), to treat yellow fever (3.55%), and to treat diarrhea (2.79%). The flowers are used as a lucky charm (0.48% of the respondents). Sap is more exploited as a glue to trap birds (1.27%). Fruits constitute a food and are eaten raw or processed into fruit juice (64.72% of respondents). For the therapeutic uses, the principal mode of use of *D. microcarpum* organs is the decoction (72.25% of the respondents), followed by the infusion (24.05%), the maceration (2.50%) and milling (1.20%).

Relations between sociolinguistic groups and organs uses

The Factorial Correspondence Analysis between the sociolinguistic groups and the uses of *D. microcarpum* organs or parts shows that the first factorial axis explains 40.45% of the total variance and the second axis gives information on 23.59% of the variations (Figure 3). Thus, the first two factorial axes account for 64.03% of the total variance. These first two axes were therefore retained to describe the relationship between the uses of *D. microcarpum* and sociolinguistic groups.

Axis 1 is positively correlated with leaves and roots use of *D. microcarpum* on the one hand, and with the sociolinguistic groups Adja, Ahoussa, Aizo, Ani, Fon, Idasha, Mahi, Nago, Sola, and Taneka on the other hand. This axis is negatively correlated with the use of sap, branch, and fruit on the one hand, and then on the sociolinguistic groups Agouna, Bariba, Mokole, Peulh and Yendé.

Axis 2 is positively correlated with the use of the trunk and flowers of *D. microcarpum* on the one hand, and the sociolinguistic groups Biali, Dendi, Ditamari, Gando, Goun, Kounteni, Kotafon, Lokpa, Waaba, Yom, Yoruba. and Zerma. On the other hand, the exploitation of the bark as well as the sociolinguistic groups Boo, Gourmantché, Kotokoli, Koura and Serima are negatively correlated to this axis (Table 2).

Determinants of *D. microcarpum* use as fuelwood

Factors determining the use of *D. microcarpum* as fuelwood in the study area are phytogeographic district, Gender, sociolinguistic group, and educational level (Table 3).

D. microcarpum is more commonly used as fuelwood by women (Figure 4a) belonging to the sociolinguistic groups Gourmantché, Kounteni, Boo, Monkole, Gando and Bariba (Figure 4b). In addition, this use for fuelwood decreases with the educational level (Figure 4c) and is more pronounced in the phytogeographical districts of Borgou-Nord, Atacora and Borgou-Sud covering together about 63% of the national territory (Figure 4d).

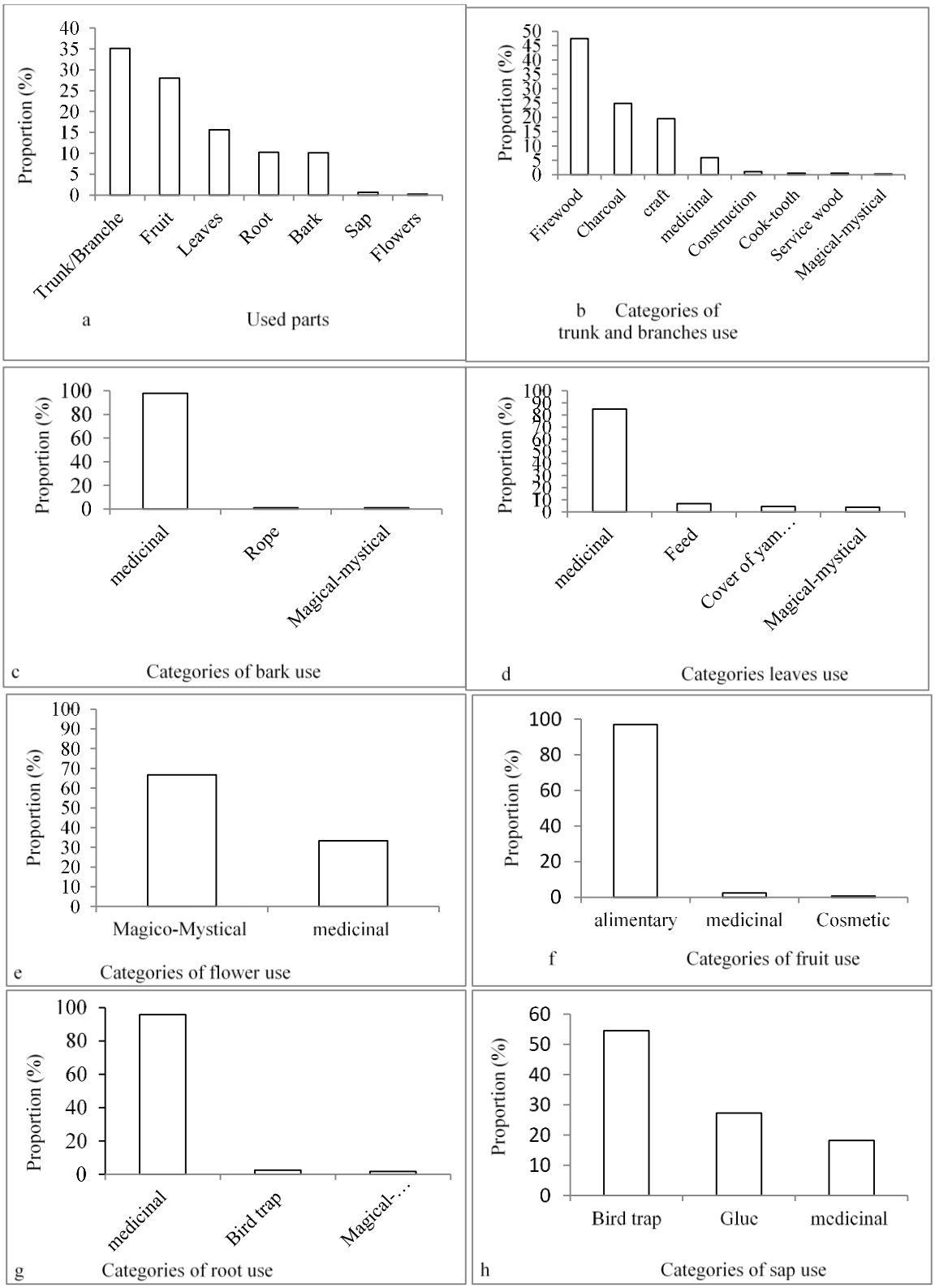
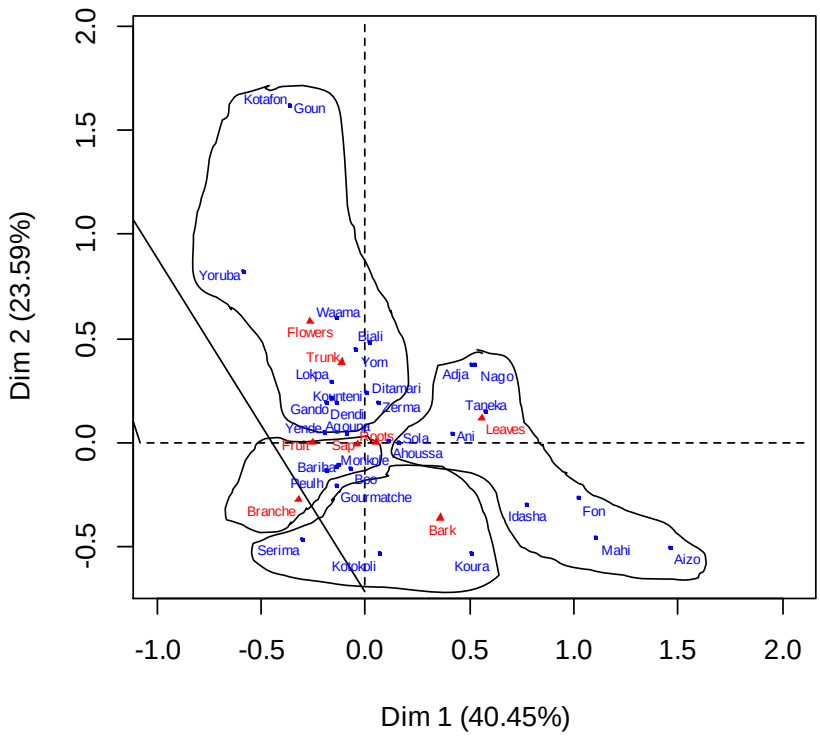


Figure 2 : Response rates and use categories of *D. microcarpum.*



Note: Dim = Dimension (Component)

Figure 3: Factorial map linking sociolinguistic groups to the use of parts / organs of *D. microcarpum.*

Table 2: Relationship between factorial axes, use of organs / parts of *D. microcar*pum and sociolinguistic groups.

Parts/organes	Component1	Component2	Groups sociolinguistic	Component1	Component2	Groups sociolinguistic	Component1	Component2
Branche	-0.3216	-0.2688	Adja	0.5092	0.3768	Kotokoli	0.0738	-0.5328
Flowers	-0.2674	0.5826	Agouna	-0.0909	0.0426	Kounteni	-0.1352	0.1930
Bark	0.3587	-0.3588	Ahoussa	0.1087	0.0046	Koura	0.5140	-0.5320
Leaves	0.5577	0.1185	Aizo	1.4613	-0.5017	Lokpa	-0.1653	0.2930
Trunk	-0.1131	0.38760	Ani	0.4184	0.0434	Mahi	1.1094	-0.4599
Roots	0.0500	-0.0005	Bariba	-0.1269	-0.1056	Monkole	-0.1328	-0.1164
Sap	-0.0383	-0.0061	Biali	0.0177	0.4825	Nago	0.5267	0.3711
Fruit	-0.2555	0.0039	Boo	-0.0731	-0.1221	Peulh	-0.1876	-0.1327
			Dendi	-0.1874	0.1941	Serima	-0.3055	-0.4616
			Ditamari	0.0055	0.2365	Sola	0.15944	-0.0022

Fon	1.0225	-0.2649	Taneka	0.5756	0.1528
Gando	-0.1588	0.2178	Waaba	-0.1342	0.5973
Goun	-0.3609	1.6185	Yende	-0.1956	0.0465
Gourmatche	-0.1378	-0.2034	Yom	-0.0425	0.4448
Idasha	0.7716	-0.2953	Yoruba	-0.5878	0.8176
Kotafon	-0.3609	1.6185	Zerma	0.0600	0.1879

Table 3: Factors determining the use of *D. microcarpum* as wood energy.

Variables	Df	Deviance	Resid.Df	Resid.Dev	Pr(>Chi)
Phytogeographic district	8	193.447	852	989.20	<2.2e-16***
Gender	1	13.108	851	976.09	0.0002941***
Sociolinguistic group	32	124.059	819	852.03	8.931e-13***
Educational level	4	13.257	815	838.78	0.0100868*

Note: Df= Degree of freedom, Pr= Probability, Resid.Df= Residual degree of freedom, Resid.Dev= Residual Deviance, *** : p< 0.001, * : p< 0.05.

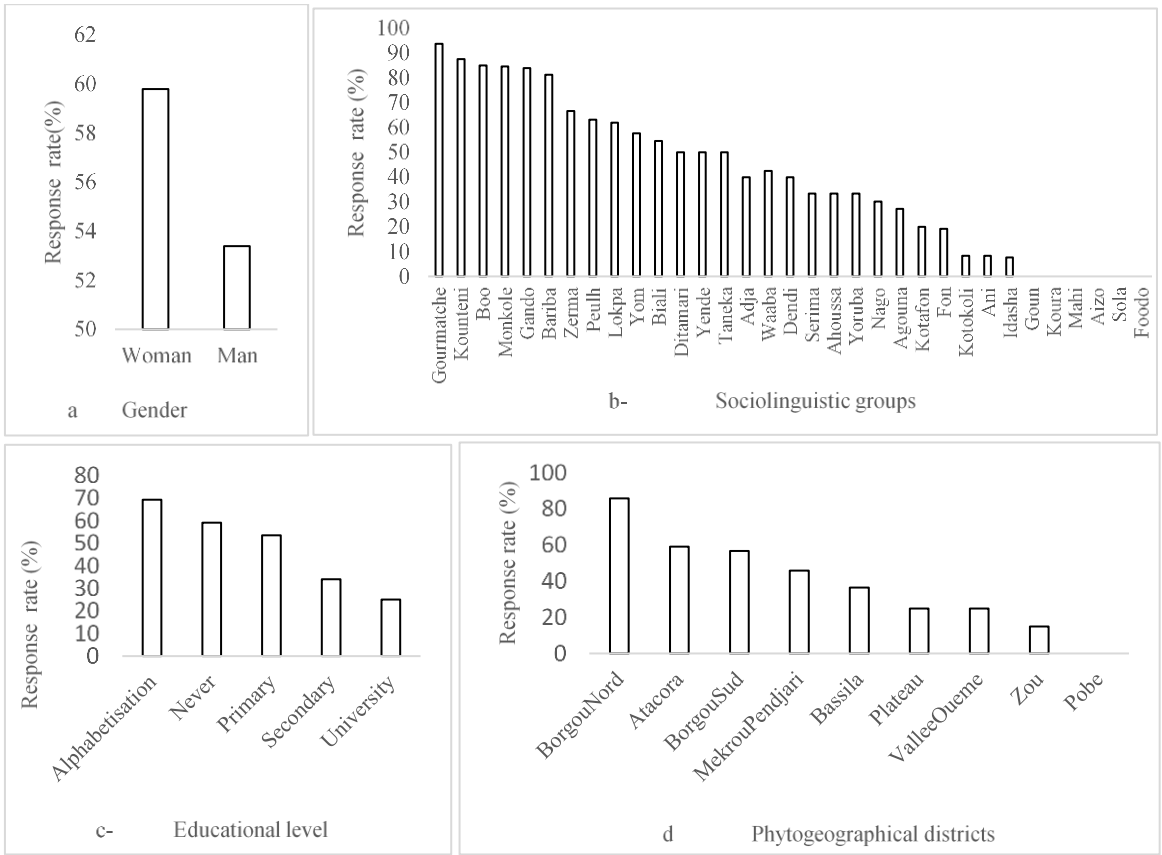


Figure 4: Links between *D. microcarpum* use as fuelwood and the gender (a), sociolinguistic group (b), educational level (c) and phytogeographical district (d).

DISCUSSION

The present study focused on the ethnobotany of *D. microcarpum* to examine possibilities of its promotion as fuelwood. It is a multipurpose species widely used in the study area in the energy, medicinal, food and cultural fields. Ethnobotanical knowledge is indeed considered in the management of forest resources because it offers opportunities for understanding ecological processes in relation to the knowledge of local populations (Dicko et al., 2017). The conservation of a resource in an environment is strongly determined by the interaction between the resource and the activities carried out by the local populations. The most important parts of the plant used by local population are the trunk and branches, fruits, leaves, roots and bark. The majority of respondents mentioned that the wood (trunk and branch) of *D. microcarpum* is heavily used as firewood. Similar results were obtained by Kouyaté (2005) in Mali, Kristensen and Balslev (2003) in Burkina and Agbo et al. (2017) in southern Benin. *D. microcarpum* is used for fuelwood due to flame intensity and the small amount of smoke emitted (Tondoh & Degrande, 2015). In the present study, *D. microcarpum* is more commonly used as fuelwood by women. Women prefer firewood to those of *Terminalia* spp., *Pterocarpus erinaceus* and *Isoberlinia doka*, because it catches fire quickly, even when it is wet (Kouyate, 2005) and is easy to split or to machine (Kaboré, 2001). *D. microcarpum* is more exploited for the supply of firewood and is an important source of income for the populations (Kouyaté, 2005). Unlike the fruits, the fuelwood trade of *D. microcarpum* is well known in the south of Mali and the fuelwood stere in rural areas was sold between FCFA 1000 and FCFA 3000 in 2005, depending on the middle and the season of the year (Kouyaté, 2005). The preference of *D. microcarpum* by women for home energy is confirmed in other studies (Dao et Lamien, 2020).

These results are not correlated with those of Dieng et al. (2016) in Senegal where *D. microcarpum* was not among the preferred species for firewood species because, according to the groups interviewed, the species is not a hard-wooded tree and other species that are more suitable for this purpose were available. To some communities as M'Bèlimè, the use of *D. microcarpum* trunk as firewood is defended. This taboo reported in many sociocul-tural areas in Mali could be understood as a conservator measure (Kouyaté, 2005). This conservatory taboo is also recorded for *Faidherbia albida* and *Vitex doniana*, in north Cameroun, believed to drive you crazy if burned and their smoke believed cause leprosy, conflicts and inevitably dissolution of the family (Seignobos, 2019), is not noticed for *D. microcarpum* in Benin by the present study. This preference and consumption of its firewood militate in favor of the domestication of *D. microcarpum* to produce fuelwood.

Determinants of the use of *D. microcarpum* as fuelwood in the study area are gender, educational level, sociolinguistic group, and phytogeographic district. The hypothesis following knowledge dynamics of gender and educational level (Gaoue et al., 2017) suggests that various individual sociocultural and demographic characteristics such as gender, ethnicity and literacy levels are correlated with the level of knowledge and use of plants by an individual (McCarter & Gavin, 2015). Thus, women tend to know more about the local medicinal flora, while a high literacy rate and better access to health and formal education is often negatively correlated with knowledge of medicinal plants (Voeks & Leony, 2004). These same observations are made for *D. microcarpum* in the context of the use of its wood for domestic energy by the local populations.

According to Gaoue and Ticktin (2007), socio-demographic characteristics are not always the only factors influencing endogenous knowledge. The present study

revealed that *D. microcarpum* is more widely used in northern Benin, particularly in the phytogeographical districts of Borgou-Nord, Atacora and Borgou-Sud. For Gaoue et al. (2017), the proximity of the resource can also influence its use. Our observations in the field confirm that *D. microcarpum* is more common in northern Benin. Further studies on the ecology of this species and its spatial distribution are needed to discuss a possible correlation between the local abundance (availability) of the species and its use for energy purposes by rural communities in the phytogeographical districts of Borgou-Nord, Atacora-Chain and Borgou-Sud. Indeed, the availability hypothesis (Gaoue et al., 2017) suggests that plants are more used when they are more accessible to local populations or are more abundant locally (Albuquerque, 2006).

For other studies, wood physical characteristics are also factors of species use as firewood. A direct relationship was observed between the physical properties of the fuelwoods and their locally perceived qualities (Ramos et al., 2008). These locally perceived qualities are relative in general to ashes production, moisture fractions, flame intensity, burn time, spark or smoke production (Ramos et al., 2008; Froumsia et al., 2016).

The ethnobotanical survey conducted in this study showed endogenous knowledge regarding the importance and use of *D. microcarpum* parts or organs and allows to classify it in the multiuse species for rural populations in Benin since all its parts are used. Apart from the high exploitation of *D. microcarpum* wood as fuelwood, its fruit is also highly consumed by local people. A fair compromise should therefore be found between the use of *D. microcarpum* as fuelwood and its exploitation as a fruit tree. Thus, data on the minimum diameter of fruiting and the diameters used for wood energy are necessary. Commercialization of the products (wood, fruits) of *D. microcarpum* can be a promising pathway and a substantial source of income for local populations, which further justifies its domestication. Given the energetic qualities of *D. microcarpum* and its preference by consumers as domestic energy source (Kouyaté, 2005; Agbo et al., 2017), the marketing of its wood could contribute effectively to compensate for a large part of the domestic energy needs of both rural and urban populations in Benin. Therefore, it's necessary to evaluate the local abundance and structure of species, its management mode for sustainable wood fire exploitation.

Conclusion

The present study identified factors influencing uses of *D. microcarpum* as fuelwood and established the links between uses of the species and the sociolinguistic groups. The sociodemographic and ecological parameters that significantly influence the use of *D. microcarpum* as fuelwood are the phytogeographic district, the gender, the sociolinguistic group and the educational level of the respondents. The species trunk and branches are the most used parts, primarily for energy purposes (firewood and charcoal). It is therefore opportune to study the possibilities of promoting the species as fuelwood in Benin to alleviate energy problems. For a better management of this important wood-energy species for the local populations, certain elements will still have to be specified such as the disponibility and the structural characteristics of the species populations in Benin, the determination of the calorific value of *D. microcarpum* wood, its forestry to favor its multiplication and its ecological preferences for its better growth after planting.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

TAS designed the study, analyzed and interpreted the data, and wrote the original

draft. AD participated in the study design, provided guidance during data collection, and edited the manuscripts. HSSB participated in the study design and was a major contributor in the writing of the manuscript. EA and AKN contributed in the study design. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

We thank local communities surveyed throughout Benin for agreeing to share their endogenous knowledge on *Detarium microcarpum.*

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