



Assessing human pressure on wild food and forage tree species for designing effective conservation actions in West Africa Sahel region

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Research

Abstract

Background: High harvesting of Non-Timber Forest Products (NTFPs) for food and fodder supply leads many tree species to be vulnerable or endangered due to overexploitation. This study aimed to assess harvesting pressure on food and forage species and to understand how the socio-economic profile of people affects their perception on species state as well as on the impact of harvesting methods on species dynamics.

Methods: Semi-structured ethnobotanical surveys were conducted near the active stakeholders involved in NTFPs harvesting - children, women, herders, and former actors (old persons >50 years old, both women and herders). Hundred and four (104) people from 4 ethnic groups were interviewed. We have calculated the overharvesting index (OI) based on three pressure parameters: Fidelity level of use (FL), Relative frequency of harvesting (FH) and Relative intensity of pruning (IP). The difference between respondent's perceptions on species state was tested using logistic regression followed by analysis of variance of the model.

Results: The overharvesting index (OI) showed that eight (8) species are overharvested of which the first three species are *Pterocarpus erinaceus* Poir (OI = 122.1%), *Saba senegalensis* (A. DC.) Pichon (OI = 100%) and *Lannea microcarpa* Engl. & K. Krause (OI = 97.4%). These overharvested species are generally exploited using destructive methods, especially branch pruning for leaves and/or fruits

harvesting. Local people's perception on species state was significantly influenced by the type of actors and their age ($p < 0.0001$ for both). This suggests that specific awareness message considering socio-economic profiles of people need to be developed for a truth conservation impact on the field. 82.3% of respondents declared that harvesting methods have no significant impact on species state, revealing that most people are still using forest resources in traditional considerations.

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**Ethnobotany Research & Applications
21:30 (2021)**

Conclusion: Raising awareness, based on scientific information highlighting the effects of harvesting methods on the regeneration and functional traits of NTFPs species, could contribute positively to changing people's consideration of the sustainable use of species.

Keywords: Harvesting methods, Local perception, NTFPs, Overharvesting, Stakeholders

Résumé

Contexte: La forte récolte de produits forestiers non ligneux (PFNL) pour l'alimentation et le fourrage rend de nombreuses espèces d'arbres vulnérables en raison de leur surexploitation. Cette étude vise à évaluer la pression de la récolte sur les espèces alimentaires et fourragères et à comprendre comment le profil socio-économique des personnes affecte leur perception sur l'état des espèces ainsi que sur l'impact des méthodes de récolte sur la dynamique des espèces.

Méthodes: Des enquêtes ethnobotaniques basées sur un interview semi-structurée ont été menées auprès des acteurs actifs impliqués dans la récolte des PFNL (enfants, femmes, éleveurs) et des anciens acteurs (personnes âgées >50 ans). 104 personnes de 4 groupes ethniques ont été interrogées. Nous avons calculé l'indice de surexploitation (OI) sur la base de trois paramètres de pression que sont le niveau de Fidélité d'utilisation (FL), la Fréquence relative de récolte (FH) et l'Intensité relative d'élagage (IP). En ce qui concerne la perception des répondants sur l'état des espèces, la différence entre les groupes a été testée à l'aide d'une régression logistique suivie d'une analyse de la variance du modèle.

Résultats: L'indice de surexploitation (OI) a montré que huit (8) espèces sont surexploitées, dont les trois premières sont représentées par *Pterocarpus erinaceus* Poir. (OI = 122,1%), *Saba senegalensis* (A. DC.) Pichon (OI = 100%) et *Lannea microcarpa* Engl. & K. Krause (OI=97,4%). Ces espèces surexploitées sont généralement exploitées par des méthodes destructrices, notamment par l'élagage des branches pour la récolte des feuilles et/ou des fruits. La perception des populations locales sur l'état des espèces a été significativement influencée par le type d'acteur et l'âge ($p < 0,0001$, respectivement). Cela suggère qu'un message de sensibilisation spécifique tenant compte des profils socio-économique des personnes doit être développé pour obtenir un impact large sur la conservation des espèces. 82,3% des personnes interrogées ont déclaré que les méthodes de récoltes n'ont pas d'impact significatif sur l'état des espèces, ce qui

révèle que la majorité des gens continuent à exploiter les ressources forestières selon leurs considérations traditionnelles.

Conclusion: La sensibilisation des populations, basée sur des informations scientifiques mettant en évidence les effets des méthodes de récolte sur la régénération des espèces de PFNL et leurs caractéristiques fonctionnelles, pourrait positivement contribuer à changer leur considération en faveur de l'utilisation durable des espèces.

Mots-clés: Méthodes de récolte, Perception locale, PFNL, Surexploitation, Parties prenantes

Background

Tropical forest ecosystems are reservoirs of biodiversity which plays a fundamental role in meeting the basic needs of local communities (Agbo *et al.* 2017). Indeed, food, medicine and energy supplying are the most important ecosystem services provided by terrestrial ecosystems to local people (Ouédraogo *et al.* 2020). West African natural vegetation is dominated by savanna ecosystems which remain the main ecosystems providing timber and non-timber forest products to local people for meeting their subsistence needs (Nacoulma *et al.* 2011, Wittig *et al.* 2007). Climate change is one of the main factors adversely affecting annual crop production in developing countries (Mbow *et al.* 2014), leading to the impoverishment and persistence food shortages in many African areas such as the Sahel region. Therefore, wild food species are heavily exploited by local people to improve food security and their livelihoods causing high human pressure on savanna species (Ouédraogo *et al.* 2017, Pouliot 2012). In addition to providing for human consumption, tree species play a critical role in livestock production in arid and semi-arid ecosystems (Bognounou *et al.* 2013). They are a potential source of forage for livestock during the dry season when is lack of fodder in grassland pastures. The harvesting NTFPs for food and forage renders many tree species vulnerable or endangered due to overexploitation and also contributes to savanna degradation resulting in biodiversity loss (Bondé *et al.* 2020). Given their importance, conservation and sustainable management of savanna species are considered a great challenge in arid and semi-arid regions. Many studies have been conducted in West Africa on food and forage species to improve their management.

These studies focused on the harvesting methods used, estimation species productivity and assessment of their vulnerability (Bognounou *et al.* 2013, Bondé *et al.* 2019, Ouédraogo *et al.* 2014,

Ouédraogo *et al.* 2017, Traoré *et al.* 2011). However, to formulate effective conservation actions (e. g. people awareness) for food and forage species, it is essential to understand people's perception on the dynamics of these species and the impact of harvesting methods used on individual trees as well as at the species population level. Socio-economic characteristics of people (ethnicity, gender, age, occupation etc.) are important factors affecting the management and uses of forest resources, including preferences and valorisation (Agùdez *et al.* 2020, Ouédraogo *et al.* 2013). In general, children (<18 years old) are rarely considered in studies dealing with local people perception of species conservation (Tiétiambou *et al.* 2016) although they are the future actor of management. Their involvement will provide a wide range of perception which could be an excellent way to define appropriate conservation actions and secure the long-term conservation of biodiversity. In addition, the degree of human pressure on species is generally specific regarding their socio-economic importance (Wezel & Lykke 2006). Therefore, assessing human pressure on specific species is essential information for designing effective conservation actions for each species. Vulnerability index is generally used to assess the potential vulnerability of species based on their use categories, the organ used and their ecological and biological characteristics (Betti 2001). The use categories of species express the attention that they

receive from community, however, the number of use categories might not correspond to real and active use of those species by the community (Albuquerque *et al.* 2009). Therefore, the common vulnerability index does not assess human pressure on the species because a species may be considered vulnerable when it is not actually exploited by people in practice. It is necessary to define parameters enable to measure effective human pressure on species. The objectives of this study were to: (i) assess harvest pressure on wild food and forage tree species and (ii) grasp people perception on species state as well as on the impact of harvesting methods used. The following three research questions are addressed:

1. are overexploited species perceived as rarest species by local people?
2. is people's perception on species state associated to their socio-economic profile?
3. are harvesting methods considered as factors influencing species dynamics?

Materials and Methods

Study site

The study was conducted in the rural municipality of Douroula located in the western part of Burkina Faso (Figure 1).

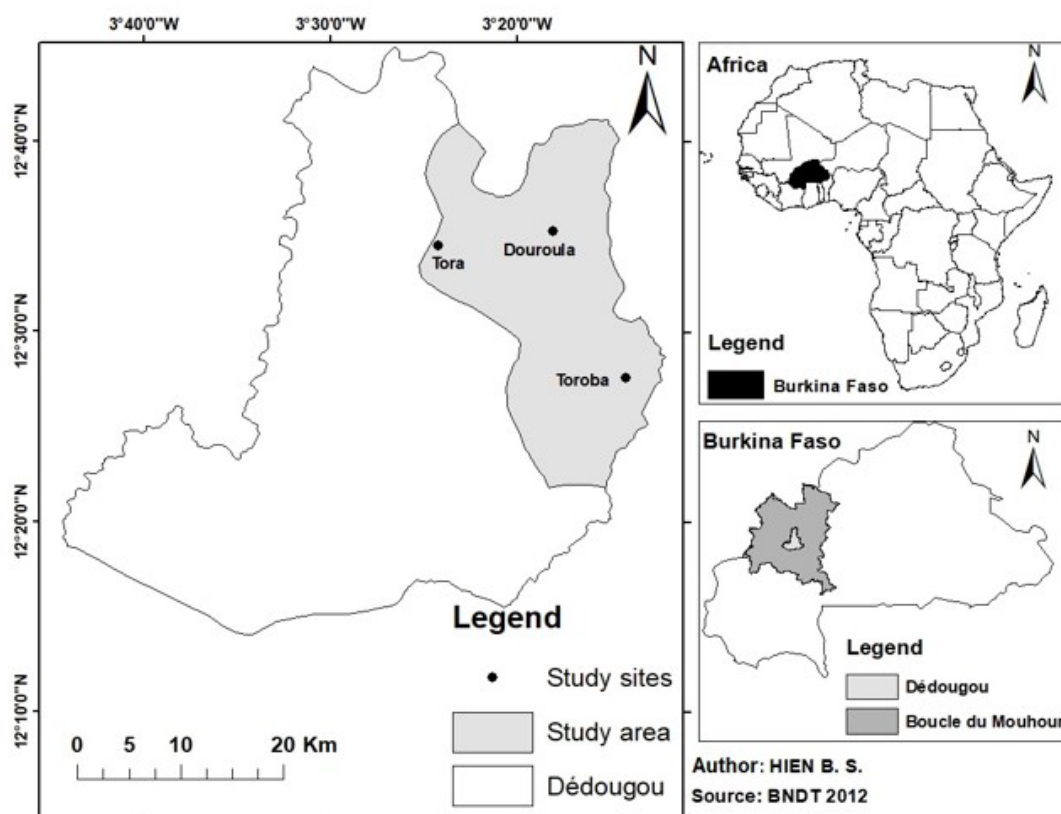


Figure 1. Location of the study area

Douroula belongs to the Boucle du Mouhoun region, which has four major ethnic groups: Bwa, Dafing, Mossi and Fulani (RGPH 2006). Regarding climate conditions, the study site is located in the Sudano-Sahelian climatic zone with annual rainfall ranging from 600 mm to 900 mm and annual temperature from 20°C to 30°C (Dipama 2010). The main soil types of the study area are represented by less developed soils, eutrophic brown soils and leached ferruginous soils (Traoré & Anne 2010). The landscape pattern is a mosaic of agroforestry parklands, natural savannas and riparian forests (Sambaré *et al.* 2011). Wood flora is dominated by Sudanian and Sahelian species such as *Vachellia seyal* P.J.H. Hurter., *Vachellia sieberiana* DC., *Combretum micranthum* G. Don, *Combretum glutinosum* Perr. ex DC, *Combretum nigricans* Lepr. ex Guill & Perr., *Guiera senegalensis* J. F. Gmel., *Anogeissus leiocarpa* (DC.) Guill. et Perr, *Burkea africana* Hook. F, *Daniellia oliveri* (R.) Hutch. & Dalz. C, *Diospyros mespiliformis* Hoschst. ex A. DC., and *Isobertinia doka* Craib. & Stapf (Traoré *et al.* 2012). The main human activities linked to the use of the region's natural resources are dominated by agriculture, animal husbandry and fishing. The Boucle du Mouhoun region faces annual food insecurity due to low agriculture productivity caused by climate variability. Therefore, wild food and forage species are subject to heavy exploitation, making these species vulnerable in this region (Gaisberger *et al.* 2017). The authors recommended the implementation of urgent conservation actions to ensure the long-term conservation of NTFP species in the region.

Data collection

Ethnobotanical surveys based on socio-economic profile of people was conducted in rural municipality of Douroula. Surveys were conducted among actors active in NTFPs harvesting (children, women, herders) and former actors (old persons both women and herders). All interviewees belonged to 4 ethnic groups, including the Dafing, Fulani, Mossi and Bwa. Children, women and herders were considered because they are the main actors involved in NTFPs harvesting. Therefore, their perception on NTFP species conservation is significant for the development of management policies. Former actors represented by old persons (>50 years old) were specifically targeted because they can provide reliable information on the spatio-temporal dynamics of NTFP species. Knowledge of these actors can help active actors to better understand the impact of human pressure on species dynamics and lead them to take actions that promote the sustainable use of the species. A total of 104 respondents were interviewed in May 2020 with at least 26 persons per

ethnic group (6 children, 7 women, 7 herders and 6 old persons) and grouped into four age classes (class 1: <18 years old; class 2: 18-36; class 3: 37-54 and class 4: >54 yearsold). A survey based on a semi-structured interview was adopted. In this interview the respondents give extensive responses to a series of general questions, some of which have been prepared in advance and some of which arise naturally during the conversation (Martin 1995). The respondent is invited to answer exhaustively in its own terms and with his own frame of reference to the questions asked to him (Séréme *et al.* 2008). This technique, also known as informal discussions, is considered the core of good participatory rural appraisal (Rastogi 1999). Therefore, it is commonly used in ethnobotanical studies in West Africa (Ouédraogo *et al.* 2013; Tiétiambou *et al.* 2016; Traoré *et al.* 2021). The main information collected were food and forage species used in practice, harvesting frequency and methods used, organ harvested, species state, impact of harvesting methods on species dynamics. Respondents were asked to list the species by their vernacular name that they use. With support of the local guide, sample of species not identified during the survey were collected and brought to the Laboratory of Plant Biology and Ecology of the University Joseph Ki-Zerbo for identification (Ramos *et al.* 2008).

Data analysis

Human pressure on individual species was assessed using three pressure parameters, namely the fidelity level of use (FL), the relative frequency of harvesting (FH) and the relative intensity of pruning (IP). FL was calculated using equation 1 which is based on effectively used of the species by respondents (Alexiades & Sheldon 1996). FH was calculated based on the number of times that respondents harvest the species per week (equation 2) while IP related to branch pruning for leaves and/or fruit harvesting was calculated using equation 3. Branch pruning is a destructive method that affects morphological (number of branches, crown) and physiological (seed production and quality) traits of species. The perceptible consequences of this method are often the death of trees and a reduction in seed production during several years with corollary on the regeneration of the species. When tree branches are pruned, they could take some few years to have new fruiting branches (Sida *et al.* 2018). Therefore, pruning was considered as strong pressure on species compared to fruit gathering. The importance of human pressure on a given species was estimated by summing the three pressure parameters and was considered as overharvesting index (OI).

$$FL (\%) = \frac{\text{Number of respondents using species } i}{\text{Total number of respondents}} \times 100 \quad (1)$$

$$FH (\%) = \frac{\text{Total number of times that species } i \text{ was harvested by respondents per week}}{\text{Total number of times that all species were harvested}} \times 100 \quad (2)$$

$$IP (\%) = \frac{\text{Number of respondents who harvest species } i \text{ using branch pruning}}{\text{Total number of respondents}} \times 100 \quad (3)$$

Values of FL, FH and IP are ranging from 0 to 100% and those of OI from 0 to 300% (OI = FL + FH + IP). Selection approach adopted by Snook *et al.* (2005) was applied in this study for selecting overharvested species. Therefore, quantile analysis was performed to overharvesting indexes and species with OI above the 75th percentile (third quartile) were considered as overharvested species in the study area. Logistic regression was used to test the difference between socio-economic groups in terms of their perception on species state as well as the difference in harvesting methods used. For data analysis, responses of informants were coded using two scale points: 0 = declining and 1 = abundant for species state; 0 = fruit gathering and 1 = branch pruning for harvesting methods used. Generalized Linear Model (family = binomial, link = logit) followed by analysis of variance of the model was performed to test difference between groups both for perception of people on species state and harvesting methods used. Scores 0 = declining and 1 = abundant was also used to appreciate the overall perception of each group on species state by calculating the mean values, which varied from 0 to 1. Mean scores tending toward 0, indicate that species are declining while species are considered abundant when mean scores tend toward 1. Moreover, these mean scores were calculated for each species to appreciate respondents' perception on individual species. However, these mean scores were applied for species cited by at least 5 respondents. All statistical analyses were performed using the statistical software R 3.6.2. (R core Team 2019).

Results

Overharvested species

In study site, 29 tree species were cited as species frequently used for food and fodder supplying. Of these, 12 species are harvested for human consumption and 17 species for animal feed (Table 1).

Overharvesting index (OI) calculated from three pressure parameters showed that eight (8) species are overharvested (OI \geq 3rd quartile) by people. These species are represented by *Pterocarpus erinaceus* Poir. (OI = 122.1%), *Saba senegalensis*

(A. DC.) Pichon (OI = 100%), *Lannea microcarpa* Engl. & K. Krause (OI = 97.4%), *Khaya senegalensis* (Desr.) A. Juss (OI = 82.3%), *Tamarindus indica* L. (OI = 73.4%), *Parkia biglobosa* (Jacq.) R. Br. ex G. Don (OI = 69.8%), *Vitellaria paradoxa* C.F.Gaertn (OI = 69.1%) and *Pterocarpus lucens* Guill. & Perr. (OI = 53.6%). Except for *Vitellaria paradoxa* C.F.Gaertn, all overharvested species are primarily harvested using branch pruning. Index for species belonging to the degree "medium-harvesting" (median \leq OI \leq 3rd quartile) and "low-harvesting" (OI<median) are indicated in Figure 2.

Local people perception on species state

Statistical analysis showed that local people's perception of the current and future status of species used is not significantly influenced by their ethnicity (Table 2). All ethnic groups perceived the species to be abundant (mean score > 0.50) in their present state (Table 3). Contrary to ethnic group, actor type and age of respondents were found to be significant factors affecting people perception on species state (Table 2). At the actor level, both extreme perceptions indicating that species are abundant and declining in their present state were recorded in the children group (mean score = 0.79) and the stockbreeder group (mean score = 0.48) respectively. Regarding respondents age, children (class 1) considered that species are abundant (mean score = 0.79) in the present state while species are declining (mean score = 0.34) according to old persons (class 4). Detailed scores per actor type and age class are given in Table 3.

Among overharvested species, four species were perceived as declining species by respondents, especially *Pterocarpus erinaceus* Poir. (mean score = 0.33), *Khaya senegalensis* (Desr.) A. Juss (mean score=0.33), *Parkia biglobosa* (Jacq.) R. Br. ex G. Don (0.33) and *Pterocarpus lucens* Guill. & Perr. (mean score = 0.31). In contrast, *Lannea microcarpa* Engl. & K. Krause (score = 0.94), *Saba senegalensis* (A. DC.) Pichon (mean score = 0.64), *Tamarindus indica* L. (mean score = 0.86) and *Vitellaria paradoxa* C.F.Gaertn. (mean score = 0.70) are perceived as abundant species. Mean scores for all species are presented in appendix (Table A1).

Table 1. Species used by respondents and their corresponding use category, part used and harvest methods

Use category	species used	Part used	Harvest method
Food	<i>Adansonia digitata</i> L.	Le	Pr+Co
	<i>Balanites aegyptiaca</i> (L.) Delile	Le-FI-Fr	Pr+Ga
	<i>Bombax costatum</i> Pellegr. & Vuillet	Le-FI	Pr+Co
	<i>Diospyros mespiliformis</i> Hochst. ex A. Rich.	Fr	Pr+Co
	<i>Gardenia erubescens</i> Stapf & Hutch.	Fr	Co
	<i>Lannea microcarpa</i> Engl. & K. Krause	Fr	Pr
	<i>Parkia biglobosa</i> (Jacq.) R. Br. ex G. Don	Fr	Pr+Co
	<i>Saba senegalensis</i> (A. DC.) Pichon	Fr	Pr+Co
	<i>Sclerocarya birrea</i> (A. Rich.) Hochst.	Fr	Co
	<i>Tamarindus indica</i> L.	Le-Fr	Pr+Co
	<i>Vitellaria paradoxa</i> C.F.Gaertn.	Fr	Ga
	<i>Ximenia americana</i> L.	Fr	Co
Forage	<i>Boscia angustifolia</i> A. Rich.	Le	Pr
	<i>Boscia senegalensis</i> (Pers.) Lam. ex Poir.	Le	Pr
	<i>Cassia sieberiana</i> DC.	Fr	Co+Ga
	<i>Entada africana</i> Guill. & Perr.	Le	Pr
	<i>Ficus gnaphalocarpa</i> (Miq.) A. Rich	Le	Pr
	<i>Khaya senegalensis</i> (Desr.) A. Juss.	Le	Pr
	<i>Leptadenia hastata</i> (Pers.) Decne.	Le	Pr
	<i>Piliostigma reticulatum</i> (DC.) Hochst.	Fr	Co
	<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	Fr	Co
	<i>Pterocarpus erinaceus</i> Poir.	Le	Pr
	<i>Pterocarpus lucens</i> Guill. & Perr.	Le	Pr
	<i>Senegalia laeta</i> (R.Br. ex Benth.) Seigler & Ebinger	Le	Pr
	<i>Senegalia macrostachya</i> (Rchb. Ex DC.) Kyal. & Boatwr	Fr	Co+Ga
	<i>Sterculia setigera</i> Del.	Le	Pr
	<i>Stereospermum kunthianum</i> Cham.	Le	Pr
	<i>Tapinanthus</i> Sp.	Le	Pr
<i>Vachellia seyal</i> P.J.H.Hurter	Le	Co+Ga	

Pr: Pruning ; Ga: Gathering ; Co: Collecting ; Le: Leaves ; FI: Flower ; Fr: Fruits

Table 2. Summary of statistical analysis (GLM) presenting the effect of the perception of respondent on species state

	Df	Sum sq	Mean sq	F value	Pr (>F)
Ethnic group	3	0.84	0.842	3.861	0.050
Actor	3	3.35	3.349	15.364	1.03 e ⁻⁴ ***
Age	3	8.74	8.736	40.076	6.03 e ⁻¹⁰ ***

Note: *** indicated significant factors (p<0.0001)

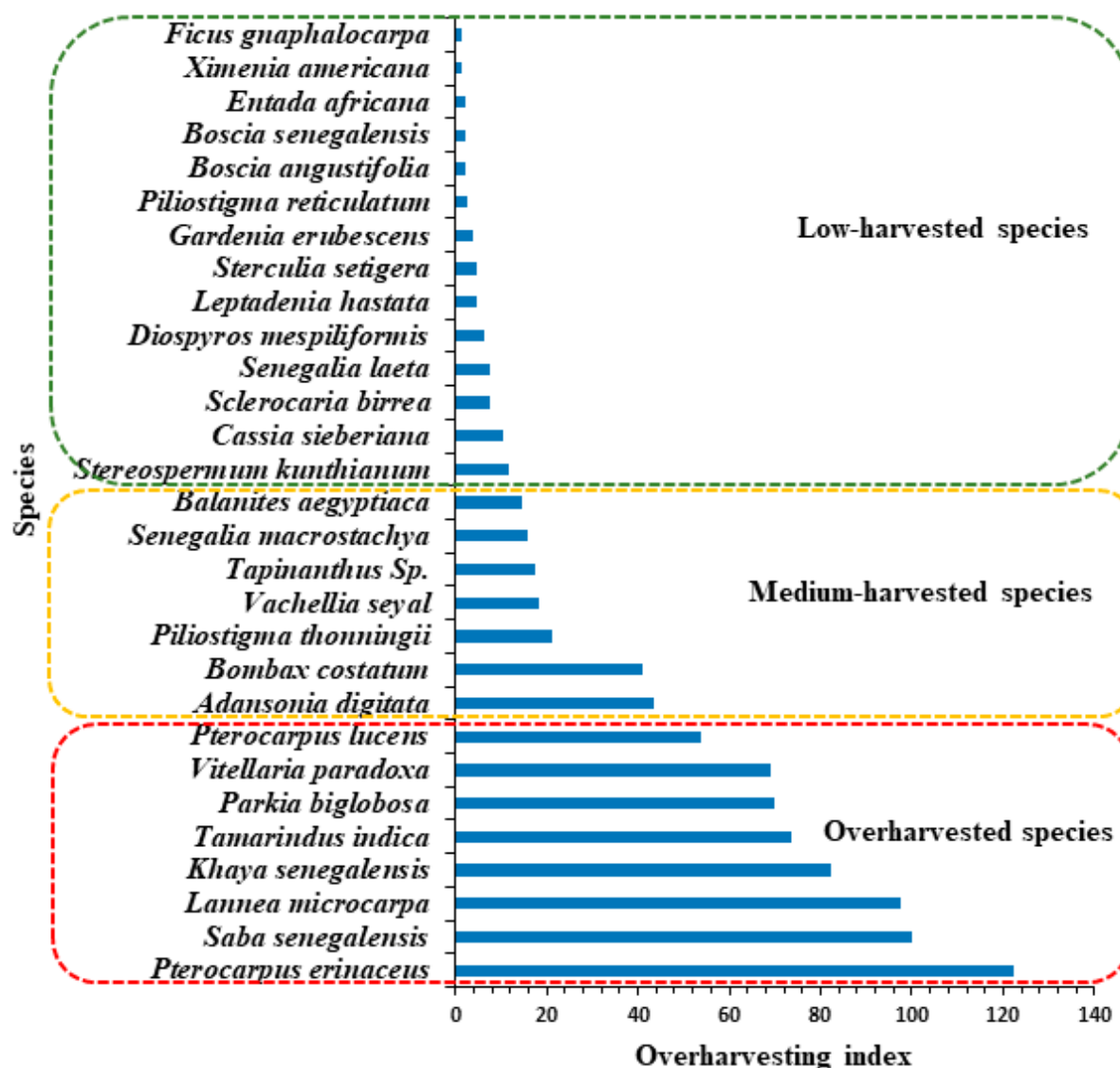


Figure 2. Harvesting pressure on food and forage tree species in Douroula.

Table 3. Appreciation of local people perception on species state and on harvesting method used based on mean score values (MS)

		Species state	Method used
Ethnic groups	Dafing	0.57	0.81
	Fulani	0.56	0.74
	Mossi	0.57	0.74
	Bwa	0.57	0.83
Actors	Children	0.79	0.76
	Women	0.51	0.78
	Herders	0.48	0.78
	Former actors	0.25	0.83
Age classes	Class 1	0.79	0.76
	Class 2	0.50	0.79
	Class 3	0.49	0.79
	Class 4	0.34	0.82

Note: For species state, MS>0.50 indicates that the species are abundant while for the harvesting method used, MS>0.50 indicates that branch pruning is used more for harvesting than gathering

Harvesting methods used and people perception on their impact on species

GLM results showed that there is no significant difference between socio-economic groups in terms of methods used for harvesting, indicating the use of a given method is not associated with a specific group. Regarding the respondent's perception on method used, 82.3% of respondents mentioned that the harvesting methods (table 1) do not have a significant effect on species dynamics while 17.7% of respondents gave a opposite perception.

Discussion

Overharvested species

Human pressure on the species was measured in terms of the actual use of the species by people, the frequency of harvesting and the method harvesting used. Species found to be overharvested belong to both food species (*S. senegalensis* (A. DC.) Pichon, *L. microcarpa* Engl. & K. Krause, *T. indica* L., *V. paradoxa* C.F. Gaertn. and *P. biglobosa* (Jacq.) R. Br. ex G. Don) and forage species (*P. erinaceus* Poir., *K. senegalensis* (Desr.) A. Juss and *P. lucens* Guill. & Perr.). Fruits from the first group of species are available during the food shortage season and are therefore intensively harvested by people to meet their daily food needs (Thiombiano *et al.* 2010). They are also harvested to generate income, especially by poorest households to meet certain financial needs such as schooling, purchasing medicine, food and dressing (Lamien *et al.* 2009, Pouliot 2012). For instance, the selling of *V. paradoxa* C.F. Gaertn., *P. biglobosa* (Jacq.) R. Br. ex G. Don, *T. indica* L. and *S. senegalensis* (A. DC.) Pichon fruits has proven to be one of the most important sources of income for households in The South-western region of Burkina Faso (Ouédraogo *et al.* 2013). Regarding the second group of species, their leaves are heavily harvested by herders to provide forage for livestock (Gaoué & Ticktin 2009). *P. erinaceus* Poir., *K. senegalensis* (Desr.) A. Juss. and *P. lucens* Guill. & Perr. are cited as the main sources of forage in dry season. Because forage resources are insufficient in dry season, branches of these species are therefore strongly pruned to feed livestock (Nacoulma *et al.* 2011). In the study area, *P. erinaceus* Poir. is the most overharvested species to feed livestock both for extensive and intensive livestock farming. In the last system, branches of the species are pruned, and leafy twigs are collected and brought to home for livestock feeding (Figure 3). In general, overharvested species are those whose products are available in food shortage period for both humans and animals, indicating that harvesting pressure on species increases with needs.

Local people perception on species state

Our findings showed that local perception on species state in the study area is not dependent on ethnic group. In general, local knowledge of species uses, management and ecology is associated with people ethnicity (Ayantunde *et al.* 2008, Elias *et al.* 2012), suggesting that people's perception of species dynamics may likely vary across ethnic groups. In this study, similar perception observed among ethnic groups on species state indicates that appreciation of resources' availability is independent of ethnicity. Due to the fact that the ethnic groups use the same species for food and forage supply in a specific ecological zone, their perception of the species availability tends to be harmonized. Some authors have also found that ethnicity does not have a significant influence on local knowledge in oil plant uses in Western part of Burkina Faso (Tiétiambou *et al.* 2016). Actor type and age of respondents were found to be important factors affecting people perception on species state for both current and future state. The socio-economic profile of respondents significantly influenced their perception on species state. For actors mainly involved in harvesting, processing and selling NTFP for food (children and women) species are perceived to be abundant, while those involved in forage harvesting (herders) consider species to be declining. These perceptions could be related to the interest that each professional group gives to specific groups of species. Children and women are generally focused on the harvesting of fruit species which are the most present in agroforestry parks. Food species such as *V. paradoxa* C.F. Gaertn. *T. indica* L., *L. microcarpa* Engl. & K. Krause, *P. biglobosa* (Jacq.) R. Br. ex G. Don are the main species generally protected during field clearing (Augusseau *et al.* 2006, Yaméogo *et al.* 2005). These species are therefore frequently observed in the parklands, giving these actors the impression that the species they exploit are abundant. In contrast, herders focus primarily on tree forage species that are rarely conserved by people in parklands. Traditionally, grazing for tree forage is generally done in natural savanna ecosystems (Bognounou 2009). The West African savannas are undergoing rapid land-use changes due to rapid human population growth and the resulting increased interest in cash-crop production, infrastructure, and forest product harvesting (Ouédraogo *et al.* 2010, Wittig *et al.* 2007), leading to the decline of the populations of many trees' species in croplands. In this context, forage species that used to be available near the villages are becoming rare and are observed at long distance. As a result, herders travel long distances in the dry season to find fodder for animals, which explains their perception of species decline.

With respect to age, children felt that food and forage species are abundant in their current state while older persons felt the opposite (i. e. species are declining). Older persons are likely to have a better perception of the changes in plant formations over time. This is because people who have lived in a given area for least 20 years witness changes in the

landscape and increased human pressure on certain species, and thus can provide accurate information about species dynamics more than children (Ouoba *et al.* 2014, Paré *et al.* 2010). Some studies have also shown that children have little botanical and ethnobotanical knowledge compared to old persons (Ayantunde *et al.* 2008, Tiétiambou *et al.* 2020).



Figure 3. Process of harvesting *Pterocarpus erinaceus* Poir. leafy branches for livestock feeding: (A) Branch pruning; (B) Harvesting of leafy twigs; (C) Storage of leafy twigs and (D) Livestock feeding

Harvesting methods used and people perception on their impact on species

The results showed that harvesting methods used by people were not associated to their socio-economic profile, suggesting that people use almost the same methods regardless of their ethnicity, profession and age. For most respondents (82.3%), harvesting methods used (uncontrolled branch pruning, fruit gathering and direct fruit harvesting on trees) did not have significant impact on species state. Regarding

fruit harvesting and gathering, their effects on species dynamics are often not perceptible in the short term, which may explain why people considered these methods to have no significant impact on species state. However, these methods can have a significant effect on species population dynamics. In the medium to long term, they can cause an imbalance between young and adult individuals of the species because they contribute to the reduction of seedling recruitment in natural

ecosystem and can change the age classes distribution individuals (Mapongmetsem *et al.* 2012). For branch pruning, the majority of people also think that using this method to harvest fruits and leaves does not impact the species being exploited. A survey conducted in Burkina Faso on *P. erinaceus* Poir. showed that only less than 5% of respondents believe that branch pruning affects the species dynamic (Rabiou *et al.* 2017). These results reveal that people still exploit forest resources according to traditional and empirical considerations. However, scientific studies undertaken on productivity of some forage species such as *Faidherbia albida* (Del.) Chev., *K. senegalensis* (Desr.) A. Juss. and *Azvelia africana* Smith ex Pers. have shown that intensive and frequent pruning of branches for forage harvesting reduce their fruit production and seed availability for seedlings recruitment (Gaoué & Ticktin 2007, Nacoulma *et al.* 2016, Sida *et al.* 2018). In fact, branch pruning compromises seed production in the short and medium term since pruned branches may take several years to produce again. According to Bognounou *et al.* (2008), repeated pruning of the same individual trees over several years leads dangerously, and in some cases irreversibly, to the decline of populations of forage species.

Conclusion and implication for conservation

This study highlighted food and forage tree species that are subject to overharvesting by local people in the western region of Burkina Faso. Specific conservation actions should be developed to ensure the conservation of these species. For example, *L. microcarpa* Engl. & K. Krause and *V. paradoxa* C.F.Gaertn. are among the overexploited species, even though they are perceived as abundant by local people. This indicates that if concrete conservation actions are not implemented, overexploitation will lead to the decline of populations of these species as is the case of *P. erinaceus* Poir.. Tree planting and assisted natural regeneration of these species are avenues to be explored to increase the availability and productivity of these species, which could reduce human pressure on them. This study also showed that the perception of local people on the state of the species varies according to their role in the exploitation of NTFPs and their age. Therefore, in order to have a real impact on the ground in terms of species conservation, it is imperative that awareness on sustainable management of these species and environmental education take these factors into account to provide appropriate training and awareness messages to each specific group. Contrary to the perception on the state of the species, the majority of respondents declared that harvesting methods do not have a significant impact

on species state, revealing that people continue to exploit forest resources without being aware of the impact of harvesting methods used on these resources. Based on scientific information that highlights the effects of harvesting methods on the regeneration of NTFPs species and their functional traits, awareness raising could contribute to a positive change in people's attitudes towards sustainable use of the species.

First, for *V. paradoxa* C.F.Gaertn., *P. biglobosa* (Jacq.) R. Br. ex G. Don, *S. macrostachya* (Rchb. Ex DC.) Kyal. & Boatwr, whose fruits and/or seeds are entirely harvested and cooked by the people, the technique of partial harvesting of the fruits could be adopted to maintain a seed potential on each individual and to carry out tree planting and assisted natural regeneration of these species to reduce the harvesting pressure on these individuals. Second, for *P. erinaceus* Poir., *K. senegalensis* (Desr.) A. Juss., *P. lucens* Guill. & Perr., *A. digitata* L., *B. costatum* Pellegr. & Vuillet, which are heavily pruned for their leaves and/or flowers, partial pruning of small branches for leaves and/or flowers could allow them to produce the seeds needed for regeneration of these species.

Declarations

Abbreviation list: Co: Collecting; FH: Frequency of Harvesting; FL: Fidelity Level of use; FI: Flower; Fr: Fruits; Ga: Gathering; GLM: Generalized Linear Model, IP: Intensity of Pruning; MS: Mean Score, NTFP: Non-Timber Forest Product; OI: Overharvesting Index; Pr: Pruning

Ethics approbation and participation consent: Individual consent to participate in the study was obtained prior to the administration of the questionnaire. Only people that consented to participate in the study were considered.

Data and material availability: In this study, data treated are available for eventual request by the journal.

Funding: This work was funded by Rufford Foundation, through Rufford Small Grant awarded to Bondé Loyapin [27752-1] and by the Ministry of Higher Education, Scientific Research and Innovation of Burkina Faso for scholarship provided to Hien Bossila Séraphin [00V929]

Interest conflict: authors declare that there is no conflict of interest.

Author's contribution: BSH: data collection and analysis, manuscript writing; LB: Study design, data analysis and manuscript writing; SSD, FB, IJB and OO: manuscript revision.

Acknowledgements

We are grateful to Rufford Foundation and the Ministry of Higher Education, Scientific Research and Innovation of Burkina Faso for their support. We thank Mr Bakari Démé for field assistance and local people for their active participation during data collection. The authors are grateful to the anonymous reviewers for the constructive comments that greatly improved this manuscript.

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Appendix

Table A1. Mean scores indicating species state according to local people perception and frequency of use

Species	Present state	Frequency of use
<i>Tapinanthus</i> sp.	0.14	8.3
<i>Stereospermum kunthianum</i> Cham.	0.2	5.2
<i>Bombax costatum</i> Pellegr. & Vuillet	0.31	20.8
<i>Pterocarpus lucens</i> Guill. & Perr.	0.31	23.9
<i>Pterocarpus erinaceus</i> Poir.	0.33	55.2
<i>Khaya senegalensis</i> (Desr.) A. Juss.	0.33	36.4
<i>Parkia biglobosa</i> (Jacq.) R. Br. ex G. Don	0.33	31.2
<i>Senegalia macrostachya</i> (Rchb. Ex DC.) Kyal. & Boatwr	0.44	10.4
<i>Vachellia seyal</i> P.J.H.Hurter	0.54	12.5
<i>Saba senegalensis</i> (A. DC.) Pichon	0.64	44.8
<i>Vitellaria paradoxa</i> C.F. Gaertn.	0.7	53.1
<i>Cassia sieberiana</i> DC.	0.71	7.3
<i>Adansonia digitata</i> L.	0.81	19.8
<i>Tamarindus indica</i> L.	0.86	33.3
<i>Balanites aegyptiaca</i> (L.) Delile	0.87	8.3
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	0.91	13.5
<i>Lannea microcarpa</i> Engl. & K. Krause	0.94	42.7