

Characterization of Ecosystem Services Provided by *Detarium microcarpum* around the Protected Forest of Patako (Senegal)

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ABSTRACT

Woody species provide several ecosystem services to rural people. This is also the case for *Detarium microcarpum*, a characteristic leguminous tree of African savannas belonging to the Fabaceae family. This study aimed at identifying and characterizing its ecosystem services in the Protected Forest of Patako and surrounding areas. Twelve focus groups were organized in four villages, three in each, composed of men, women and young men. Resource persons were also interviewed individually. Results showed that *Detarium microcarpum* provided 11 ecosystem services that belong to the three categories: provisioning, regulating, and cultural services. The total use value of these ecosystem services was 3.92. Bark, branches and fruits were the most used parts with plant part values of 0.25, 0.17 and 0.17, respectively. Specific uses concerned essentially food, firewood and medicinal products. In traditional medicine, intraspecific use of bark and roots for the treatment of dermatosis was found to be above 0.6. These findings highlight the importance of native species in rural people's lives and the necessity to better manage stand populations of *Detarium microcarpum* in the Protected Forest of Patako particularly, and in all protected forests in general.

KEYS WORDS: ecosystem services, *Detarium microcarpum*, Protected Forest of Patako, Senegal.

INTRODUCTION

Vegetation provides various ecosystem services for human communities [1, 2, 3]. It not only provides people with food, shelter and medicine, but also generates wealth and blossoms out spiritually.

Ecosystem services can be explained as benefits that people obtain from ecosystems [2]. These benefits are provided by a large range of ecosystems or by components of these ecosystems. Ecosystem services are generally analysed at community level [4, 5, 6], but can also be investigated for one or a set of species [7, 8, 9]. Depending on the scale, these studies showed the interactions that happened between components of ecosystems on one hand, and the impact on human communities on the other. Ecosystem services are particularly important for the poorest rural people, who depend on them in their daily lives [10]. Therefore, in order to better manage natural ecosystems and their related services, it is necessary to understand how these benefits are used or enjoyed. This is very important, since some of these uses have endangered the sustainability of ecosystems, and most ecosystem services cannot be replaced by technology once they have disappeared [1].

Taking the case of *Detarium microcarpum*, this study aimed to better understand the importance of native species in the provision of ecosystem services in order to identify threats that compromised the sustainability of these benefits and help decision-makers in the development of management plans. The objective of this study was to identify and characterize the ecosystem services provided by *Detarium microcarpum*. The specific objectives were: 1) to identify ecosystem services provided by *Detarium microcarpum*, 2) to determine the use value linked to these ecosystem services; and 3) to determine the importance of different *Detarium microcarpum* parts.

MATERIALS AND METHODS

Material

Detarium microcarpum is a tree with a straight bole belonging to the Fabaceae family [11]. Its height can reach 8-10 meters (Photo 1). Its bark is smooth, light gray to black and its fleshy fruits are ovoid, more or less flattened, and contain a mealy greenish pulp [12]. The species is found irregularly in Guinean and Sudanian savannas, dry forests, and fallows, and its range extends from the Senegal-Cameroon axis to Sudan [12]. In the area covered by this study, the species is mainly confined in the woodlands. Its stand population is stable and

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marked by an abundant natural regeneration in the Protected Forest of Patako [13]. However, field observations and interviews revealed that the population of *Detarium microcarpum* is actually under pressure because of medicinal use of the tree species. In surrounding areas of the Protected Forest of Patako, the species is poorly represented [14].

Study site

This study was conducted in the Protected Forest of Patako, which is located between 13°37' and 13°44'N and 16°08' and 16°20'W, and in the surrounding zone. The forest is located in the Sudanian zone in western Senegal (Figure 1). The climate of the study area is characterized by an alternation of dry season from November to June and a rainy season from July to October, and the mean annual rainfall is estimated between 700 and 800 mm [15]. The vegetation inside the forest is composed of shrubby savanna, woodland, gallery forest and mangrove [13, 15]. In areas surrounding the forest, the agrarian landscape is characterized by the presence of few trees that local communities have spared from cutting when clearing to install new farms [16, 17].

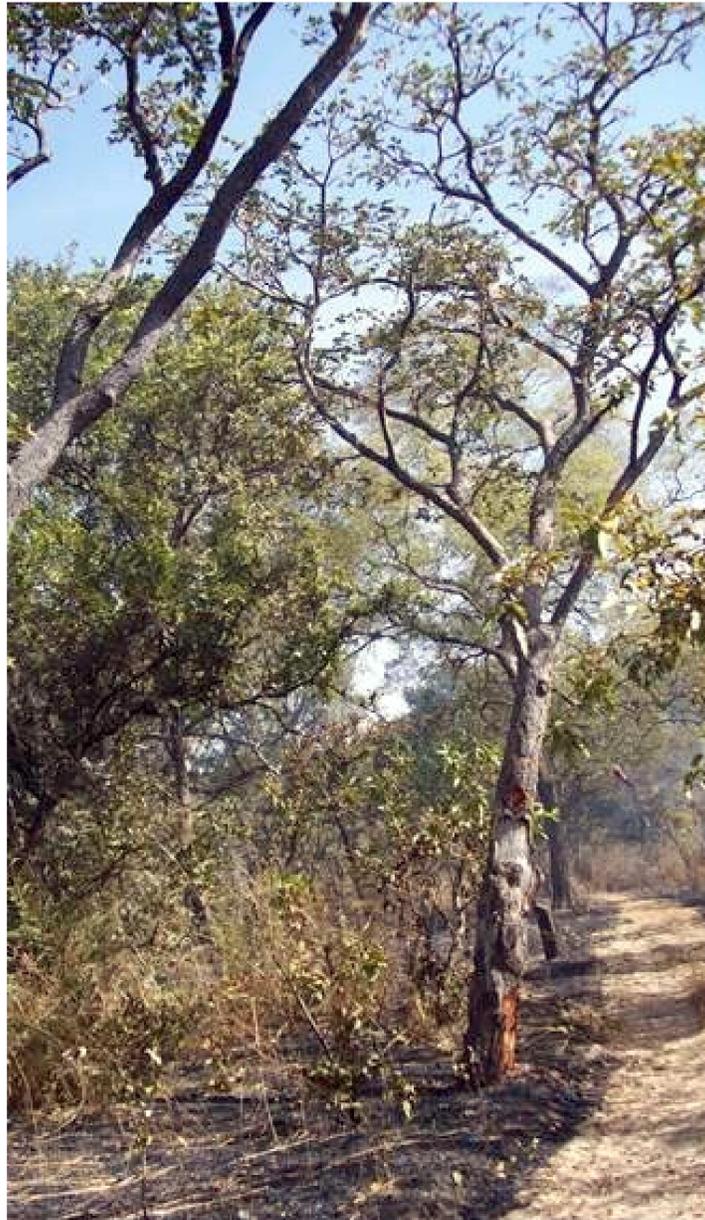


Photo 1: *Detarium microcarpum* inside the Protected Forest of Patako

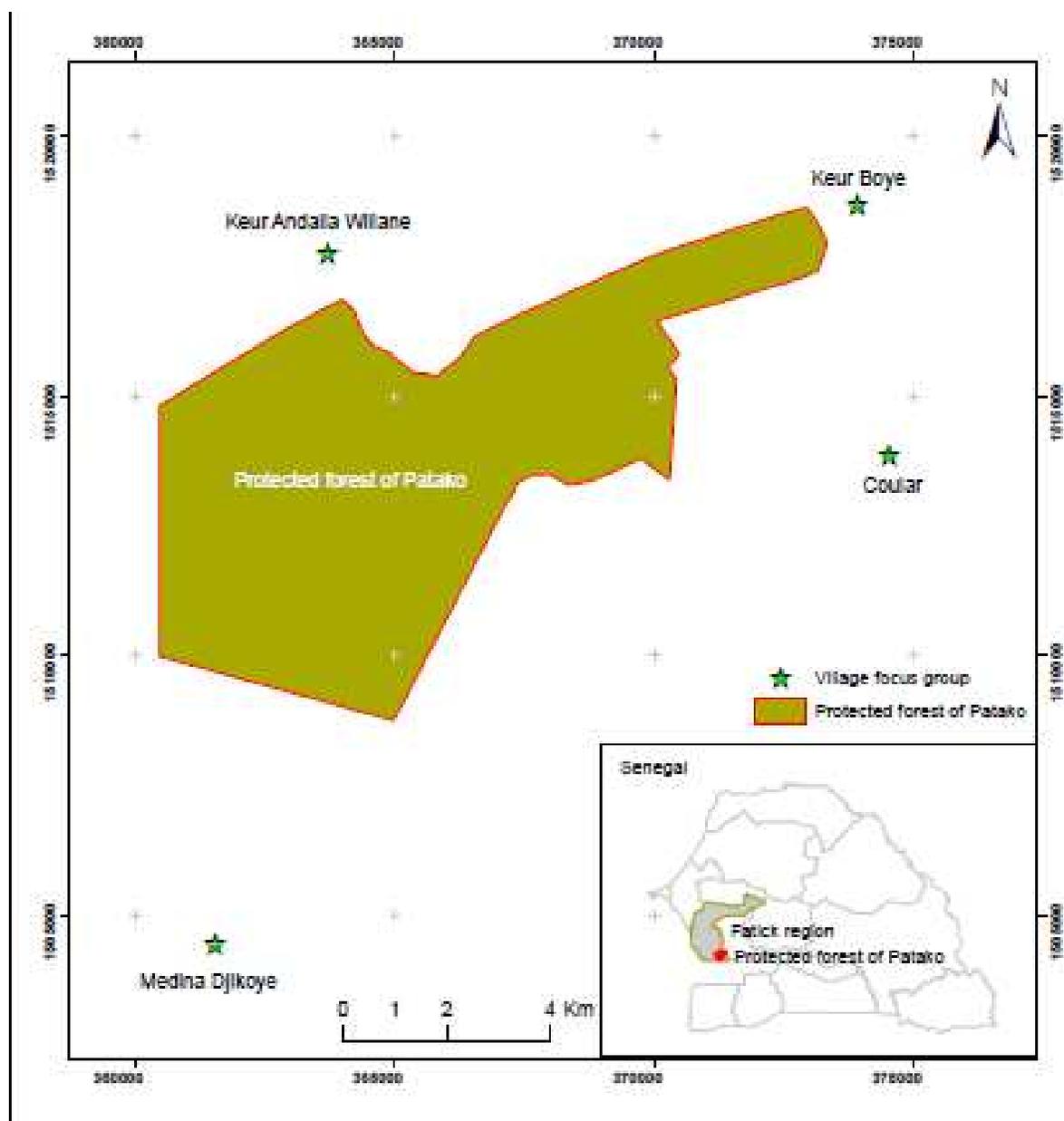


Figure 1: Location of study site

The population is mainly constituted by four ethnic groups: Wolof (over 60%), Mandinka (18%), Serer (12%) and Fulani (5%) [18]. The economy of the area is based on agriculture and livestock. Like the majority of the Senegalese population, residents of the study area are poor with a poverty rate of 68% in 2010 [19].

Data collection and analysis

Ethnobotanical data was collected between January and November, 2012, in a radius of five kilometers around the Protected Forest of Patako. Focus groups were interviewed in four villages. In each village, three focus groups were organized separately with women, men and young men. The groups interviewed were composed of four to eight persons, with a total of seventy-five respondents. Questions addressed all uses and usefulness of all *Detarium microcarpum* parts, place of supply, and factors that positively or negatively influenced the dynamics of the stand population. For each plant part, participants in focus groups first gave information on questions asked, after which they were also asked to build use matrix. For that purpose 50 small stones were given to them to be shared in the boxes corresponding to each part of the plant. The number of stones allocated to each part was based on the importance of its uses. For each type of use or usefulness and for each focus group, a score of 0 was assigned if no mention was made, and a score of 1 if mentioned. Based on this information, ecosystem

services provided by the species were identified and classified based on the Millennium Ecosystem Assessment (MEA) [2] categories: provisioning, regulating and cultural services. Ethnobotanical use value (UV) of *Detarium microcarpum* was calculated for each category of ecosystem services; then its total use value (UV_t) was determined according to the formulas adapted from Albuquerque *et al.* [20] and Dossou *et al.* [21].

$$UV = \frac{\sum U_i}{n} \text{ and } UV_t = \sum UV$$

where UV=Use value; U_i=number of citations for each ecosystem service type mentioned by each focus group and n=total number of focus-groups. UV_t is the total of UVs for all ecosystem service provided by *Detarium microcarpum*.

The scores were also used to calculate the Reported Use (RU), the plant part value (PPV) and the intraspecific use value (IUV) developed by Gomez-Beloz [22] and used in different contexts by Avocèvo *et al.* [23], Atakpama *et al.* [24] and Kébenzikato *et al.* [25]. The RU is the total number of uses reported for a plant. Its value is obtained by the sum of use citations for each plant part [RU=ΣRU_(plant parts)]. The PPV is the ratio between the number of reported uses for each plant part and total number of reported uses for that plant [PPV=RU_(plant part)/RU]. The specific use (SU) refers to the number of times a specific use is mentioned by focus groups for a given plant part. The IUV gives an idea of the importance of use within a specific plant part. It is obtained by the following formula: IUV=SU_(plant part)/RU_(plant part).

Based on the number of stones put in each box of the matrix, a Principal Component Analysis (PCA) was used to investigate the relationship between the use of plant parts and the categories of respondents.

Individual interviews were also conducted with 13 resource persons to better document the medicinal uses of the species that play an important role in people's health. Besides, field observations inside the Protected Forest of Patako allowed us to have an idea about the status of the stand population of *Detarium microcarpum* and the pressures exerted on the species.

RESULTS

Ecosystem services provided by Detarium microcarpum and use value

Eleven types of ecosystem services were identified by people living around the Protected Forest of Patako. Information from focus groups showed that the majority of ecosystem services provided by *Detarium microcarpum* belonged to the category of provisioning services, which are mainly represented by food, medicinal products, and firewood (Table 1). In this category, these three types of goods accounted for 81% of citations from the focus groups. The UV for provisioning services was 3.58. Concerning regulating services (the contribution of *Detarium microcarpum* in promoting rainfall), the UV was 0.17. Cultural services (mystical practices) obtained a UV of 0.17. The UV of all ecosystem services provided by the tree was estimated at 3.92.

Table 1: Ecosystem services provided by *Detarium microcarpum* and related percentage of citations

Category	Ecosystem services types	Number of citation	Percentage
Provisioning services	Food	12	25.53
	Medicinal products	11	23.40
	Firewood	12	25.53
	Timber	2	4.26
	Exudate	2	4.26
	Fodder	1	2.13
	Seeds	2	4.26
	Coating	1	2.13
Regulating services	Contribution to rainfall	2	4.26
Cultural services	Talisman and mystical practices	1	2.13
	Prediction	1	2.13

Importance of *Detarium microcarpum* parts uses for local population

Data analysis showed that *Detarium microcarpum* had a total RU of 71 and that bark, fruits and branches were the most used parts. RU and PPV were highest for these three plant parts, followed by roots (Table 2).

Bark and roots were specifically used for medicinal purposes to treat dermatosis (IUV=0.61 and 0.67, respectively) and other illnesses, such as intestinal worms (IUV=0.11), fall in virility (IUV=0.11) and rheumatoid arthritis (IUV=0.06). This form of use was confirmed by resource persons and people interviewed, who several times indicated that *Detarium microcarpum* was the original plant for treating dermatosis. Leaves were also used for this purpose. Other medicinal applications of *Detarium microcarpum* parts were cited by key persons, who indicated their use for the treatment of hemorrhoids, wounds, long term illness, mental disorder, burns, prostate problems, paralysis and the prevention of epidemics. Interviews and field observations in the

forest also showed that medicinal uses of the species resulted in its uncontrolled exploitation, evident in excessive debarking and digging for roots that compromise the sustainability of the stand population. Bark, roots and seeds are also used for protection and mystical purpose.

Results also revealed that fruits of *Detarium microcarpum* were almost specifically used for household consumption and rarely for sale on commercial markets (IUV=1). They are consumed fresh in the forest. People also buy dried fruits in local markets, but they generally come from other locations of Senegal or Mali.

Branches and trunks were mostly used for firewood (IUV_{branches}=0.92 and IUV_{trunk}=1) and house construction, but according to the respondents, these types of use were exceptional, because people believe that this wood has poor fire properties and is easily eaten by termites.

Exudates were used in crafts for painting water jugs and as glue for axes for woodcutters.

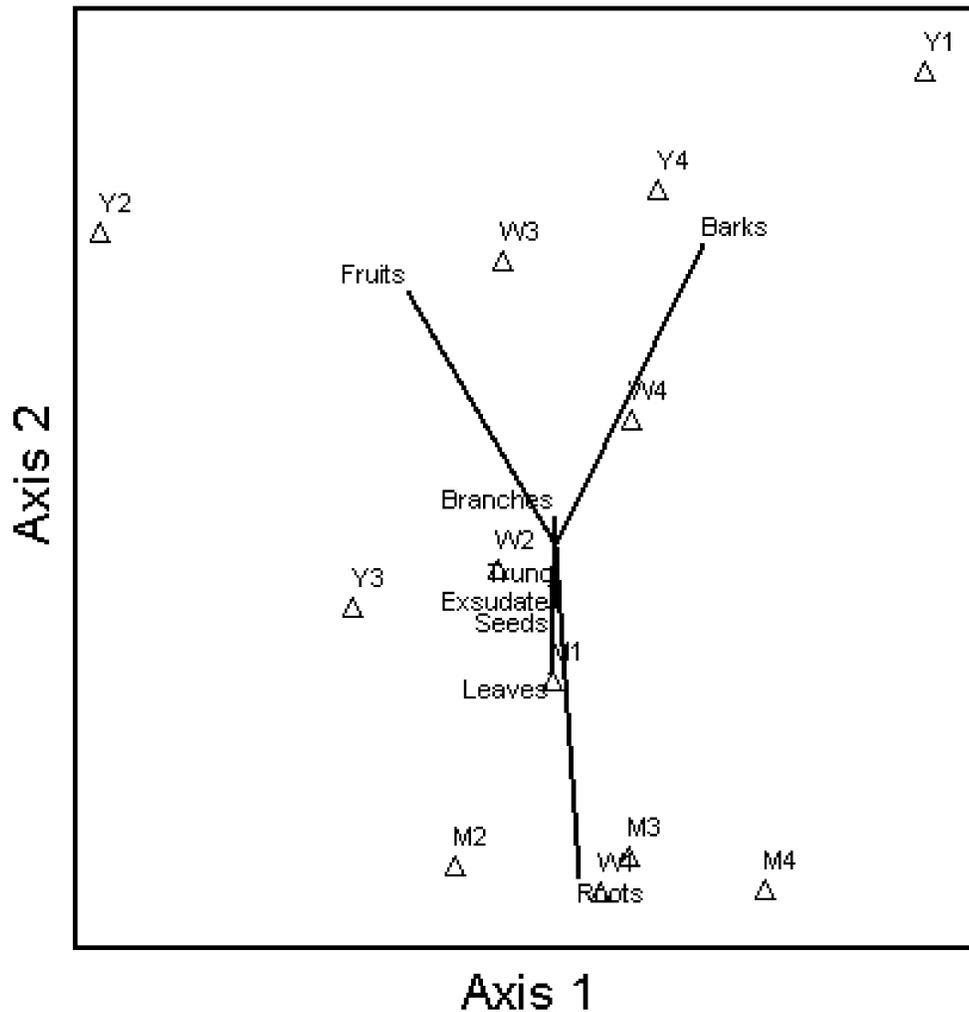
Data showed that plant parts of *Detarium microcarpum* were mostly taken from the Protected Forest of Patako and rarely from surrounding areas around the forest or bought at the weekly markets.

Table 2: Importance plant use indices of *Detarium microcarpum*.

Parts	RU (plant part)	PPV	Specific reported use	SU	IUV
Bark	18	0.25	Dermatoses	11	0.61
			Stomach pain	1	0.06
			Chest pain	1	0.06
			Intestinal worms	2	0.11
			Joints paints	1	0.06
			Mystical protection and practices	1	0.06
			Divination	1	0.06
Roots	9	0.13	Dermatoses	6	0.67
			Stomach pain	1	0.11
			Mystical protection and practices	1	0.11
			Enhancement of virility	1	0.11
Leaves	7	0.10	Dermatoses	2	0.29
			Stomach pain	1	0.14
			Baby care	2	0.29
			Fever	1	0.14
			Fodder	1	0.14
Fruits	12	0.17	Food	12	1.00
Exudates	3	0.04	Craft (glue, coat)	1	0.33
			Caries	1	0.33
			Incense	1	0.33
Seeds	3	0.04	Seeds	2	0.67
			Mystical protection and practices	1	0.33
Branches	12	0.17	Firewood	11	0.92
			Timber	1	0.08
Trunk	7	0.10	Firewood	7	1

RU: Reported Use; PPV: Plant Part Value; SU: Specific reported Use; IUV: Intraspecific Use Value

The PCA indicated that the use of fruits and bark differed from that of roots, leaves, trunks and seeds (Figure 2). Young men and women were likely to use more fruits and bark, while men preferred the roots because of their use to cure typical male problems, such as fall in virility and prostate disorders.



Y: young men; W: women; M: men

Figure 2. Ordination showing parts of *Detarium microcarpum* used by informants of different gender and age groups.

DISCUSSION

The results of this study showed that *Detarium microcarpum* provides several ecosystem services that mainly belong to the provisioning category. The number of ecosystem services reported for this species (11) was less than those provided by *Cordyla pinnata* (20 ecosystem services) in the area covered by this study [26]. The dominance of ecosystem services belonging to the provisioning category can be explained by the location of the species in the Protected Forest of Patako and its low presence in surrounding areas, which prevents the local population from perceiving or enjoying regulating services such as shade. Thus, apart from the intrinsic value of each species and its contribution in promoting rainfall [27], an option value was also placed on *Detarium microcarpum*, which means that future utility may be different from that recognized presently. The UV of provisioning services provided by *Detarium microcarpum* in this study (UV=3.58) was higher than the one found in the Sahelo-Sudanian zone of Senegal, where its UV was 0.05 [8], which must be attributed to a lower

abundance of the tree species in the Sahelo-Sudanian zone, where the species was only appreciated for traditional medicine.

This study also revealed that the main parts of the plant used were fruits, bark, roots and branches, which had the highest ethnobotanical values. Respectively, they were essentially used for human consumption, traditional medicine and firewood.

Indeed, *Detarium microcarpum* is one of species in which fruits are most used in African savannas [28, 29]. In this study, fruits were found to be directly consumed by local people, while Kouyate *et al.* [30] showed that *Detarium microcarpum* fruits were also transformed into cake, couscous or alcoholic beverages in Mali, where the species is more abundant.

Bark and roots were mainly used in traditional medicine, specifically against dermatosis. The RU value of the bark was found to be superior to that of *Mauritia flexuosa* [22], but inferior to that of *Sterculia setigera* and *Adansonia digitata* [24, 25]. As regards roots, similar RU to ours was found for *Sterculia setigera* and *Adansonia digitata* [24, 25]. In the case of *Pentadesma butyracea*, barks and roots were also among the parts that had highest values (PPV and IUUV) and they were also used for pharmacopeia [23]. For other tree species, e.g. *Adansonia digitata*, in addition to its use in traditional medicine, bark served in rope making ($0.14 \leq \text{IUUV} \leq 0.62$) and was also involved in craft [25]. The strong evidence of usage of *Detarium microcarpum* bark and roots in traditional medicine, as found in our study, suggests a great threat to the sustainability of the tree species. Indeed, according to Peters [32], bark and roots are vital parts of the tree, and their exploitation weakens the tree and may even lead to its death. For instance, the strong pressure on the roots of *Caesalpinia bonduc* in Benin is the main threat to the survival of the species [33].

In our study, 17 medicinal applications were cited. This is more than those found by Atakpama *et al.* [23] for *Sterculia setigera* in Togo (14 medicinal applications). Some of the illnesses cited in this study have already been identified in the same area, Mali and eastern Senegal [16, 31, 34]. The species had other therapeutic indications in Mali, where it is used to treat malaria and meningitis [31].

The results also showed that the IUUVs of branches and trunk for firewood are high. This value is superior to those reported for the wood of *Sterculia setigera* [24] in Togo for the same purpose. However, despite this high value, *Detarium microcarpum* was not among preferred species for firewood in the area covered by this study [17]. The use of *Detarium microcarpum* for lumber was also found to be limited because, according to the groups interviewed, the species is not a hard-wooded tree and it is easily attacked by termites. Such low use can be explained by the abundance of woody resources in the Protected Forest of Patako [13] and the availability of other species that are more suitable for this purpose.

Leaves were cited to be used for traditional medicine as was the case in Mali, where they were the most used part of *Detarium microcarpum* in traditional medicine [31]. Several other therapeutic specific uses in addition to digestive system disorders treatment were also identified for the leaves of *Pentadesma butyracea* in Benin [23]. But *Detarium microcarpum* plant parts were not identified for use in human consumption as opposed to *Adansonia digitata*, where leaves were eaten in sauce with IUUV of 0.47 to 1 [25]. Foliage of the *Detarium microcarpum* was also found to be used for small livestock feeding during the dry season when the herbaceous layer disappears. Otherwise, this kind of fodder was not common in the area because other tree species, e.g. *Bombax costatum*, *Adansonia digitata*, *Ficus sycomorus* and other more palatable species, are available inside the forest [16].

The results of this study revealed that the extent of utilization of parts of *Detarium microcarpum* was different between men and women. The preference of women and young men for fruits and bark was due, on one hand, to the availability of the fruit that was harvested during outings for wood collection, hunting or pastoralism and, on the other hand, by the accessibility of bark that is used to treat dermatosis, a problem that generally affects all segments of the population. The fact that men used more roots can be explained by the mystical characteristics attributed to the roots and by the types of ailments for which they are used. Even if most respondents involved in focus groups avoided talking about it, interviews with resource persons showed that roots were used to treat prostate disorders and to enhance virility. The roots of many tree species are generally used to treat or prevent prostate problems [35, 36]. The women group who cited use of roots was composed of women whose husbands were traditional healers, and from them they obtained knowledge about these uses.

Conclusion

This study showed that *Detarium microcarpum* provides several ecosystem services and that most of them belong in the provisioning category, which has high use value. The species is particularly useful for food, firewood and traditional medicine. Results also demonstrated that fruits, bark, roots and branches are the most used parts and that the highest intraspecific use values were found for the use of bark to treat dermatosis, consumption of fruits and the use of branches and trunk for firewood. Fruits are mainly consumed fresh or dried, whereas bark, roots and leaves generally are employed in traditional medicine or in mystical practices.

Due to this great importance in the provision of ecosystem services and the type of plant parts that are more used, it had been noted that *Detarium microcarpum* was facing strong pressure in the Protected Forest of Patako.

In order to guarantee the sustainability of the species and relative ecosystem services, competent authorities should manage the forest better, for example by the establishing good practices in medicinal products extraction.

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