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Management methods of agroforestry parks and local perception of their ecosystem services in the Sudano-Sahelian zone of Burkina Faso

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ABSTRACT

Objectives: Agroforestry parks, which are characteristic of agrarian systems in Burkina Faso, are currently experiencing degradation, affecting the social life of rural populations. For the sustainability of production, a better understanding and analysis of the management of these parks and their provided services is necessary.

Methodology and Results: Parks management methods in the Saria and Yilou zones, agroforestry species and their ecosystem services were identified through a semi-structured interviews and direct observations among 152 farmers. Assisted natural regeneration (96% and 97%), organic fertilisation (93% and 96%) at Yilou and Saria respectively, pruning (84%) at Saria and mulching (94%), livestock parking (91%), planting (87%), zaï (100%) and ridging (98%) at Yilou are the main management methods of the parks. Woody plants are mainly kept in the parks because of their ability to maintain soil fertility (100%) and to provide food (100% and 98%) and medicinal products (96% and 95%) at Saria and Yilou respectively.

Conclusions and application of findings: These results indicate that agroforestry parks are real areas for soil rehabilitation and the supply of wood and non-wood forest products. It is therefore necessary to focus on good management techniques such as planting, protection of regeneration, use of organic fertiliser and animal parking for the restoration and maintenance of agroforestry parks ecosystem services.

Keywords: Assisted natural regeneration; farmlands management, conservation of woody plants; soil rehabilitation; West Africa.

INTRODUCTION

In the agrarian systems of West African arid and semi-arid zones, trees and shrubs are deliberately maintained in association with crops for multiple uses. The woody species in these systems, qualified as 'agroforestry parks', provide to populations ecosystem services such as the production of food and medicinal goods, fodder and wood (Ngom *et al.*, 2014; Cissé *et al.*, 2018). Agroforestry parks also play a fundamental role in maintaining the balance of ecosystems. Many studies have highlighted the importance of woody species in maintaining or improving soil fertility, increasing crop production and mitigating the effects of climate change (Chirwa, 2003; Nair *et al.*, 2009). Traditionally, Burkinabe farmers, like those in the Sahel, manage trees and shrubs in the field to ensure that they are preserved on the one hand, and that they continue to play their full role in the provision of ecosystem services on the other. Reforestation, maintenance of natural regeneration and sanitary cutting are the main management methods for agroforestry parks met in the field (Yaméogo *et al.*, 2013).

However, the perception of the preservation of trees and shrubs in the agrarian environment differs according to the users. This sociological and behavioural aspect is shared by populations living in different climatic conditions (Larwanou *et al.*, 2006). Moreover, as traditional structures are nowadays in a state of flux, it is indispensable to understand the dynamics of these evolutions in order to better understand how populations manage their crop ecosystems according to Chaumié (1985). The present study was conducted in seven village terroirs in the central-western and central-northern regions of Burkina Faso, taking into account the south-northern rainfall gradient. The difference in rainfall conditions automatically implies that there are points of divergence in the perception of the preservation, utility and management of woody species in agrarian systems. The main objective of the study was to analyse the main practices, the management mode and the local perception of agroforestry parks and their ecosystem services in the Sudano-Sahelian zone of Burkina Faso. Specifically, it aimed to identify agricultural and agroforestry practices in the Saria and Yilou zones, to characterise and compare the ecosystem services associated with agroforestry species in these two zones, and to determine the management constraints and socio-economic factors that influence the integration of woody species into farms.

MATERIALS AND METHODS

Study area: The study area comprises two sites, Yilou and Saria. At the Yilou site, the study was conducted in four villages (Barsa, Sindri, Vousnango and Yilou) located in the rural commune of Guibaré, in the province of Bam (**Figure 1**). The rural commune of Guibaré is located 70 km from Ouagadougou and 36 km from Kongoussi. The coordinates of the rural commune of Guibaré are 1°30'12" and 1°44'59" west longitude and 12°59'04" and 13°11'00" north latitude. The population of the said commune, according to the fifth general population and habitation census of 2019, was 37,431 inhabitants (INSD, 2022). The main income-generating activities practised by the population are agriculture, livestock, gold panning, trade and handicrafts. The rural commune of Guibaré has a sub-Sahelian climate with an annual rainfall of between 600 and 700 mm (Fontès & Guinko, 1995). There are two seasons: a dry season from October to May, with temperatures that can reach 40°C, and a rainy season. The rains are irregular and unevenly distributed in space and time within the same season and from one season to the next. The rural commune of Guibaré is characterised by soils that are poor in phosphorus, nitrogen and organic matter. It is

made up of granitic rocks and has a relatively uneven relief. This is the area where many ubiquitous Sudanian species interfere. The following highly ubiquitous Sudanian species are particularly abundant in this sector: *Acacia macrostachya* Rchb. ex DC., *Combretum micranthum* G.Don, *Combretum glutinosum* Perr. ex DC., *Combretum nigricans* Lepr. ex Guill. & Perr., *Guiera senegalensis* J. F. Gmel. The most regular tree species are *Vitellaria paradoxa* C.F.Gaertn., *Anogeissus leiocarpa* (DC.) Guill. & Perr., *Balanites aegyptiaca* (L.) Delile, *Lannea microcarpa* Engl. & K.Krause, *Faidherbia albida* (Delile) A.Chev., *Tamarindus indica* L., *Adansonia digitata* L. and *Sclerocarya birrea* (A.Rich.) Hochst. There are certain agricultural techniques, such as water and soil conservation, that allow for land valorisation. These techniques include zaï, half-moons and stone dams, among others. The main food crops grown are sorghum, millet, cowpea, maize and rice. Cash crops include groundnuts, sesame and Bambara groundnut. Livestock is the second most important economic activity in terms of income after crops. It is practised extensively and is characterised by small ruminants and poultry, which dominate in number. At the Saria site, the study was conducted in three villages (Nandiala, Nassoulou and Saria). These villages are located in three communes of the Boulkiemdé province: Nandiala, Kindi and Koudougou (**Figure 1**). These three communes lie between latitudes 12°04'18" and 12°34'23" North and longitudes 1°57'28" and 2°32'21" West. Saria's climate is North Sudanian, with a dry season from November to April and a rainy season from May to October. The average annual rainfall is about 800 mm with high inter-annual variability. The average annual temperature is 28°C, with extreme temperatures fluctuating between 12°C in December-January and 40°C in March-April. This site is subject to two types of wind: a humid wind called monsoon, which blows from May to October and a hot and dry wind called Harmattan, which occurs from December to April. The Saria site has a lateritic plateau morphology. The soils of Saria are characterised by phosphorus deficiency, low soil organic matter content and low cation exchange capacity. They rapidly asphyxiate in the event of continuous cultivation and the use of non-organic chemical fertilisers (Zougmoré *et al.*, 2004). Its vegetation is characterised by shrubby to woody savannahs and agrosystems (agroforestry parks and fallows) dominated by species such as *Guiera senegalensis* J. F. Gmel, *Combretum nigricans* Lepr. ex-Guill. et Perr., *Piliostigma reticulatum* (DC.) Hochst, *Vitellaria paradoxa* C.F.Gaertn., *Faidherbia albida* (Delile) A.Chev., *Lannea microcarpa* Engl. et K. Krause, *Tamarindus indica* L. and *Khaya senegalensis* (Desr.) A. Juss (Sanou *et al.*, 2022). The landscape is invaded by a heavy colony of *Azadirachta indica* A. Juss. (Neem) (Bationo *et al.*, 2004). The production systems encountered at the Saria site are: the agropastoral system and the park system, which is the most widespread. The main crops are sorghum, millet, maize, Bambara groundnut, groundnuts and cowpeas. According to the fifth general population and habitation census of 2019, the population of the three communes of the Saria site was 290025 (INSD, 2022). The main income-generating activities practiced by the population are agriculture, livestock, trade and handicrafts.

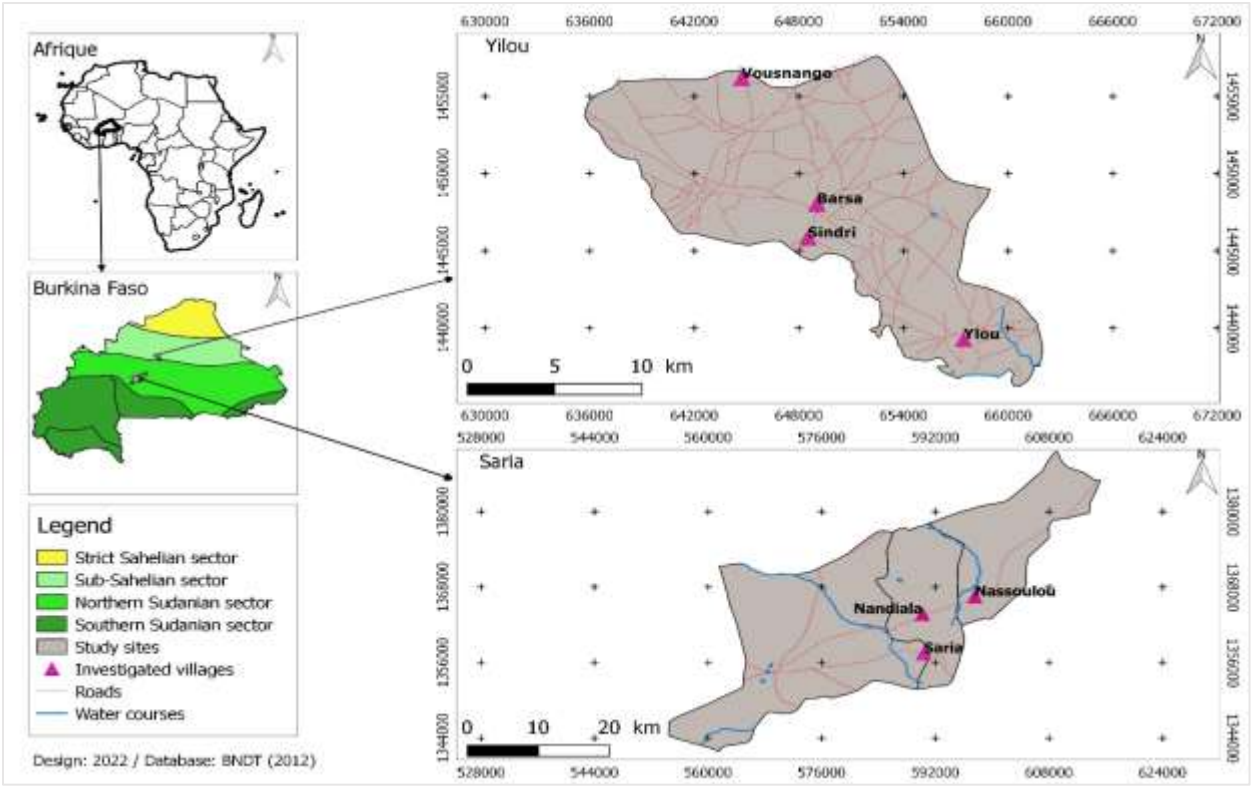

Figure 1: Location map of study area

Sampling and data collection: The simple random sampling technique, without distinction of gender, ethnicity or religion, made it possible to retain a number varying from 18 to 25 households or farms per village as the observation unit (Houéhanou *et al.*, 2016). Thus, the sample size was 82 people spread over the four villages at the Yilou site and 70 people spread over the three villages at the Saria site. The interviewees were the heads of the farms, who have a right of control over the management of trees in the fields. Individual interviews were conducted using a direct questionnaire with open-ended and semi-structured questions (Klotoé *et al.*, 2013). The questions focused on the management of woody plants in the fields. They concerned agricultural and agroforestry practices, the choice of woody species conserved in parks, woody management methods, the causes of woody conservation and the needs met by the latter and finally the constraints in the management of woody species in agrarian systems. The interviews were conducted in the national language "Moore" at the homes of the farmers or on the farms (Tyano *et al.*, 2020). In addition, direct observations were made in the fields of the respondents. Woody species were directly identified and their names in the local language were noted. The scientific names of species and families were updated according to the nomenclature adopted in the catalogue of vascular plants of Burkina Faso (Thiombiano *et al.*, 2012). The Order No. 2004-019 determining the list of forest species benefiting from special protection measures of the Ministry in charge of the Environment (MECV, 2004) was used to identify threatened species benefiting from special protection in Burkina Faso.

Data analysis: The data collected was entered and organised using Microsoft Excel spreadsheet. They were then analysed using R 4.2.1 software and the following indices were calculated:

- the percentage of services citation: in each category, it was calculated by multiplying the number of services mentioned by one hundred and then dividing by the total number of services listed in the category (Cissé *et al.*, 2018).
- the cultural index of importance (CI) was used to capture the variability of knowledge related to agroforestry species, according to the formula of Tardío & Pardo-de-Santayana (2008) adapted:

$$IC = \sum_{S=s1}^{S_{Nu}} \sum_{i=1}^{i=n} \frac{SRs_i}{N}$$

Nu is the total number of service categories; SR is the number of services reported; Si is the number of services mentioned by an informant i; N is the total number of informants.

The cultural index of importance, according to Tardío & Pardo-de-Santayana (2008), is appropriate for comparing between groups the perceptions related to agroforestry species, in a context of social mutations that affect the knowledge associated with plant resources.

Descriptive analyses according to farm classes were carried out using data on the socio-economic and environmental characteristics of farms. A matrix of environmental characteristics was therefore developed and subjected to multivariate analysis at the 5% threshold to determine the main factor determining the level of biodiversity and tree density on the farms. The characterisation of the biodiversity of agroforestry parks consisted in determining the diversity parameters of the woody component.

RESULTS

Socio-economic characteristics of farm managers: The heads of farms interviewed for this study are of Mossi ethnicity (100%), and the majority are agro-pastoralists (93.6% in Yilou and 64.3% in Saria). The women are only 12.2% and 14.3% respectively in Yilou and Saria. The majority of farm managers have not attended school (69.5% in Yilou and 61.4% in Saria). Of those who have attended school, only 12.9% have reached post-primary level in Saria. The age groups [45; 60] and [60; 75] account for 36.6% and 32.9% of respondents in Yilou and 31.4% and 30% of respondents in Saria respectively (**Table 1**).

Table 1: Socio-economic characteristics of farm managers

Sites	Villages	Gender	Ethnicity	Main activity	Level of education	Age
Yilou	Barsa (21) Sindri (20) Vousnango (23) Yilou (18)	Men (87.8%) Women (12.2%)	Mossi (100%)	Agriculture (6.1%) agro-pastoralism (93.6%)	Not enrolled (69.5%) Koranic school (9.8%) Rural school (7.3%) Primary school (13.4%)	<30 =1.2% [30;45[= 22% [45;60[= 36.6% [60;75[=32.9% [75;+[=7.3%
Saria	Nandiala (22) Nassoulou (25) Saria (23)	Men (85.7%) Women (14.3%)	Mossi (100%)	Agriculture (35.7%) agro-pastoralism (64.3%)	Not enrolled (61.4%) Rural school (5.7%) Primary school (20%) Secondary school (12.9%)	<30 =8.6% [30;45[= 25.7% [45;60[= 31.4% [60;75[=30% [75;+[=4.3%

Socio-economic and biophysical characteristics of farms: The biophysical and socio-economic characteristics of the farms vary from one site to another (**Table 2**). The average age of the farms is 30.20 ± 16.55 years in Yilou and 36.61 ± 23.17 years in Saria. The farms are headed by a farm manager whose average age is 55.34 ± 13.28 and 51.21 ± 13.98 years in Yilou and Saria respectively. These are small farms with an average area of less than 4 ha, most of which were acquired through inheritance. The farms in Yilou are denser (45.85 ± 17.87 individuals/ha) and richer (4.70 ± 1.73 woody species) than the farms in Saria.

Table 2: Socio-economic and biophysical characteristics of farms

Sites		**Yilou**	**Saria**
Age of farms (years)		30.20 ± 16.55	36.61 ± 23.17
Age of farm managers (years)		55.34 ± 13.28	51.21 ± 13.98
Area of farms (ha)		3.49 ± 1.89	3.08 ± 2.79
Density of woody plants (individuals / ha		45.85 ± 17.87	23.54 ± 18.71
Number of speculations		4.12 ± 1.09	3.77 ± 1.19
Specific richness of woody plants		4.70 ± 1.73	2.44 ± 1.46
Duration of cultivation phase (years)		3.83 ± 0.58	34.87 ± 23.03
Time of interruption (years)		1.46 ± 0.71	5.86 ± 1.5
Mode of acquisition of farmland	Inheritance (%)	0	1.428571429
	Gift (%)	100	88.57142857
	Loan (%)	0	10

Diversity of woody species kept in the fields: A total of 52 woody species in 41 genera and 22 families were inventoried in the fields at both sites (**Table 3**). At Yilou, 40 species in 31 genera and 18 families were recorded, compared with 34 species in 29 genera and 16 families at Saria. The most represented families (**Figure 2**) are the *Fabaceae-Caesalpinoidae* (17.65% in Saria and 15% in Yilou) followed by the *Fabacae-Mimosoidae* (17.5% in Yilou and 14.17% in Saria).

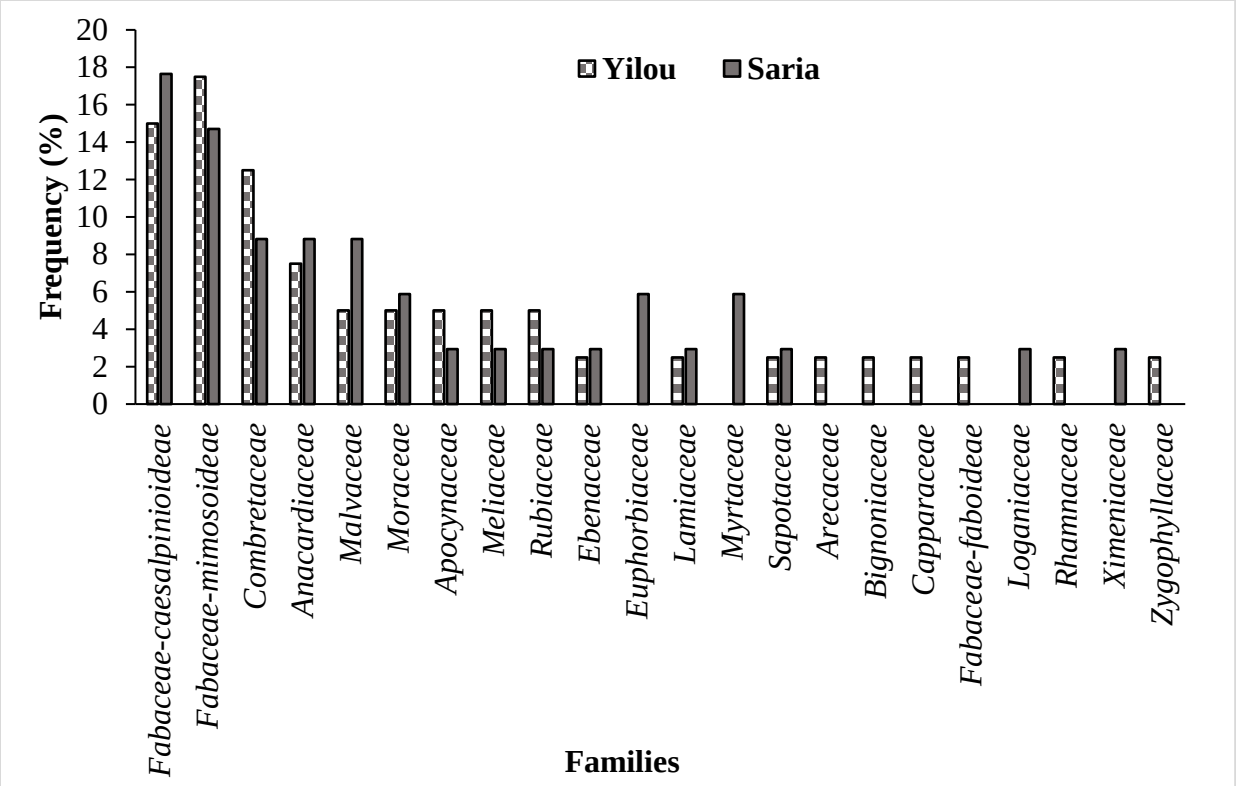

Figure 2: Spectrum of woody species families kept in the fields

The most frequent woody species in the fields are *V. paradoxa* (27.85%), *A. indica* (19.85%) and *L. microcarpa* (16.22%) in Saria and *B. aegyptiaca* (17.34%), *P. reticulatum* (16.38%) and *V. paradoxa* (12.45%) in Yilou (**Figure 3**). The species recorded in the fields represent 39.13% (in Saria) and 52.17% (in Yilou) of the plant species enjoying special protection in Burkina Faso (**Table 3**).

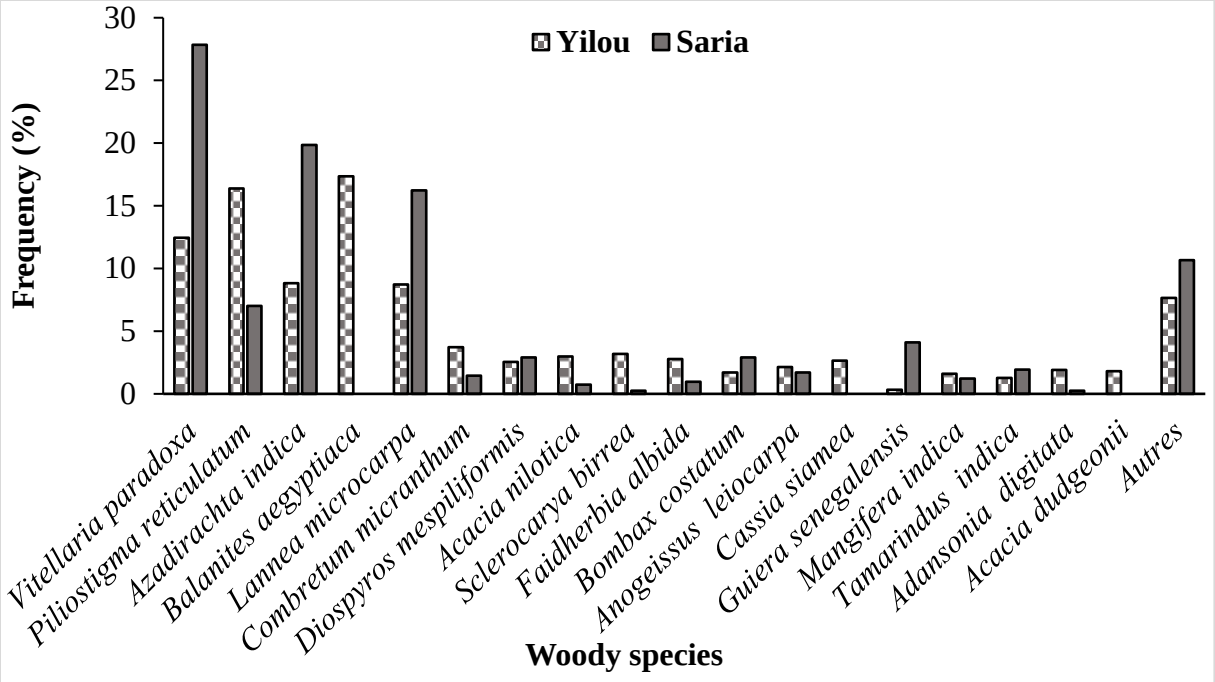

Figure 3: Spectrum of woody species kept in the fields

Table 3: List of species inventoried in the agroforestry parks

Families	**Genera**	**Species**	**Yilou**	**Saria**	**Status**
Anacardiaceae	Lannea	*Lannea microcarpa* Engl. & K.Krause	+	+	
	Mangifera	*Mangifera indica* L.	+	+	
	Sclerocarya	*Sclerocarya birrea* (A.Rich.) Hochst.	+	+	
Apocynaceae	Calotropis	*Calotropis procera* (Aiton) R.Br.	+	+	*
	Leptadenia	*Leptadenia hastata* (Pers.) Decne.	+		
Arecaceae	Hyphaene	*Hyphaene thebaica* (L.) Mart.	+		*
Bignoniaceae	Stereospermum	*Stereospermum kunthianum* Cham.	+		*
Capparaceae	Cadaba	*Cadaba farinosa* Forssk.	+		*
Combretaceae	Anogeissus	*Anogeissus leiocarpa* (DC.) Guill. & Per	+	+	
	Combretum	*Combretum micranthum* G.Don	+	+	
	Guiera	*Guiera senegalensis* J.F.Gmel.	+	+	*
	Terminalia	*Terminalia laxiflora* Engl. & Diels	+		
		Terminalia macroptera Guill. & Perr.	+		
Ebenaceae	Diospyros	*Diospyros mespiliformis* Hochst. ex A.DC.	+	+	

Euphorbiaceae	Jatropha	*Jatropha curcas* L.		+	
		Jatropha gossypiifolia L.		+	
Fabaceae-caesalpinioideae	Afzelia	*Afzelia africana* Sm. ex Pers.		+	
	Cassia	*Cassia siamea* Lam.	+		
		Cassia sieberiana DC.	+	+	
		Cassia singueana Delile	+		
	Daniellia	*Daniellia oliveri* (Rolfe) Hutch. & Dalzi		+	
	Piliostigma	*Piliostigma reticulatum* (DC.) Hochst.	+	+	
		Piliostigma thonningii (Schumach.) Milne	+	+	
	Tamarindus	*Tamarindus indica* L.	+	+	
Fabaceae-faboideae	Pterocarpus	*Pterocarpus lucens* Lepr. ex Guill. & Perr.	+		
Fabaceae-mimosoideae	Acacia	*Acacia dudgeonii* Craib ex Holland	+		
		Acacia macrostachya Rchb. ex DC.	+	+	
		Acacia nilotica (L.) Willd. ex Delile su	+	+	
		Acacia senegal (L.) Willd.	+		
		Acacia seyal Delile	+	+	*
	Faidherbia	*Faidherbia albida* (Delile) A.Chev.	+	+	
	Parkia	*Parkia biglobosa* (Jacq.) R.Br. ex G.Don		+	
	Prosopis	*Prosopis africana* (Guill. & Perr.) Taub.	+		
Lamiaceae	Tectona	*Tectona grandis* L.f. [cult.]		+	
	Vitex	*Vitex doniana* Sweet	+		*
Loganiaceae	Strychnos	*Strychnos spinosa* Lam.		+	
Malvaceae	Adansonia	*Adansonia digitata* L.	+	+	
	Bombax	*Bombax costatum* Pellegr. & Vuill.	+	+	*
	Sterculia	*Sterculia setigera* Delile		+	
Meliaceae	Azadirachta	*Azadirachta indica* A.Juss.	+	+	*
	Khaya	*Khaya senegalensis* (Desr.) A.Juss.	+		
Moraceae	Ficus	*Ficus ingens* (Miq.) Miq.		+	
		Ficus polita Vahl	+		
		Ficus sycomorus L.	+	+	

Myrtaceae	Eucalyptus	*Eucalyptus camaldulensis* Dehnh.		+	*
	Psidium	*Psidium guajava* L.		+	
Rhamnaceae	Ziziphus	*Ziziphus mauritiana* Lam.	+		
Rubiaceae	Gardenia	*Gardenia ternifolia* Schumach. & Thonn.	+	+	
	Mitragyna	*Mitragyna inermis* (Willd.) Kuntze	+		*
Sapotaceae	Vitellaria	*Vitellaria paradoxa* C.F.Gaertn.	+	+	*
Ximeniaceae	Ximenia	*Ximenia americana* L.		+	
Zygophyllaceae	Balanites	*Balanites aegyptiaca* (L.) Delile	+		*

*****: fully protected species in Burkina Faso; +: presence.***

Management of agroforestry parks: Agricultural and agroforestry practices: In total, 22 practices were inventoried in the fields (**Figure 4**). The survey data reveal the predominance of producers practising assisted natural regeneration (ANR, 96% in Yilou and 97% in Saria) and using organic manure as fertiliser (93% in Yilou and 96% in Saria). The practices of mulching, livestock parking and planting are more accentuated in Yilou: 94%, 91% and 87% of the heads of farms respectively carry out these practices, whereas in Saria they constitute 44%, 10% and 50% respectively. In addition, practices such as zaï (100%) and ridging (98%) are essentially carried out by farmers from Yilou, whereas in Saria, the practices are pruning (84%) and grassed strips (49%).

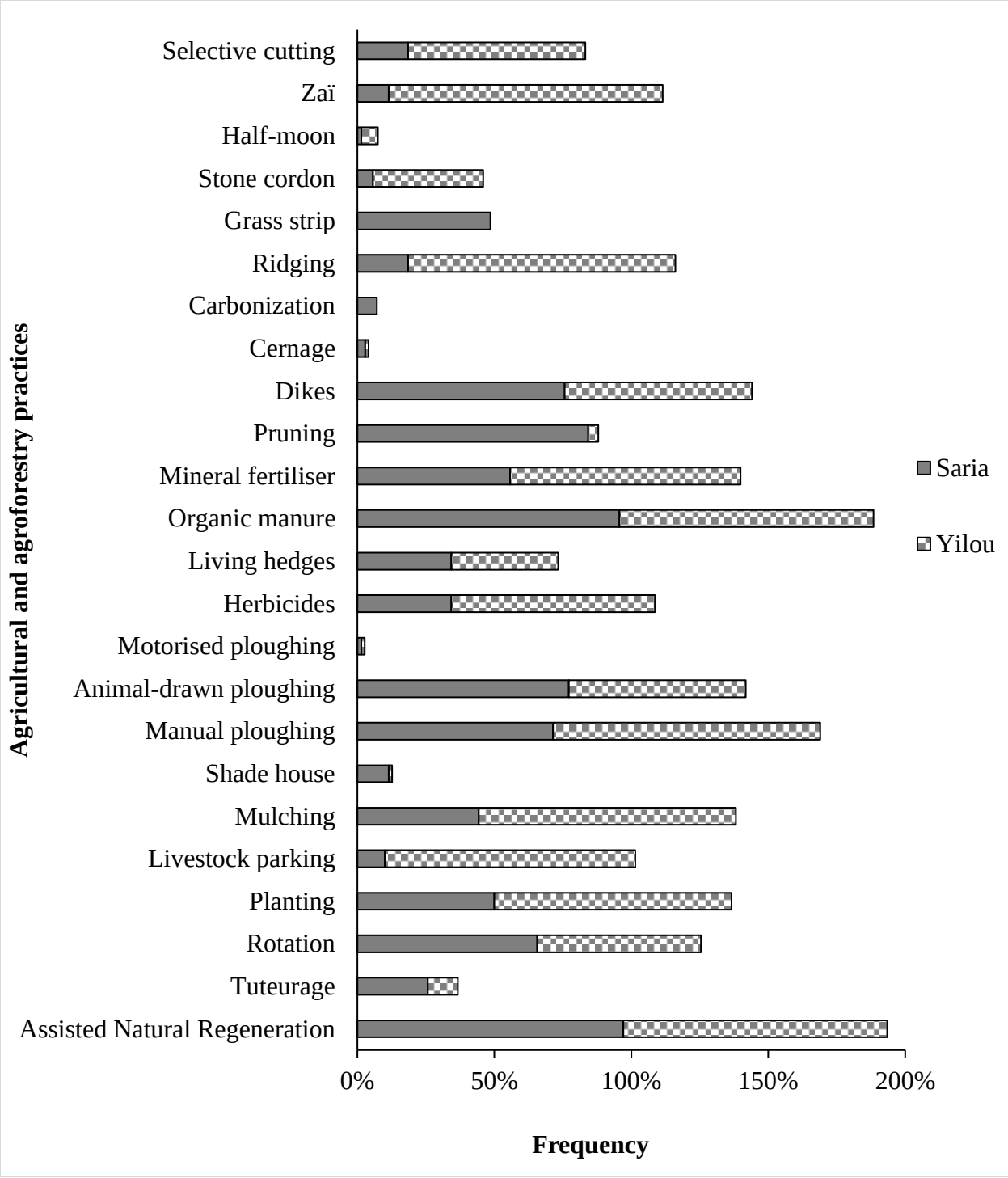

Figure 4: Agricultural and agroforestry practices

Influence of agricultural and agroforestry practices on woody density and species richness: Generalized linear models (GLM) showed that practices such as ridging and half-moons tended to significantly improve woody density in agroforestry parks. Only the practice of zaï has significantly positive effects on the species richness of the woody stand in agroforestry parks (**Table 4**).

Table 4: Effect of agricultural and agroforestry practices on woody density and species richness

	Woody density				**Woody species richness**			
	Estimate	**Std.Error**	**t value**	**Pr(>|t|)**	**Estimate**	**Std.Error**	**t value**	**Pr(>|t|)**
(Intercept)	3.44111	0.33027	10.419	< 2 e-16 ***	1.31026	0.25372	5.164	8.54 e-7 ***
Grass strip	0.05927	0.13954	0.425	0.67173	0.14795	0.10899	1.357	0.1769
Ridging	0.21103	0.1595	1.323	0.18806	0.50844	0.12245	4.152	5.82 e-5 ***
Half-moon	0.14987	0.10593	1.415	0.15944	0.1976	0.0855	2.311	0.0223 *
Dikes	0.1277	0.10837	1.178	0.24075	0.07747	0.08601	0.901	0.3694
Pruning	-0.0879	0.15084	-0.583	0.56105	-0.1933	0.12246	-1.578	0.1169
Mineral fertiliser	0.08861	0.13741	0.645	0.52016	-0.0621	0.10562	-0.588	0.5577
Organic manure	-0.2644	0.20792	-1.272	0.20575	-0.1312	0.1608	-0.816	0.4161
Living hedges	0.13507	0.09382	1.44	0.15229	0.05769	0.07501	0.769	0.4431
Herbicides	0.06496	0.11058	0.587	0.55789	-0.0222	0.08649	-0.256	0.798
Animal-drawn ploughing	-0.0739	0.10544	-0.701	0.48466	-0.0143	0.08397	-0.17	0.8652
Manual ploughing	-0.1582	0.14572	-1.086	0.2795	-0.2138	0.11125	-1.921	0.0568
Mulching	-0.1046	0.12848	-0.814	0.41705	0.00107	0.10335	0.01	0.9917
Livestock parking	0.25456	0.13309	1.913	0.05792	0.13358	0.10452	1.278	0.2035
Planting	0.12258	0.11556	1.061	0.29071	-0.0815	0.08895	-0.916	0.3615
Assisted Natural Regeneration	-0.0331	0.24103	-0.137	0.89098	-0.1045	0.17966	-0.581	0.5619
Rotation	-0.1591	0.11087	-1.435	0.15367	-0.1035	0.08884	-1.165	0.2462
Zaï	0.29297	0.1062	2.759	0.00662 **	0.07309	0.08532	0.857	0.3932

*Significance of the codes: 0 '***' 0.001 '**' 0.01 '*' 0.05*.

Ecosystem services provided by woody species and their conservation causes in agroforestry parks: According to the farm managers surveyed, agroforestry parks provide real sources of supply of various goods and services. A total of 23 types of ecosystem services were mentioned by the respondents and classified in the four main categories of ecosystem services (**Figure 5**). For all the producers, maintaining soil fertility (100%), providing food (100% in Saria and 98% in Yilou) and medicinal products (96% in Saria and 95% in Yilou), attracting rainfall (100% in Yilou and 96% in Saria) and providing wood for energy were the most frequently mentioned reasons for managing trees in the fields.

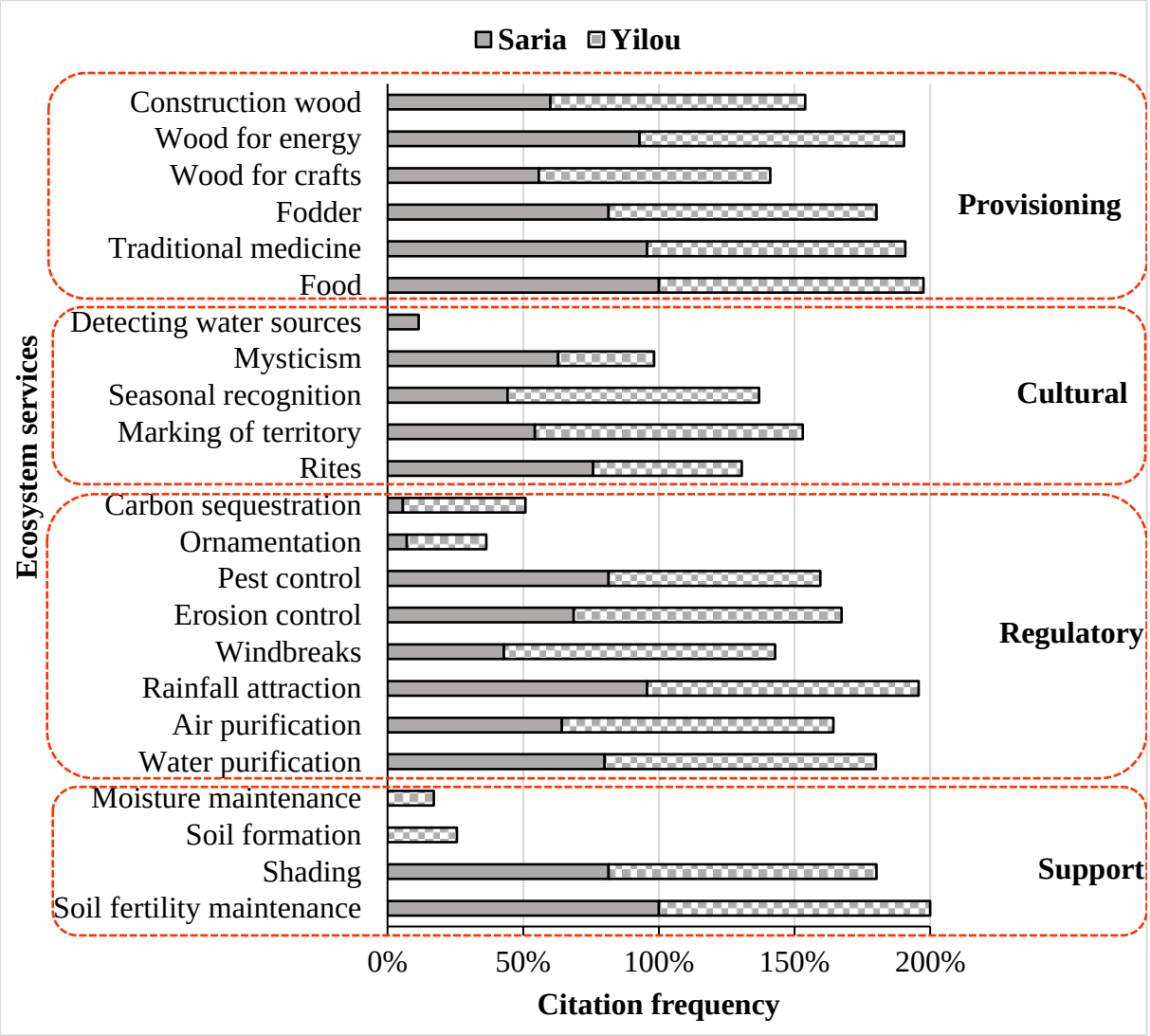

Figure 5: Ecosystem services provided by woody species and their conservation causes

Local perception of ecosystem service categories across study sites: The cultural index of importance shows that the perception of the ecosystem service categories varies between the study sites (**Figure 6**). This index shows that regulating services (6.51) are the most perceived by the communities of Yilou, whereas in Saria, it is the perception of provisioning services (5.68) that is predominant.

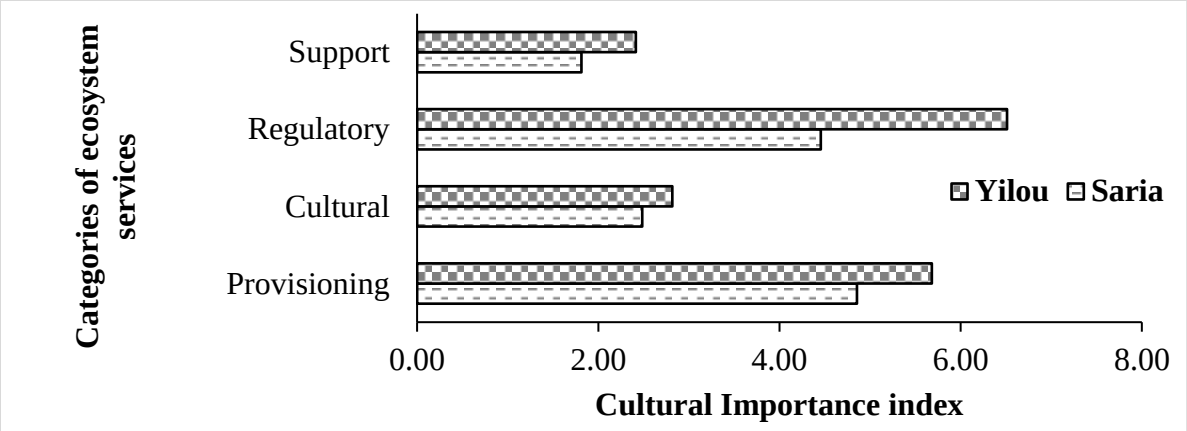

Figure 6: Cultural importance index of ecosystem service categories

Management constraints of agroforestry parks: According to the farm managers, the main constraints in the management of agroforestry parks are the free grazing of animals (85.37%) and the lack of water due to low rainfall (58.54%) in Yilou, and clandestine cutting (34.29%) generally done by women in search of wood for energy in Saria (**Figure 7**). Other constraints such as parasite attacks (20.73% in Yilou) and the ageing of the stand (12.86% in Saria) were also mentioned by the farm managers.

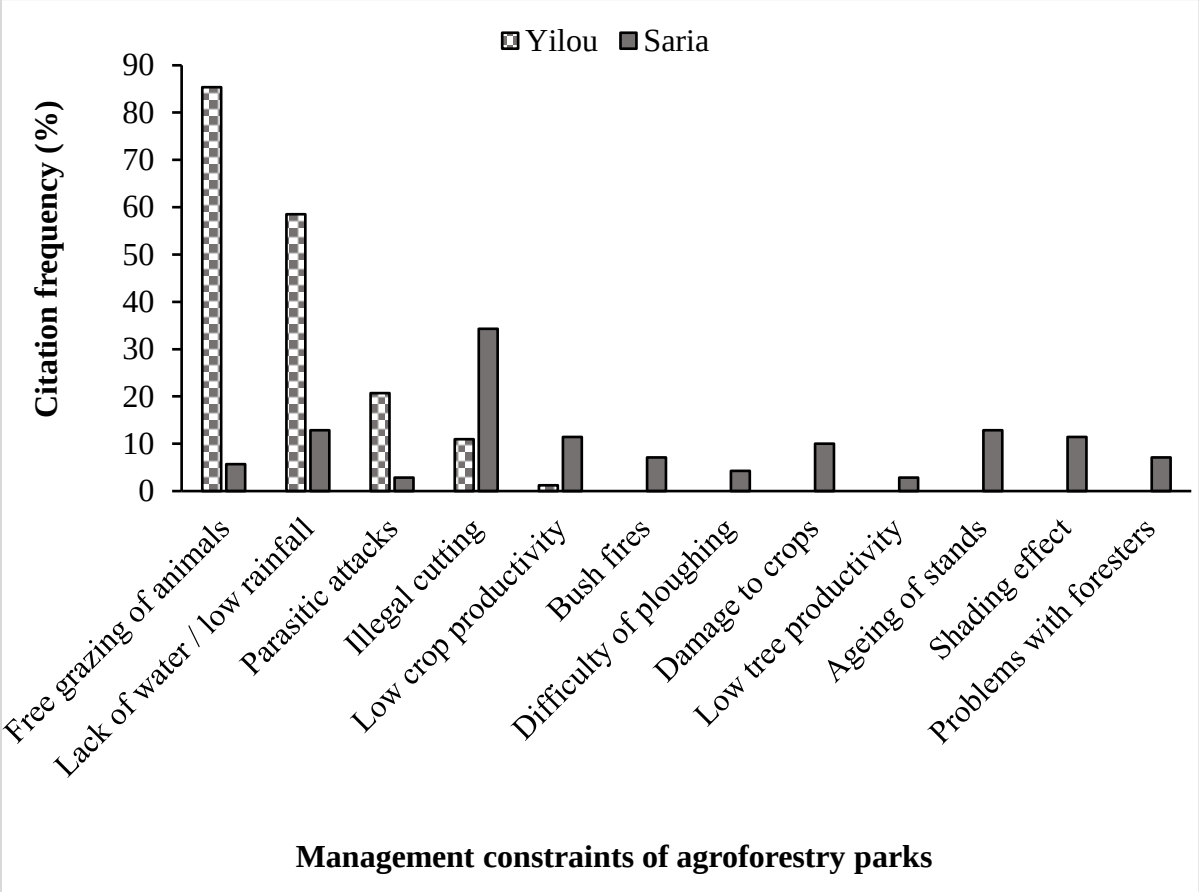

Figure 7: Constraints in agroforestry parks management.

DISCUSSION

The structure of farms in the Sudano-Sahelian zone of Burkina Faso is largely dominated by small family farms acquired mainly through inheritance (Yaméogo, 2009). Moreover, field observations revealed that each household tends to become autonomous by farming its own field. According to Cissé (2020), these types of farms are characterised by a lack of adequate means for mechanisation and the development of cash crop farming. The farmers at the Yilou and Saria sites have a good knowledge of the importance of woody plants in their fields. All of them keep woody plants on their farms. However, the number of species kept in the fields varies from one phytogeographical zone to another. It is higher in agroforestry parks in the sub-Sahelian climatic zone than in agroforestry parks in the northern Sudanian climatic zone. The high number of woody species and the high richness found in the Yilou agroforestry parks, where rainfall is scarcer, could be seen as an adaptation strategy developed by farmers in this zone to diversify their production and better cope with production constraints. This could also be seen as an awareness of the population on the effects of climate change due to the sensitisation of the state technical agents and the numerous projects and NGOs that have intervened in the area. Neya *et al.* (2018) had obtained similar results in their studies on the profiles of agroforestry parks in three climatic zones of Burkina Faso. Furthermore, agroforestry parks constitute an important refuge for threatened species. Indeed, the species present in the agroforestry parks of Yilou and Saria cover respectively 52.17% and 39.13% of the plant species enjoying full protection in Burkina Faso. The management of agroforestry parks is an old practice of Burkinabe farmers with management methods depending on the culture of the people (Yaméogo *et al*., 2005). However, the disparity that exists between the two climatic zones concerned is probably due to climatic constraints. In addition to practices such as livestock parking, farmers in the arid zone of Yilou not only assist natural regeneration but also undertake the planting of woody species in their fields on a larger scale than their peers in the semi-arid zone of Saria. A similar observation was made by Larwanou *et al*. (2006) in the Sahelian zone of Niger. According to these authors, there has been a growing awareness among dryland farmers in recent years of the climatic adversity that threatens them. Other common management practices for woody plants are selective cutting and pruning. The leaf biomass from these practices is mainly used to mulch encrusted areas of the field. This could contribute to water and soil conservation. According to Tyano *et al*. (2020), farmers believe that mulching allows good crop growth and improved yields. The average duration of the interruption of the cultivation phase is much shorter in Yilou than in Saria. This short interruption period does not allow for a reconstitution of soil fertility, which very often results in a reduction of crop yields (Yaméogo, 2009). Thus, in the absence of long periods of interruption, the good productivity of the land and the good yield of the crops can only be maintained if organic matter in the form of manure and compost is returned to the soil. This would justify the extensive use of organic manure by both arid and semi-arid farmers. In addition, practices such as zaï, ridging and mulching are carried out by the majority of producers in Yilou. In addition, due to a lack of resources, farmers in both zones have identified a number of woody species, depending on the zone, that are likely to maintain or rapidly restore soil fertility. The main species listed by the producers and which are kept in the fields for this purpose are *Vitellaria paradoxa*, *Azadirachta indica* and *Lannea microcarpa* at Saria and *Balanites aegyptiaca*, *Piliostigma reticulatum* and *Vitellaria paradoxa* at Yilou. These species are

managed by simple management techniques such as assisted natural regeneration and pruning at Saria and assisted natural regeneration and selective cutting at Yilou. Producers' resolve to conserve woody species in the agrarian spaces reveals the importance they attach to them. However, for keeping woody species in the fields are diverse (Yaméogo *et al.,* 2013). The cultural importance index shows that the perception of ecosystem service categories varies across climatic zones. This means that the knowledge related to ecosystem services of woody plants conserved in the field differs from one community to another. In the dryland zone of Yilou, regulating services (CI = 6.51) are the most perceived by farmers among the four categories inventoried. This result suggests that woody plants are kept in the fields for their ability to mitigate the effects of climatic hazards and this is why these populations consider certain large trees as rainmakers. A similar finding was made by Lykke (2000) in Senegal where local people believe that large trees have the power to attract rain. For them, it rains well if the vegetation is dominated by large trees. Woody plants are also kept in the fields for shade and as anti-erosion devices, windbreaks and living hedges. In the semi-arid zone of Saria, provisioning services (CI = 5.68) are the most important. Cissé *et al.* (2018) reported similar results for agroforestry parks in the Boura watershed in the Sudanian zone of Burkina Faso. These results show that woody plants are maintained in the fields for their important utilitarian values (Yaméogo *et al.,* 2005). The products of woody plants kept in the fields are used for human and animal food (fodder), traditional medicines and, as wood for energy, services and construction. According to Boffa (2000), these products obtained from field trees are also marketed and provide substantial income to households. According to Gning *et al.* (2013), in addition to being an almost indispensable food supplement for people in rural areas, wood plants are also valued for its wood and its role in maintaining and improving soil fertility. In both zones, the maintenance of soil fertility is the most important service. According to the respondents, the perception of this service would be much more related to the fertilisation roles played by species such as *Faidherbia albida* and *Azadirachta indica* and to the use of *Piliostigma reticulatum* and *Guiera senegalensis* as mulching. From the point of view of agricultural and agroforestry practices, the ridging and the half-moons tend to improve woody density in agroforestry parks. Only zaï has significantly positive effects on the species richness of the woody stand in agroforestry parks. These results are probably a consequence of improved environmental conditions. Yaméogo (2012), in his work on the rehabilitation of degraded forest ecosystems in the Sudanian zone of Burkina Faso, also found that plots managed by water and soil conservation and soil defence and restoration techniques significantly improved the floristic diversity and density of woody plants. According to this author, with the effect of climate change and accelerating soil degradation, even an area that is not recognised as an area of zaï applicability is likely to be receptive to the use of the technique. The main constraints in the management of agroforestry parks lie in the exercise of certain human activities and are aggravated by climatic conditions. Indeed, livestock farming, which is practised by the majority of producers, is conducted according to a system in which animals graze freely. These animals cause enormous damage to both the crops and the woody species kept on the farms. This situation is very often accentuated by irregular rainfall with pockets of drought, precursors of water stress for crops and woody species, especially those in regeneration. In addition, for energy wood needs, some people, especially women, are said to be engaged in clandestine cutting of woody species kept in the fields of other people. This means that it

will still take time for awareness raising to be carried out and for it to result in a significant change in the mentalities of certain sections of the population. Butane gas is still inaccessible to these populations, so they use almost 100% wood for energy. Alternative solutions should therefore be considered and the public authorities are called upon to take more awareness raising and support actions for these rural populations.

CONCLUSION AND APPLICATION OF RESULTS

Farmers in Burkina Faso have knowledge and experience of integrating trees into their farming systems going back several centuries. They have developed agroforestry parks over several generations in order to diversify subsistence production, create income and thus minimise environmental risks. The main reasons that guide farmers' choice to keep woody plants in their fields in the Yilou and Saria zones, as identified by this study, are mainly the maintenance of soil fertility, the provision of food, traditional pharmacopoeia products and firewood. It is obvious that despite the existence of a significant potential in certain areas such as Saria, the populations do not make enough efforts in terms of conservation and enrichment of their parks with woody species. In such a case, it would be interesting to undertake awareness-raising sessions and even training on the usefulness and adoption of good management methods for agroforestry parks. These sessions could be conducted by the populations living in the Yilou dryland area, as they are more aware of the need for good management of these parks not only for their ecosystem services but also for future generations. However, the current management of these agroforestry parks as a whole offers hope for the sustainability of agrosystem productivity in Burkina Faso. Furthermore, in order for producers to continue to benefit from the advantages of their parks, research should continue with the aim of equipping them with adequate technical skills to preserve the natural resources found there.

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