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Research Article

Promoting private forests for biodiversity conservation and ecosystems restoration in the Sahel region

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Abstract

Private forests have the potential to mitigate biodiversity loss and improve community livelihoods. However, information on the socio-ecological factors that drive their establishment and long-term management are limited. This study aimed to narrow this gap by assessing the potential of privately-owned forests in conserving biodiversity and supporting the livelihoods of communities in northern Burkina Faso. Floristic data were collected within 26 plots (900 m^2 each) equally distributed between private Gourga forest, established in 1980) and its adjacent communal areas. Sixty-three (63) private landowners were interviewed in order to underpin their motivations and associated traditional knowledge and a stakeholder's workshop was conducted to develop conservation models for private forests and participatory implementation roadmap. Findings revealed that species richness was 132 in the Gourga forest and 85 in the communal areas, highlighting the importance of private forest in species conservation. Local communities recognized the provisioning (36.46%), regulating (28.46%) and supporting (22.48%) of ecosystem services provided by the Gourga forest as motivating factors. The main barriers to their establishment and management include lack of financial resources (35%), scarce lands (26%) and human pressures (8%). The implementation of private forests will need to be supported by the enactment of a secure land tenure policy, as well as payment for ecosystem services (PES) policies, incentivizing locals. We suggest decision makers mainstream privately-owned lands into national conservation strategies and design incentives policies to motivate local communities' engagement.

Key words: Burkina Faso, conservation, ecosystem services, Gourga forest, private forest, private land, species diversity

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Introduction

The degradation of ecosystems and biodiversity loss are still on the rise, with severe impacts on people around the world (Ceballos et al. 2015). To halt and reverse the decline of biodiversity, there have been calls for national governments to expand the coverage of protected areas and ensure the conservation of 30% of the Earth's land and sea areas by 2030 (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2018); Tsioumani 2020). Indeed, protected areas (PAs) are an important strategy for conserving biodiversity and improving human well-being through ecosystem goods and services (Bonet-Gracia et al. 2015; Adams et al. 2018). In addition, they constitute an essential tool to boost local economies and combat climate change (Watson et al. 2014). However, population growth and other related variables such as habitat destruction and the negative effects of climate change undermine the capacity of protected areas to achieve their conservation outcomes (Fousseni et al. 2012). In West Africa, natural ecosystems are undergoing fast land-use changes due to rapid human population growth and increasing agricultural (cash-crop) production, infrastructural development, rangeland expansion and forest product harvesting (Wittig et al. 2007; Ouédraogo et al. 2010). The pressures on natural ecosystems jeopardize their sustainability. For instance, in Burkina Faso, federal protected areas considered as the main vehicles for biodiversity conservation are under threat from croplands expansion and illegal trees logging, resulting in the loss of some protected areas (Ouoba 2006). This indicates that state-owned protected areas have limited capacity to ensure biodiversity conservation. In addition, while there is a willingness to increase conservation areas network, Lambin et al. (2011) reported the scarcity of public domains to establish new protected areas.

In this context, additional initiatives need to be promoted to compensate for the limits of state protected areas. Thus, governments and conservation planners are increasingly exploring privately-owned conservation areas (PCAs) as a bottom-up approach to achieve national and global conservation goals (Stolton et al. 2014). To that end, the World Commission on Protected Areas (WCPA) raised the international profile of private land conservation in conservation strategies (Stolton et al. 2014), spurring the emergence of privately-owned lands as biodiversity conservation instruments (Juffe-Bignoli et al. 2014). Recent works stated that privately-owned land is an innovative and effective approach to strengthen conservation efforts (Cortés Capano 2021). These new conservation areas have the potential to complement the existing protected area networks, and eventually play a key role in mitigating global biodiversity loss and climate change (Kamal et al. 2015). The mainstreaming of privately-owned lands into national biodiversity conservation strategies has piqued the interest of policy makers and key stakeholders, such that several governments have recently established private land conservation (PLC) mechanisms (International Land Conservation Network 2016). To support decision making, various types of research have been conducted globally to assess the ecological, economic, and social benefits of forestry and the motivations behind the establishment of private conservation areas (Gooden et al. 2019). Recent studies have revealed that most of the research on private land conservation has been carried out in the United States of America, Australia, South Africa, and Canada (Cortés Capano et al. 2019). Spatial variability of climatic conditions, ecosystems, plant diversity and socio-economic activities affects biodiversity use, management, and conservation practices (Levers et al. 2018), suggesting that finer scale information on conservation strategies is greatly needed to achieve global conservation goals. In Burkina Faso, socio-ecological information supporting the establishment and management of private forests, as well as associated challenges and constraints, are poorly addressed, limiting the integration of private forests in the conservation policies of the country. The objectives of this study, therefore, were to: (i) assess the contribution of private forests in plant species conservation in northern Burkina Faso; (ii) assess the key ecosystem services provided by private forests to local communities; (iii) identify barriers to the establishment and management of private forests, and (iv) propose sustainable community-based measures for the sustainability of biodiversity conservation on private lands. Three research questions were addressed in this study:

(i) Is private forest efficient in threatened species' conservation?
(ii) Do local communities perceive the role of private forests in the support of their livelihoods?
(iii) Do local people have the willingness to establish private forests?

Materials and methods

Description of the study area

This study was carried out in the municipality of Ouahigouya where the Gourga forest is geographically located at 13.35°N, 2.30°W. This private Gourga forest covers an area of 28 ha (Fig. 1). The Gourga forest is located in the Sudano-sahelian zone, characterized by a short rainy season from June to October (4–5 months) and a long dry season (7–8 months) Dipama (2010). Average annual rainfall varies from 600 to 900 mm, and average monthly temperatures vary from 20 to 30 °C. The vegetation is characterized by desert and Sahelian species and the common species encountered are *Vachellia seyal* Delile, *Combretum glutinosum* Perr. ex DC., *Balanites aegyptiaca* (L.) Delile, *Cassia sieberiana* DC., *Combretum micranthum* G.Don, and *Combretum nigricans* Lepr. ex Guill. & Perr. (Sambaré et al. 2011) including *Andropogon gayanus* Kunth and *Zornia glochidiata* Rchb. ex DC., which are the representative grasses (Maisharou 2014). Pressure on land use is extremely high in this area due to intensive livestock production. Farming methods are still traditional and are mainly food crops, predominantly sorghum and millet. Soils are generally degraded in the study area (Fig. 2a). Therefore, some traditional agricultural practices such as semi-circular dikes and *zaï* are undertaken by farmers for soil restoration and fertilization before planting. Rainfall irregularities, as well as deforestation and livestock grazing, lead to vegetation loss and land degradation, which are the main challenges for sustainable development in the region. The Gourga forest was created in 1980 and owned by Mr. Yacouba SAWADOGO, a farmer and right livelihood award winner known as "*the man who stopped the desert*". The overall objective of creating the forest was to build local resilience to the adverse impacts of climate change experienced in the drought 1970s period in the Sahel, resulting in the loss of many woody species. The ecological landscape of the forest is completely different to its communal areas (Fig. 2b).

Ecological data collection

Floristic data were collected in 26 individual plots equally distributed in two land use types, including the Gourga forest, which is privately owned, and the communal areas used as control areas in the framework of this study. In both areas main plots of individual surface of 900 m^2 (30 m × 30 m) were installed for the inventory of woody species (Nacoulma et al. 2011; Samandoulgou et al.

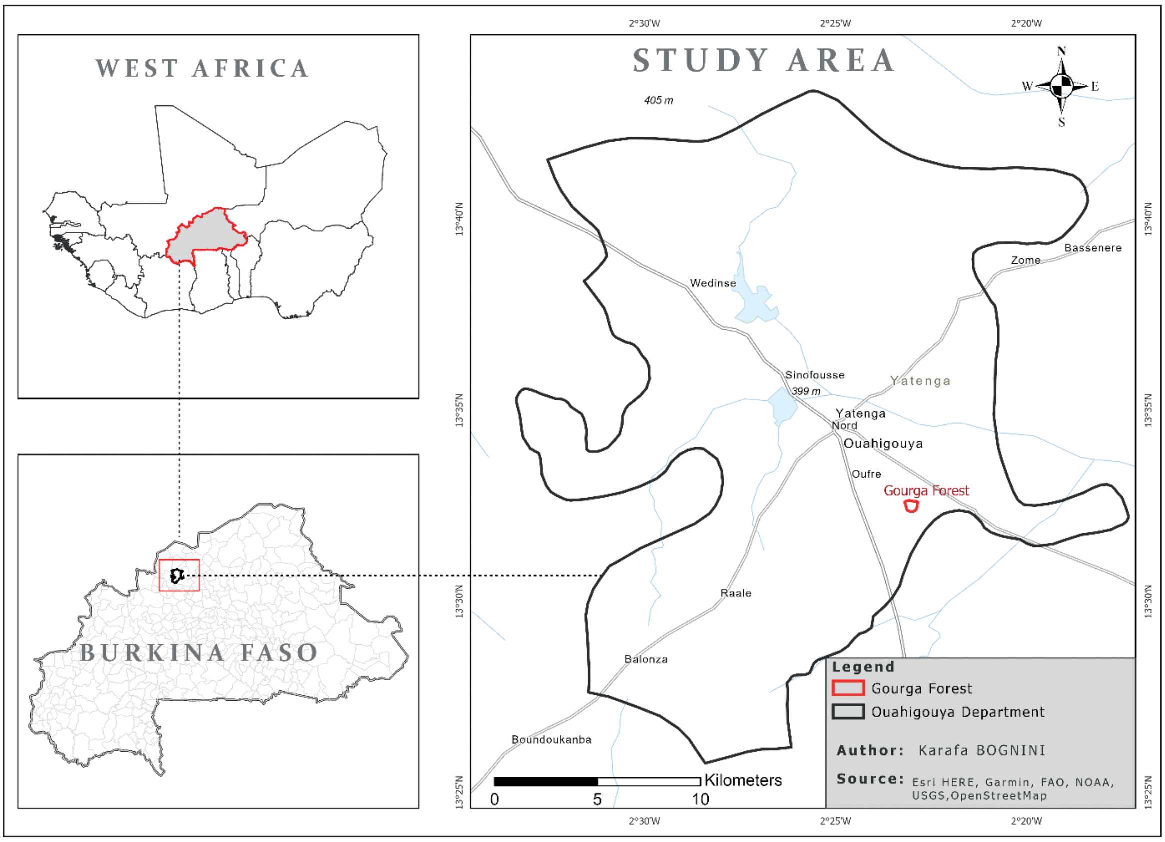

Figure 1. Location of the study area.

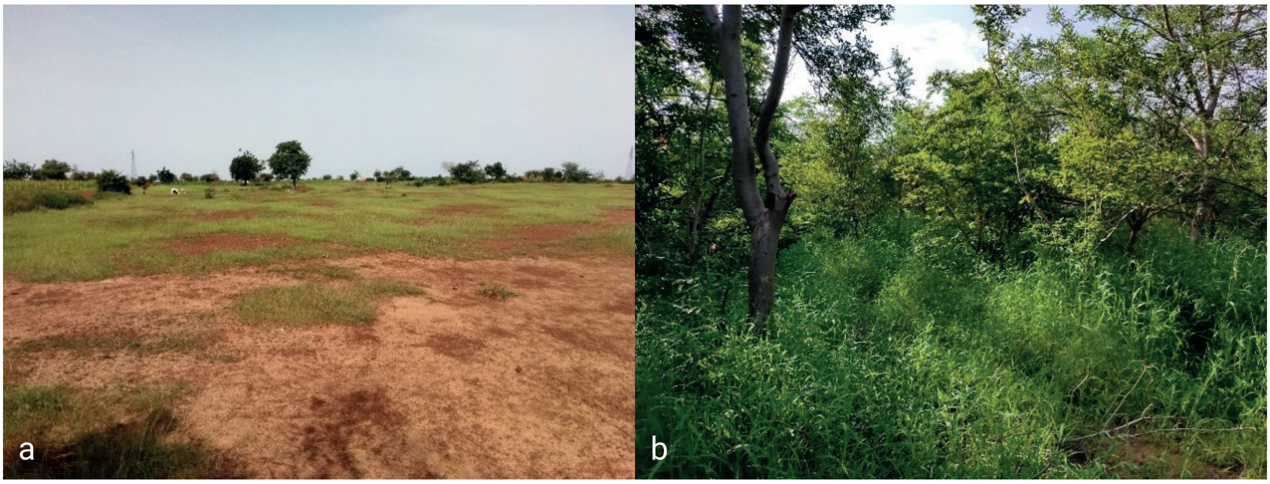

Figure 2. Overview of the study area during data collection period (**a**) communal area and (**b**) Gourga forest.

2019). Within each main plot, a subplot of 100 m² (10 m × 10 m) was installed for the inventory of herbaceous species. The inventory consisted of systematic counting and listing of all plant species present in each specific plot. All species were directly recorded with their scientific names. For species unidentified on the field, representative samples were collected and brought to the Laboratory of Plant Biology and Ecology of Université Joseph KI-ZERBO for identification. All species were listed using the nomenclatures of Angiosperm Phylogeny Group (APG) IV and Kyalangalilwa et al. (2013).

Social data collection

Social data related to private forest was collected in three nearest villages (Gourga, Saye, and Somiaga) to the Gourga forest. Based on their proximity and daily interaction with the forest, people living close to it could probably provide better information on its ecosystem services that they benefited from (N'Da et al. 2008; Oldekop et al. 2015). On this point, the surveys mainly targeted men, who according to social practices are the only landowners (Coulibaly-Lingani et al. 2009). Individual semi-structured interviews were performed with the Gourga forest owner and landowners from three different villages (Ouédraogo et al. 2020). In total, 63 landowners aged from 24 to 70 with 21 landowners per sampled village were interviewed. An interview was conducted with the Gourga forest owner (Mr. Yacouba SAWADOGO) to collect data on the benefits and constraints of forest management. For landowners, the main information collected concerned their perception of the key ecosystem services provided by the Gourga forest, their willingness to establish a private forest and related main constraints, as well as their recommendations to boost the private forest sector in Burkina Faso.

Stakeholder's workshop

Based on the barriers to private land conservation perceived by the communities, a stakeholder's consultative workshop was convened in the municipality of Ouahigouya using the qualitative Delphi method (Peter et al. 2021). The workshop aimed to bring together various stakeholders and determine a private land conservation model suitable to the national context. Indeed, the workshop gathered conservation-based NGOs, landowners, researchers from biodiversity areas, and experts from land and natural resource managing government institutions. The main question of the workshop was "*what is the appropriate private land conservation model for Burkina Faso and its implementation measures*?" In addition, participants were asked to rate the recommendations formulated by the communities and express their insights on conservation on private land. Recommendations were scored on a four-point scale (0–3), which correspond to: 1 = very important; 2 = less important and 3 = not important.

Data analysis

The ecological data were synthesized to constitute a floristic database arranged according to the taxonomic hierarchy (family, genus, and species). Plant diversity was described at family and species levels. At family level, the relative diversity of family (RDF) was calculated for each family in both land use types using equation 1.

$$\text{RDF} = (\text{number of species in a family} / \text{total number of species}) \times 100 \quad (1)$$

At species level, the common metrics widely used for assessing plant community diversity were calculated: species richness (SR), mean species richness per plot (MSR), Shannon index (H) and Pielou index (E) (Gnoumou et al. 2011; Bondé et al. 2013). SR is estimated by the total number of species recorded in an area. Hence, it refers to the number of taxa found in an area, without assessing their frequency or abundance. Therefore, it is not a meaningful measure for comparing community diversity. For this reason, H and E, which consider both the relative abundance of species and the total specific richness, are used to characterize the floristic diversity of environments. H quantifies the heterogeneity of the specific diversity of an environment, while E evaluates the equitability of all individuals among all species in the environment. PC-ORD 6.0.4 was used to calculate the number of species per plot, Shannon's diversity and Pielou's equitability indices. To assess the impact of land use on the species diversity, a non-parametric test (Wilcoxon test) at the 5% threshold was performed for each diversity index. For social data, we performed a generalized linear model (GLM) with Poisson error distribution to compare counting data (number of threats and number of ecosystem services) according to respondent age and locality (distance to the studied private forest). All statistical tests were generated using R software 4.0.3.

The stakeholders scored the recommendations formulated by the landholders as a way to motivate them to involve conservation and prioritized them following their importance. Further on, participants discussed the private land conservation model suitable for the socio-economic context of the country and agreed on its implementation measures. Graphical representation of the degree of consensus per recommendation was generated.

Results

Species diversity and land use pattern

In the whole study area, the surveys revealed a floristic richness of 217 herbaceous and woody species. Of these, the flora of the Gourga counted for 132 species (Appendix 1) whilst the communal areas counted for 85 species (Appendix 2). In general, the GF recorded higher values of relative diversity for all species families (Fig. 3). Families with one species (i.e., family relative diversity = 0.46%) are represented by other in the Fig. 3. The mean species richness and Shannon index based on wood species were significantly influenced by land use with higher values in the GF (Table 1). However, for the Pielou equitability index values, no difference was observed between the Gourga forest and the communal areas.

Particularly protected woody species encountered in the study area

By cross checking the species surveyed in the forest with the red list of the International Union for Conservation of Nature (IUCN) and the list of species under special protection in Burkina Faso, it was possible to establish the list of both threatened and those highly protected in Burkina Faso (Table 2). Overall, the finding revealed 46 woody species with special status according to the IUCN Red List of Threatened Species in the study area. 26 of them were only found in the Gourga Forest and 2 in the communal areas whilst 18 species were common to both areas. Among these species, 41 were in the category of least concern (LC), one specie is near threatened (*Dalbergia melanoxylon* Guill. & Perr.) and two are threatened species (*Adansonia digitata* L. and *Vitellaria paradoxa* C. F. Gaertn.). Furthermore, the study identified 12 woody species with special protection status in Burkina Faso with 11 species growing in the Gourga forest and 1 species in communal areas.

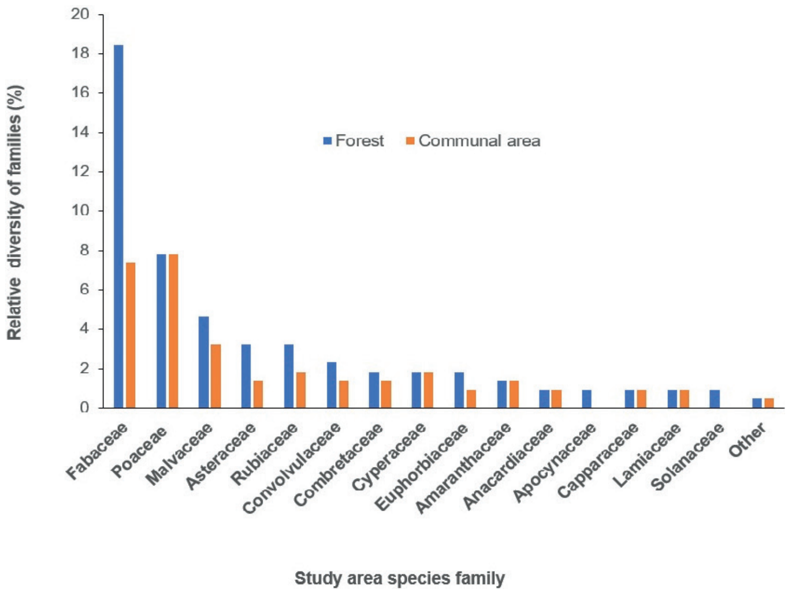

Figure 3. Relative diversity of families according to land use.

Table 1. Summary of diversity indexes of the woody species according to land use type.

	Total species richness	Mean species richness	Shannon index	Pielou index
Gourga forest	55	10.15 ± 4.16a	1.85 ± 0.56a	0.82 ± 0.11a
Communal area	27	4.46 ± 4.17b	1.07 ± 0.43b	0.84 ± 0.14a

Mean ± SD. Indexes with the same letter are statistically not different at 5% level.

Communities' perception of the private land conservation

Key ecosystem services of the Gourga forest

Statistical analyses revealed no influence of both the respondent's age and location (distance to the forest) on their perception regarding ecosystem services. In general, the results showed that communities of the three surveyed villages clearly perceived the key ecosystem services from the Gourga forest. Actually, the communities identified 17 goods and services (Fig. 4). provided by the Gourga forest. The findings showed that the provisioning of services accounts for 36.46% of the total services while the regulating of services accounts for 28.46%. Further on, the findings highlighted that a supporting service was fairly provided by the forest (22.48%). The category of cultural services was rarely mentioned (12.83%) by the population.

Certainly, concerning the category of provisioning services, the respondents highlighted that the forest plays a crucial role in traditional medicine (79.36%), supply of fruits (36.5%), and forage for livestock (9.52%). The cultural services mentioned include shade production (15.87%), village reputation (9.52%), and tourism value (6.34%). The three services (aesthetics, research, and education) are sparsely cited with a rate of 3.17% per service. Finally, respondents cited human well-being (1.58%) and social cohesion (1.58%). In terms of regulatory services, the respondents mentioned soil fertilization (36.5%), improved rainfall (26.98%), air purification (23.8%)

Table 2. Species with particular status observed in the whole study area.

Family	Species	Occurrence			
		Forest	Communal area	IUCN's status	National protection status
Olacaceae	*Ximenia americana* L.	+	-	LC	PP
Fabaceae	*Senegalia ataxacantha* DC.	+	-	LC	
Fabaceae	*Vachellia nilotica* subsp. *Leiocarpa*	+	-	LC	
Fabaceae	*Senegalia senegal* (L.) Willd	+	-		PP
Malvaceae	*Adansonia digitata* L.	+	+	VU	PP
Annonaceae	*Annona senegalensis* Pers.	+	-	LC	
Combretaceae	*Anogeisus leiocarpa* (DC.) Guill. & Perr.	+	-		PP
Meliaceae	*Azadirachta indica* A.Juss.	+	+	LC	
Zygophyllaceae	*Balanites aegyptiaca* (L.) Del.	+	+	LC	
Fabaceae	*Senna sieberiana* DC.	+	+	LC	
Fabaceae	*Boscia senegalensis* Lam	+	+	LC	
Malvaceae	*Ceiba pentandra* (L.) Gaertn.	+	-	LC	PP
Fabaceae	*Combretum aculeatum* Vent.	+	-	LC	
Fabaceae	*Combretum fragans* F.Hoffm.	+	-	LC	
Fabaceae	*Combretum glutinosum* Perr. ex DC.	+	+	LC	
Fabaceae	*Combretum marginatum* Engl. & Diels	+	-	LC	
Fabaceae	*Combretum micranthum* G. Don	+	+	LC	
Fabaceae	*Combretum molle* R. Br.ex G. Don	+	-	LC	
Fabaceae	*Combretum nigricans* Lepr. Ex Guill. & Perr.	+	-	LC	
Fabaceae	*Dalbergia melanoxylon* Guill. & Perr (African Blackwood)	+	-	NT	PP
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC.	+	+	LC	
Fabaceae	*Faidherbia albida* (Del.) A. Chev	+	+	LC	PP
Moraceae	*Ficus platyphylla* Del.	+	-	LC	
Phyllanthaceae	*Flueggea virosa* (Roxb. Ex Willd.)	+	-	LC	
Rubiaceae	*Gardenia ternifolia* Schumach & Thonn. subsp. *Ternifolia*	+	-	LC	
Malvaceae	*Grewia bicolor Juss.*	+	-	LC	
Apocynaceae	*Holarrhena floribunda* (G. Don) T. Durand. & Schinz	+	-	LC	
Euphorbiaceae	*Jatropha gossypiifolia* L.	+	+	LC	
Anacardiaceae	*Lannea microcarpa* Engl. & K. Krause	+	+	LC	
Capparaceae	*Maerua angolensis* DC.	+	-	LC	
Capparaceae	*Maerua crassifolia* Forssk	+	-	LC	
Fabaceae	*Parkia biglobosa* (Jacq.) Benth.	+	-	LC	PP
Fabaceae	*Prosopis africana* (Guill. & Perr.) Taub.	+	+	LC	PP
Fabaceae	*Pterocarpus lucens* Lepr. ex Guill. & Perr.	+	-	LC	PP
Fabaceae	*Senegalia dudgeoni* Craib ex Holl.	+	-	LC	
Fabaceae	*Senegalia macrostachya* (Rchb. Ex DC.) Kyal. & Boatwr	+	-	LC	
Bignoniaceae	*Stereospermum kunthianum* Cham.	+	-	LC	
Combretaceae	*Terminalia avicennioides* Guill. & Perr.	+	-	LC	
Fabaceae	*Vachellia seyal* (Delile.) P.J.H. Hurter	+	+	LC	
Combretaceae	*Guiera senegalensis* J.F. Gmel.	+	+	LC	

		Occurrence			
Fabaceae	*Vachellia sieberiana* DC.	+	+	LC	
Sapotaceae	*Vitellaria paradoxa* C. F. Gaertn.	+	+	VU	PP
Rhamnaceae	*Ziziphus mauritiana* Lam.	+	+	LC	
Fabaceae	*Senegalia dudgeoni* Craib ex Holl.	-	+	LC	
Fabaceae	*Faidherbia albida* (Del.) A. Chev.	+	+	LC	
Fabaceae	*Tamarindus indica* L.	-	+	LC	PP

Legend: LC: Least concerned; PP: Particular protection; VU: Vulnerable; NT: Nearly threatened; +: Present in the area; -: Not present in the area.

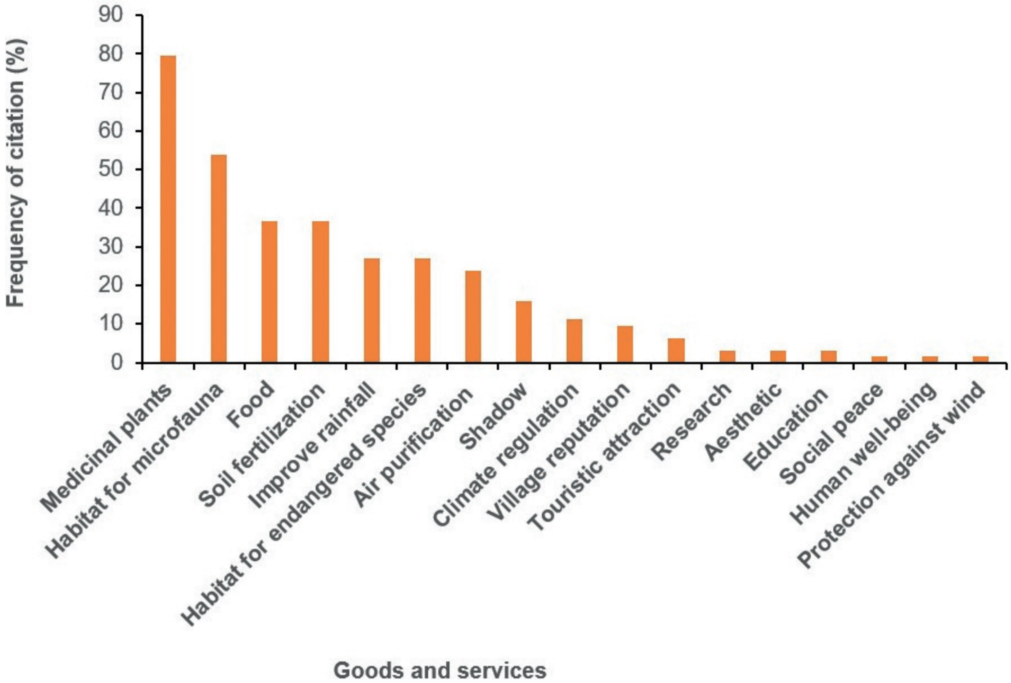

Figure 4. Species goods and services of the Gourga forest based on communities' perception.

and improved climate (11.11%). As for the category of support services, the respondents cited among others the refuge of plant species (26.98%), the refuge of animal species (53.96%) and, finally, the protection against winds (1.58%).

Communities' perception on private forests establishment constraints

General linear model (GLM) showed that there was no significant relationship between the respondents' location and age on the constraints to private forests forest establishment. Respondents identified 11 key constraints preventing them from establishing their own forests (Fig. 5). Findings revealed that land scarcity and lack of financial resources were the constraints most perceived by the communities. Despite these constraints, 100% of the surveyed landowners expressed a willingness to establish their own private forests. Therefore, they suggested 11 recommendations to motivate private landowners to engage in biodiversity conservation. These recommendations include financial support, capacity building, trees, and seedling, working materials, land security, parcel of land, water, sensitization, monitoring, conservation agreements, and promotion of green jobs (Fig. 6).

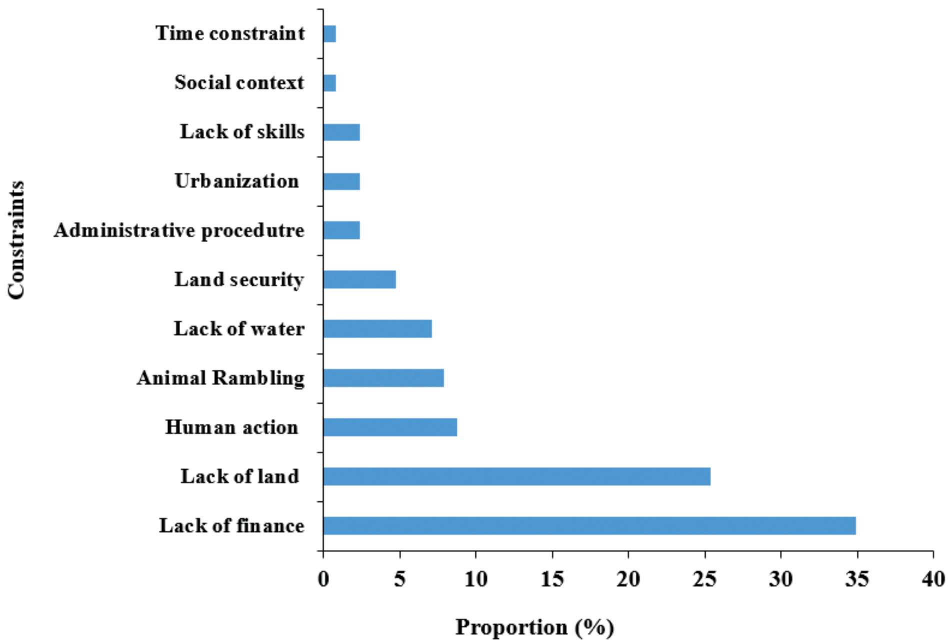

Figure 5. Communities' perception on private forest establishment constraints.

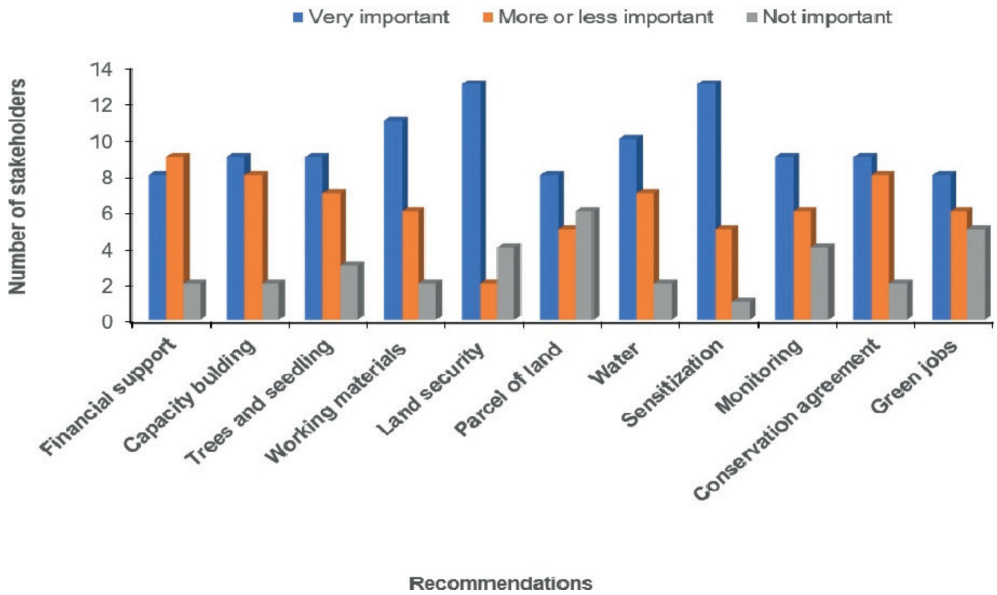

Figure 6. Stakeholder ranking of private land conservation enforcement measures.

Stakeholders' perception of incentive measures for private land conservation

The stakeholders' workshop revealed the social acceptability of private land conservation by different stakeholders. The findings showed that the stakeholders had different perceptions of the eleven recommendations addressed by landowners. Thus, upon deep discussions on these recommendations, the stakeholders ranked them based on their efficiency (Fig. 6). Results indicated that stakeholders perceived that land tenure security and landowners' awareness raising as key pathways to promote private land conservation in Burkina Faso. Furthermore, all stakeholders viewed the provision of working materials such as barrows, grating, conservation agreements between landholders and decision makers, and water as very pressing for promoting private land conservation. Nevertheless, the participants mentioned financial support as a more or less important measure.

The stakeholders, upon discussing the recommendations formulated by the landowners, indicated that the provision of financial resources in advance is not necessary for the promotion of private land conservation. Nevertheless, they proposed the development of some financial incentive instruments that could motivate landowners to engage in conservation programs. In this respect, all stakeholders identified the payment for ecosystem services as a conservation scheme.

Stakeholders stressed that the legal framework for land management is not suitable for the national social context. They reported that current land legislation lacks the capacity to secure privately-owned lands. However, the workshop identified a few measures that could support the integration of privately-owned lands in biodiversity conservation strategies. These measures include legal security of privately-owned land and easing regulations on the exploitation of natural resources in private forests.

Discussion

Species diversity and land use

The survey findings highlighted a significant floristic richness of the Gourga forest compared to the communal areas. This high species richness of the Gourga forest and the other diversity indexes could be linked to the sustainable land management practices and daily monitoring actions by the forest owner. These practices include semi-circular dikes, zai plantation pits, stone/vegetation dikes, composting, farmer-assisted natural regeneration, small-scale dams, stone cordons, and village irrigation systems. The forest also is roughly sheltered from human activities. These findings corroborate those observed by Bondé et al. (2013), who showed that protected areas are subject to less anthropogenic pressure than fallow lands which occur most of the time on communal areas and explain therefore the species richness of protected areas.

By way of contrast, the findings highlighted a low floristic diversity in the communal areas. This low species richness may be linked to anthropogenic actions combined with grazing activities, which are highly developed in the area. These findings support those of Soulama et al. (2015) who reported that vegetation in unprotected areas (fallows, grazing areas) is the most degraded due to exacerbation of anthropogenic pressure. In similar research, Kouassi et al. (2012) observed a similar trend in Côte d'Ivoire where work proved that savannah formations are the most affected by anthropogenic activities.

The largest families in both sites were the Fabaceae with 27% of forest species and 37% of communal area species and the Combretaceae with 20% of forest species and 11% of communal area species. This high prevalence of these families could be explained by the resilience capacity of these species. The findings are in line with those reported by Ouédraogo et al. (2020) who found in a similar study the prevalence of those two families in eastern Burkina Faso. This could be linked by their capacity to resist ecological and human constraints as highlighted by Bognounou et al. (2009) and Savadogo et al. (2016). Indeed, their findings indicated that these species are resilient to water stress and rainfall deficiency.

Communities' perception of the Gourga forest priority ecosystem services

The GLM analysis showed that there was no significant difference between both age and distance on the respondents' perception of the forest ecosystem services. Therefore, respondents from all age groups and villages regardless of distance perceive the ecosystem services of the forest. This robust perception of the ecosystem services of the forest could be related to the fact that both old and young people nowadays have a better awareness of the importance of natural resources on their livelihoods and well-being. The finding revealed that the Gourga forest supports the riparian communities with eighteen goods and services. These benefits refer to the classification provided by the (Millennium Environmental Assessment 2005) which recognized four main categories of ecosystem services (provisioning, regulating, supporting and cultural) with the prevalence of provisioning service. Therefore, of the total provided ecosystem services, the provisioning services were more perceived by the respondents. These findings support those observed by the Ouédraogo et al. (2020). Indeed, in their work on local people's perceptions of ecosystem services in PAs in eastern Burkina Faso, they found that people living around a PA were familiar with these four categories of ecosystem services. Despite the private ownership of the Gourga forest, the communities have recognized its range of services and benefits. Indeed, 79.36% of the respondents recognized the medicinal value of the forest whilst of them 36% indicated that the forest produces fruits. These results imply that private land conservation could be a complementary approach to improve the community's livelihood through its multiple benefits similar to those of a public forest. Further on, 26.99% of the respondents indicated that the forest contributes to the improvement of local rainfall while 23.8% of them think that it improves air purification. These findings show the potential of the forest to mitigate climate change effects. This implies that private land conservation could be an effective approach to support communities' resilience in a world threatened by climate change impact (Raymond et al. 2015).

Sustainability of private land conservation strategy

During social surveys, people suggested recommendations to promote private land conservation in Burkina Faso. Following the workshop, the stakeholders agreed on individual private land conservation as the appropriate model. For this purpose, the stakeholders prioritized the recommendations made by the populations according to their level of importance. The workshop insights show that securing land tenure and sensitizing landowners are more urgent than financial support. The results of the workshop are in line with the conclusions of Silva et al. (2021) who in a very recent study in Brazil underlined the crucial role of land tenure security in the promotion of private forestry. Indeed, the applicable land tenure laws do not guarantee sustainable investments on private land. As a follow-up to the stakeholders' insights on sustainable private land conservation in Burkina

Faso, we suggest the further promotion of the tripartite contracts between landowners, the central government and any local government hosting a private forest.

Further, to ensure that private forests are conserved in the long term, stakeholders highlighted the need for conservation agreements between landowners and the government. In particular, stakeholders stressed that land security alone does not guarantee the perpetuity of conservation activities on the privately-owned land. The finding supported the conclusions of the work of Kamal et al. (2015) who found that conservation agreements are effective legal instruments under which, ownership of the land (habisus) is conferred to a legal entity or government agency, while use rights (fructus and usus) revert to the landowner by right. We assume that this approach could serve as a window for private forestry in Burkina Faso.

Conclusion

This study, which assessed the potential of private forests, confirmed their effectiveness in conserving biodiversity and supporting local communities' livelihood if several conditions or factors are met. Therefore, findings indicated the potential of private forests as an option to increase the national protected areas network. Furthermore, this study made it possible to understand the motivations behind the establishment of the forest and the key constraints to private land conservation. Indeed, the study combined a mixed method to assess the floristic richness of the Gourga forest and to understand people's perception of private land conservation. The findings highlighted that the forest vegetation was more diverse than the communal areas. The ethnobotanical surveys provided information on forest management practices and economic management strategies. The study revealed that the Gourga forest is a source of income for the landowner and a livelihood for his family. Nevertheless, the forest owner reported some management constraints. The second phase of the ethnobotanical study identified the key ecosystem services provided to the communities despite the forest private ownership. Regarding the benefits associated with the establishment of a private forest, communities have expressed their willingness to initiate their creation. However, the research identified a few constraints that would prevent people from engaging in biodiversity conservation. Finally, the stakeholders' workshop explored the plausible future of private forests and their implementation strategies.

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Additional information

Conflict of interest

No conflict of interest was declared.

Ethical statement

No ethical statement was reported.

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Author contributions

Karafa Bognini as the main author, he conceptualized the work, collected data and prepare a first draft of this paper. Loyapin Bondé as part of the supervision team, designed the methodology and reviewed and edited this paper. Sié Sylvestre Da, Abisha Mapendembe supervised the research implementation. Roch Yao Gnabeli was the main supervisor during data collection.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Appendix 1

Table A1. Full species recorded in the private forest Gourga.

N°	Family	Species
1	Olacaceae	*Ximenia americana* L.
2	Fabaceae	*Senegalia ataxacantha* DC.
3	Fabaceae	*Vachellia nilotica* subsp. *Leiocarpa*
4	Fabaceae	*Senegalia senegal* (L.) Willd
5	Malvaceae	*Adansonia digitata* L.
6	Annonaceae	*Anona senegalensis* Pers.
7	Combretaceae	*Anogeisus leiocarpa* (DC.) Guill. & Perr.
8	Meliaceae	*Azadirachta indica* A.Juss.
9	Zygophyllaceae	*Balanites aegyptiaca* (L.) Del.
10	Fabaceae	*Senna sieberiana* DC.
11	Fabaceae	*Boscia senegalensis* Lam
12	Fabaceae	*Ceiba pentandra* (L.) Gaerth.
13	Fabaceae	*Combretum aculeatum* Vent.
14	Fabaceae	*Combretum fragans* F.Hoffm.
15	Fabaceae	*Combretum glutinosum* Perr. ex DC.
16	Fabaceae	*Combretum marginatum* Engl. & Diels
17	Fabaceae	*Combretum micranthum* G. Don
18	Fabaceae	*Combretum molle* R. Br.ex G. Don
19	Fabaceae	*Combretum nigricans* Lepr. Ex Guill. & Perr.
20	Fabaceae	*Dalbergia melanoxylon* (African Blackwood)
21	Fabaceae	*Dichrostachys cinerea* (L.) Wight & Arn.
22	Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC.
23	Fabaceae	*Faidherbia albida* (Del.) A. Chev.
24	Rubiaceae	*Feretia apodanthera* Del.
25	Moraceae	*Ficus platyphylla* Del.
26	Phyllanthaceae	*Flueggea virosa* (Roxb. Ex Willd.)
27	Rubiaceae	*Gardenia ternifolia* Schumach & Thonn. subsp. *Ternifolia*

N°	Family	Species
28	Rubiaceae	*Gardenia sokotenis* Hutch.
29	Malvaceae	*Grewia bicolor* Juss.
30	Malvaceae	*Grewia lasiodiscus* K. Schum.
31	Apocynaceae	*Holarrhena floribunda* (G. Don) T. Durand. & Schinz
32	Euphorbiaceae	*Jatropha gossypiifolia* L.
33	Anacardiaceae	*Lannea microcarpa* Engl. & K. Krause
34	Asclepiadaceae	*Leptadenia hastata* (Pers.) Decne.
35	Capparaceae	*Maerua angolensis* DC.
36	Capparaceae	*Maerua crassifolia* Forssk
37	Moringaceae	*Moringa oleifera* Lam
38	Fabaceae	*Parkia biglobosa* (Jacq.) Benth.
39	Fabaceae	*Piliostigma reticulatum* (DC.) Hochst.
40	Fabaceae	*Prosopis africana* (Guill. & Perr.) Taub.
41	Fabaceae	*Pterocarpus lucens* Lepr. ex Guill. & Perr
42	Polygaceae	*Securidaca longipedunculata* Fresen.
43	Apocynaceae	*Saba senegalensis* var. *glabriflora* (Hua) Pichon
44	Anacardiaceae	*Sclerocarya birrea* (A. Rich.) Hochst. Subsp. Birrea
45	Fabaceae	*Senegalia dudgeoni* Craib ex Holl.
46	Fabaceae	*Senegalia macrostachya* (Rchb. Ex DC.) Kyal. & Boatwr
47	Bignoniaceae	*Stereospermum kunthianum* Cham.
48	Loranthaceae	*Tapinanthus globiferus* var. *glabriflora* (Hua) Pichon
49	Combretaceae	*Terminalia avicennioides* Guill. & Perr.
50	Combretaceae	*Terminalia macroptera* Guill. & Perr.
51	Fabaceae	*Vachellia seyal* (Delile.) P.J.H. Hurter
52	Combretaceae	*Guiera senegalensis* J.F. Gmel.
53	Fabaceae	*Vachellia sieberiana* DC.
54	Sapotaceae	*Vitellaria paradoxa* C. F. Gaertn.
55	Rhamnaceae	*Ziziphus mauritiana* Lam.
56	Malvaceae	*Waltheria indica* L.
57	Fabaceae	*Senna obtusifolia* (L.) H. S. Irwin & Barneby
58	Poaceae (Gramineae)	*Pennisetum pedicellatum* Trin.
59	Poaceae (Gramineae)	*Aristida kerstingii* Pilg.
60	Poaceae (Gramineae)	*Setaria pumila* (Poir.) Roem. & Schult.
61	Asteraceae	*Aspilia africana* (Pers.) C.A. Adams
62	Convolvulaceae	*Ipomoea argentaurata* Hall. f.
63	Acanthaceae	*Blepharis maderaspatensis* (L.) B. Heyne ex Roth
64	Rubiaceae	*Spermococe intricans* (Hepper) H.M.Burkill
65	Asteraceae	*Bidens engleri* O.E. Schultz
66	Fabaceae	*Chamaecrista mimosoides* (L.) Greene
67	Poaceae (Gramineae)	*Brachiaria lata* (Schumach.) C.E. Hubbard
68	Fabaceae	*Alysicarpus ovalifolius* (Schum.) J. Léonard
69	Rubiaceae	*Spermacoce ruelliae* DC.
70	Fabaceae	*Zornia glochidiata* Reichb. ex DC.
71	Amaranthaceae	*Pandiaka heudelotii* (Moq.) Hiern

N°	Family	Species
72	Fabaceae	*Desmodium adscendens* (Sw.) DC. var. *adscendens*
73	Fabaceae	*Cassia absus* L.
74	Poaceae (Gramineae)	*Microchloa* sp.
75	Malvaceae	*Sida ovata* Forssk
76	Fabaceae	*Desmodium ospriostreblum* Chiov.
77	Rubiaceae	*Spermacoce filifolia* (Schumach. & Thonn.) J.-P. Lebrun & Stork
78	Poaceae (Gramineae)	*Brachiaria villosa* (Lam.) A. Camus
79	Fabaceae	*Stylosantes erecta* P.Beauv.
80	Poaceae (Gramineae)	*Microchloa indica* (L. f.) P. Beauv.
81	Malvaceae	*Sida alba* L.
82	Poaceae (Gramineae)	*Aristida adscensionis* L.
83	Solanaceae	*Physalis micrantha* L.
84	Malvaceae	*Corchorus olitorius* L.
85	Fabaceae	*Crotalaria retusa* L.
86	Rubiaceae	*Spermacoce verticillata* L.
87	Asteraceae	*Aspilia bussei* O. Hoffm. & Muschler
88	Fabaceae	*Calopogonium mucunoides* Desv.
89	Malvaceae	*Triumfetta rhomboidea* Jacq.
90	Poaceae (Gramineae)	*Elionurus elegans* Kunth
91	Fabaceae	*Indigofera senegalensis* Lam.
92	Lamiaceae	*Leucas martinicensis* (Jacq.) R. Br.
93	Poaceae (Gramineae)	*Rottboellia cochinchinensis* (Lour.) Clayton
94	Fabaceae	*Desmodium gangeticum* (L.) DC.
95	Poaceae (Gramineae)	*Digitaria horizontalis* Willd.
96	Malvaceae	*Wissadula amplissima* (L.) R.E. Pries var. *rostrata* (Schumach. & Thonn.)
97	Euphorbiaceae	*Acalypha ciliata* Forssk.
98	Solanaceae	*Physalis angulata* L.
99	Poaceae (Gramineae)	*Hackelochloa granularis* (L.) Kuntze
100	Asteraceae	*Acanthospermum hispidum* DC.
101	Euphorbiaceae	*Euphorbia hirta* L.
102	Amaranthaceae	*Achyranthes aspera* L.
103	Cyperaceae	*Kyllinga pumila* Michx.
104	Asteraceae	*Chrysanthellum indicum* DC. subsp. *Afroamericanum* B. L. Turner
105	Poaceae (Gramineae)	*Dactyloctenium aegyptium* (L.) Willd.
106	Poaceae (Gramineae)	*Eragrostis gangetica* (Roxb.) Steud.
107	Cyperaceae	*Cyperus difformis* L.
108	Convolvulaceae	*Ipomoea coscinosperma* Hochst.
109	Nyctaginaceae	*Boerhavia erecta* L.
110	Cyperaceae	*Bulbostylis* sp.
111	Vitaceae	*Cissus* sp.
112	Cyperaceae	*Fimbristylis ferruginea* (L.) Vahl.
113	Euphorbiaceae	*Euphorbia dregeana* E.Mey. Ex Boss.
114	Asteraceae	*Tridax procumbens* L.
115	Caryophyllaceae	*Polycarpaea corymbosa* (L.) Lam. subsp. *Corymbosa*

N°	Family	Species
116	Amaranthaceae	*Pupalia lappacea* (L.) Juss.
117	Fabaceae	*Indigofera erecta* Thunb.
118	Poaceae (Gramineae)	*Panicum laetum* Kunth
119	Lamiaceae	*Ocimum americanum* L.
120	Sapindaceae	*Cardiospermum halicacarbum* L.
121	Polygalaceaa	*Polygala arenaria* Willd.
122	Fabaceae	*Cassia nigricans* Vahl
123	Fabaceae	*Cassia absus* L.
124	Asteraceae	*Aspilia kotschyi* (Sch.Bip. Ex Hochst.)
125	Convolvulaceae	*Ipomoea ochracea* (Lindl.) G. Don
126	Poaceae (Gramineae)	*Panicum maximum* Jacq.
127	Convolvulaceae	*Ipomoea asarifolia* (Desr.) Roem. & Schult.
128	Fabaceae	*Vigna racemosa* (G. Don) Hutch. & Dalziel
129	Poaceae (Gramineae)	*Schoenefeldia gracilis* Kunth
130	Malvaceae	*Corchorus tridens* L.
131	Convolvulaceae	*Evolvulus alsinoides* (L.) L.
132	Scrophulariaceae	*Striga hermonthica* (Del.) Benth.

Appendix 2

Table A2. Full species recorded in the communal area.

N°	Families	Species
1	Meliaceae	*Azadirachta indica* A. Juss.
2	Myrtaceae	*Eucalyptus camaldulensis* Dehnh. [cult.]ptus globulus
3	Anacardiaceae	*Sclerocarya birrea* (A. Rich.) Hochst. subsp. *Birrea*
4	Fabaceae	*Tamarindus indica* L.
5	Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC.
6	Anacardiaceae	*Lannea microcarpa* Engl. & K. Krause
7	Fabaceae	*Vachellia sieberiana* (DC.)
8	Fabaceae	*Acacia sieberiana* DC.
9	Zygophyllacea	*Balanites aegyptiaca* (L.) Del.
10	Combretaceae	*Combretum micranthum* G. Don
11	Combretaceae	*Guiera senegalensis* J.F. Gmel.
12	Rhamnaceae	*Ziziphus mauritiana* Lam.
13	Fabaceae	*Cassia sieberiana* DC.
14	Fabaceae	*Piliostigma reticulatum* (DC.) Hochst.
15	Fabaceae	*Vachellia seyal* (Del.) P.J.H. Hurter
16	Fabaceae	*Faidherbia albida* (Del.) A. Chev.
17	Fabaceae	*Prosopis africana* (Guill. & Perr.) Taub.
18	Euphorbiaceae	*Jatropha gossypiifolia* L.
19	Malvaceae	*Adansonia digitata* L.
20	Asclepiadaceae	*Leptadenia hastata* (Pers.) Decne.
21	Fabaceae	*Bauhinia refescens* Lam.

N°	Families	Species
22	Capparaceae	*Maerua angolensis* DC.
23	Sapotaceae	*Vitellaria paradoxa* C. F. Gaertn.
24	Mimosaceae	*Acacia dudgeoni* Craib ex Holl.
25	Combretaceae	*Combretum glutinosum* Perr. ex DC.
26	Capparaceae	*Boscia senegalensis* (Pers.) Lam. Ex Poir.
27	Asclepiadaceae	*Calotropis procera* (WILLD) R. Br.
28	Fabaceae	*Senna obtusifolia* (L.) H. S. Irwin & Barneby
29	Convolvulaceae	*Ipomea coscinosperma* Hochst.
30	Fabaceae	*Zornia glochidiata* Reichb. ex DC.
31	Malvaceae	*Corchorus tridens* L.
32	Poaceae (Gramineae)	*Dactyloctenium aegyptium* (L.) Willd.
33	Poaceae (Gramineae)	*Eragrostis tenella* (L.) Roem. & Schult.
34	Poaceae (Gramineae)	*Digitaria horizontalis* Willd.
35	Poaceae (Gramineae)	*Setaria pumila* (Poir.) Roem. & Schult
36	Rubiaceae	*Spermacoce verticillata* L.
37	Malvaceae	*Sida alba* L.
38	Asteraceae	*Chrysanthellum indicum* DC. subsp. *Afroamericanum* B. L. Turner
39	Asteraceae	*Acanthospermum hispidum* DC.
40	Lamiaceae	*Hyptis spicigera* Lam.
41	Amaranthaceae	*Gomphrena celosioides* Mart.
42	Onagraceae	*Ludwigia abyssinica* A. Rich.
43	Rubiaceae	*Mitracarpus villosus* (Sw.) DC.
44	Cyperaceae	*Cyperus difformis* L.
45	Cyperaceae	*Cyperus rotundus* L.
46	Fabaceae	*Alysicarpus ovalifolius* (Schumach.) J. Léonard
47	Amaranthaceae	*Alternanthera sessilis* (L.) DC.
48	Poaceae (Gramineae)	*Hackelelochloa granularis* (L.) Kuntze
49	Cyperaceae	*Cyperus sphacelatus* Rottb.
50	Fabaceae	*Chamaecrista mimosoides* (*L.*) *Greene*
51	Malvaceae	*Melochia corchorifolia* L.
52	Poaceae (Gramineae)	*Pennisetum pedicellatum* Trin.
53	Solanaceae	*Physalis micrantha* Link
54	Euphorbiaceae	*Euphorbia hirta* L.
55	Malvaceae	*Abelmoschus esculentus* (L.) Moench
56	Amaranthaceae	*Amaranthus spinosus* L.
57	Poaceae (Gramineae)	*Panicum laetum* Kunth
58	Lamiaceae	*Leucas martinicensis* (Jacq.) Ait.f.
59	Commelinaceae	*Commelina benghalensis* L.
60	Fabaceae	*Indigofera senegalensis* Lam.
61	Scrophulariaceae	*Striga hermonthica* (Del.) Benth.
62	Sterculiaceae	*Waltheria indica* L.
63	Malvaceae	*Triumfetta rhomboidea* Jacq.
64	Fabaceae	*Arachis hypogaea* L.
65	Poaceae (Gramineae)	*Eragrostis tremula* Hochst. ex Steud.

N°	Families	Species
66	Poaceae (Gramineae)	*Eragrostis gangetica* (Roxb.) Steud.
67	Cyperaceae	*Fimbristylis hispidula* (Vahl) Kunth subsp. *bachyphylla* (Cherm.) Napper
68	Rubiaceae	*Spermacoce radiata* (DC.) Hiern
69	Poaceae (Gramineae)	*Andropogon gayanus* Kunth
70	Asclepiadaceae	*Leptadenia hastata* (Pers.) Decne.
71	Poaceae (Gramineae)	*Microchloa indica* (L. f.) P. Beauv.
72	Poaceae (Gramineae)	*Aristida adscensionis* L.
73	Acanthaceae	*Blepharis maderaspatensis* (L.) B.Heyne ex Roth
74	Asteraceae	*Bidens engleri* O.E. Schultz
75	Malvaceae	*Sida ovata* Forssk.
76	Poaceae (Gramineae)	*Brachiaria villosa* (*Lam.*) A. Camus
77	Convolvulaceae	*Evolvulus alsinoides* (L.)
78	Poaceae (Gramineae)	*Panicum maximum* Jacq.
79	Convolvulaceae	*Ipomoea eriocarpa* R. Br.
80	Poaceae (Gramineae)	*Schoenefeldia gracilis* Kunth
81	Poaceae (Gramineae)	*Elionurus elegans* Kunth
82	Rubiaceae	*Spermacoce filifolia* (Schumach. & Thonn.) J.-P. Lebrun & Stork
83	Polygalaceae	*Polygala arenaria* Willd.
84	Poaceae (Gramineae)	*Diheteropogon amplectens* (Nees) Clayton
85	Nyctaginaceae	*Boerhavia diffusa* L.