A: Survey questionnaire

Tree Diversity in Agroforestry Parklands of Obalanga, Alito and Okungur sub-counties, Kapelebyong district, Uganda

A: Introduction

1. Date: …….
2. Respondent number: ……. Farmer group name:……..
3. Village: ..... Parish: ……. Sub-county: …….
4. Sex: Male Female
5. Age: <18 years 19-35 years 36-60 years >61 years
6. Education: No formal education Primary Secondary Tertiary
7. Occupation: Farmer Fisher Trader Civil servant Others……
8. If farmer, which crops do grow?.
   ……
   ……
   ……..

B: Tree Diversity

9. Do you have trees on your cultivated or recently fallowed farm/garden?

Yes	
No	

If no, go to question 20.

10. How did then come to be in your garden?

Planted	
Retained	
Both (Planted and retained)	

11. If yes in 9 above, list those trees and their benefits to you and your household.

	Tree name (Ateso)	Benefits/uses
1		
2		
3		
4		
5		
6		
	Tree name (Ateso)	Uses
7		

8		
9		
10		

12. How did you learn to retain trees on farms/gardens?

Learnt from parents	
Learnt from neighbours	
Attended training	
Own initiative	
Community bye-laws	
Others (explain below)	

.....

13. What is the size of your garden? (Atleast one per farmer)

……

14. How many trees are in the garden mentioned in 13 above?

…….

15. What is the diameter at breast height (dbh) of the trees in 14 above?

	Tree name (Ateso)	Dbh (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
	Tree name (Ateso)	Dbh
10		
11		
12		

13		
14		
15		

16. What challenges do you face by having trees on farm/garden?
……
……
……

17. How do manage the trees in your garden/farm? Tick all that apply

None	
Prune	
Set firebreaks	
Weed	
Fence	
Others (explain)	

……

18. How did you propagate the trees you have in your garden/farm?

Seeds	
Seedlings	
Stem cuttings	
Wildings	

19. How do you harvest the products from the trees on your farm/garden? *Tick all the applicable*

Felling whole tree	
Picking from ground (fruits &	
Prune	
Picking from tree	
De-barking	
Digging roots	

20. If you answered No in 9 above, why don't you have trees on your garden/farm?
……
……
……
……

21. If you are to plant trees in your garden/farm, what would you consider when choosing the tree species?.*Tick all that apply*

Fast growing	
Provide timber	

Provide medicine	
Provide fodder	
Provide firewood	
Provide fruits, nuts, leaves (edible)	
Provide gum	
Provide construction poles	
Act as windbreaks	
Control water run-off	
Provide shade	
Improve soil fertility	
Provide habitat for biodiversity	
Others (explain)	

……
……

B: Research Report

Utilization and population dynamics of tree species in the subsistence parklands of Kapelebyong district, North eastern Uganda

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Abstract

The study was carried out in the subsistence agroforestry parklands of Kapelebyong district, Eastern Uganda to establish the diversity of tree species, uses, management practices, harvesting techniques and tree population dynamics. Data was collected using a semi-structured questionnaire administered to 60 farmers and field survey of 60 ha. of subsistence parklands. The identity of tree, uses, management practices, harvesting techniques and diameter at breast height (dbh) were captured during the survey. The voucher specimens were identified at Makerere University Herbarium. Qualitative data was collated into frequencies and presented using tables and figures. The Shannon diversity and equitability indices were used to analyse the diversity of tree species and evenness respectively. The trees provide diverse benefits with firewood, fruits, timber and shade as the most prevalent. The parklands have a species diversity index of H'=3.23, an evenness of 0.86 and a mean density of 5.7 trees ha^{-1}. The most prevalent species are *Combretum collinum* (10.8%), *Vitalleria paradoxa* (8.2%), *Mangifera indica* (7.9%) and *Combretum adenogonium* (7.4%). Nearly half of the farmers (49.0%) learnt to preserve trees on farms from their parents while 2.0% reported that they were obliged by by-laws. The prevalent tree management practices in the parklands are weeding (41.7%) and pruning (40.2%). The products are harvested mainly by pruning (28.0%), picking from tree (mainly fruits and leaves) (23.5%), felling (22.5%) and collecting from the ground (mainly fruits) (20.0%). *Pseudocedrela kotyschi, Buchinia thonningii, Combretum collinum* and *Vitalleria paradoxa* have more individuals in the lower class distributions hence positive regeneration trends. We recommend that the management of parklands in this area be enhanced through provision of forestry extension services, awareness and information dissemination as well as provision of tree planting material. This can further be enriched by research to quantify the impact of parkland trees on crop productivity, carbon sequestration and incentives for farmers to maintain trees.

Key words: Population dynamics, Utilization, agroforestry, parklands, Uganda

Introduction

Agroforestry parklands are traditional land-use systems characterized by scattered mature trees on cultivated or recently fallowed landscapes (Boffa, 1999). The trees enhance landscape connectivity, reduce pressure on forests, and provide habitat for animals and pollinators (Boffa et al. 2005); enhance soil fertility, conserve water and protect the environment (Boffa 1999). In addition, they provide timber and fuelwood, improve nutrition (fruits, nuts and leaves) and provide fodder for livestock; (Boffa 1999, Misgana et al. 2020). The indigenous trees also deliver diverse environmental services (Hillbrand et al 2017) with greater effectiveness than do plantations of exotic species (Liu *et al*. 2018). The parklands can also mitigate climate change through creation and enhancement of carbon sinks (Albrecht and Kandji, 2003). Therefore, parklands have social, economic and environmental benefits

(Melese 2017) which can address the twin objectives of biodiversity conservation and livelihoods (Scherr & McNeely 2002).

Despite the benefits derived from parklands, they face threats from anthropogenic activities. In Uganda, the indigenous trees in the parklands are increasingly over-exploited for fuelwood (charcoal and firewood) and other materials (Olupot 2015, Buyinza *et al.* 2015). Additionally, they are being replaced by exotic tree species in most tree planting initiatives and agricultural landscapes (Ministry of Water and Environment 2016, Reppin *et al.* 2020). The proliferation of exotic species makes the local communities vulnerable to health, nutrition and income adversities (Misgana *et al.* 2020). They also reduce the heterogeneity and suitability of the habitat for other flora and fauna. In Burkina Faso, the parklands' physiognomy shows lack of regeneration due to short and suppressed fallow periods (Nikiema 2005).

For a long time, the conservation of biodiversity in the tropics has been focused on the protection of natural forests and woodlands (Kassa *et al.* 2010). Conversely, less attention has been accorded to the widely dispersed woody species on farm (Melese 2017). This resonates with calls to base conservation approaches on wider conservation landscapes which include mosaics of multiple land use (Boffa *et al.* 2005). Thus, the prerequisite to optimizing the value of farmlands is to monitor the dynamics of species therein (Nikiema 2005). The study sought to establish the diversity, uses, relative representation and regeneration trends of tree species in the parklands of Kapelebyong district, Eastern Uganda. Additionally, the study sought to ascertain the parkland management and tree harvesting techniques. The findings of this study underscore the value of parklands in fulfilling the twin objectives of conservation and livelihoods, and offer insights for evidence-based management these landscapes.

Materials and Methods

Study area

The study was conducted in the sub-humid drylands of Kapelebyong district, North Eastern Uganda where 91.9% of the households are involved in subsistence crop growing (UBOS 2017). The major crops grown in this area include millet, rice, sorghum, cowpeas, groundnuts, green grams, cassava and sweet potatoes (Ojelel & Kakudidi 2015). They also rear livestock such as cattle, goats and sheep; and the region relies on animal traction.

The survey was specifically conducted in three sub-counties namely Obalanga, Alito and Okungur (Fig. 1). This area is located between 33°30'E to 33° 45'E and 2°24'N to 2°45'N. The vegetation is predominantly savannah dominated by *Combretum* species and *Vitalleria paradoxa* and punctuated by seasonal as well as permanent streams. The area experiences a humid and hot climate with 1000-1350mm of rainfall and 18-31.3^{0}C temperature (Egeru 2012).

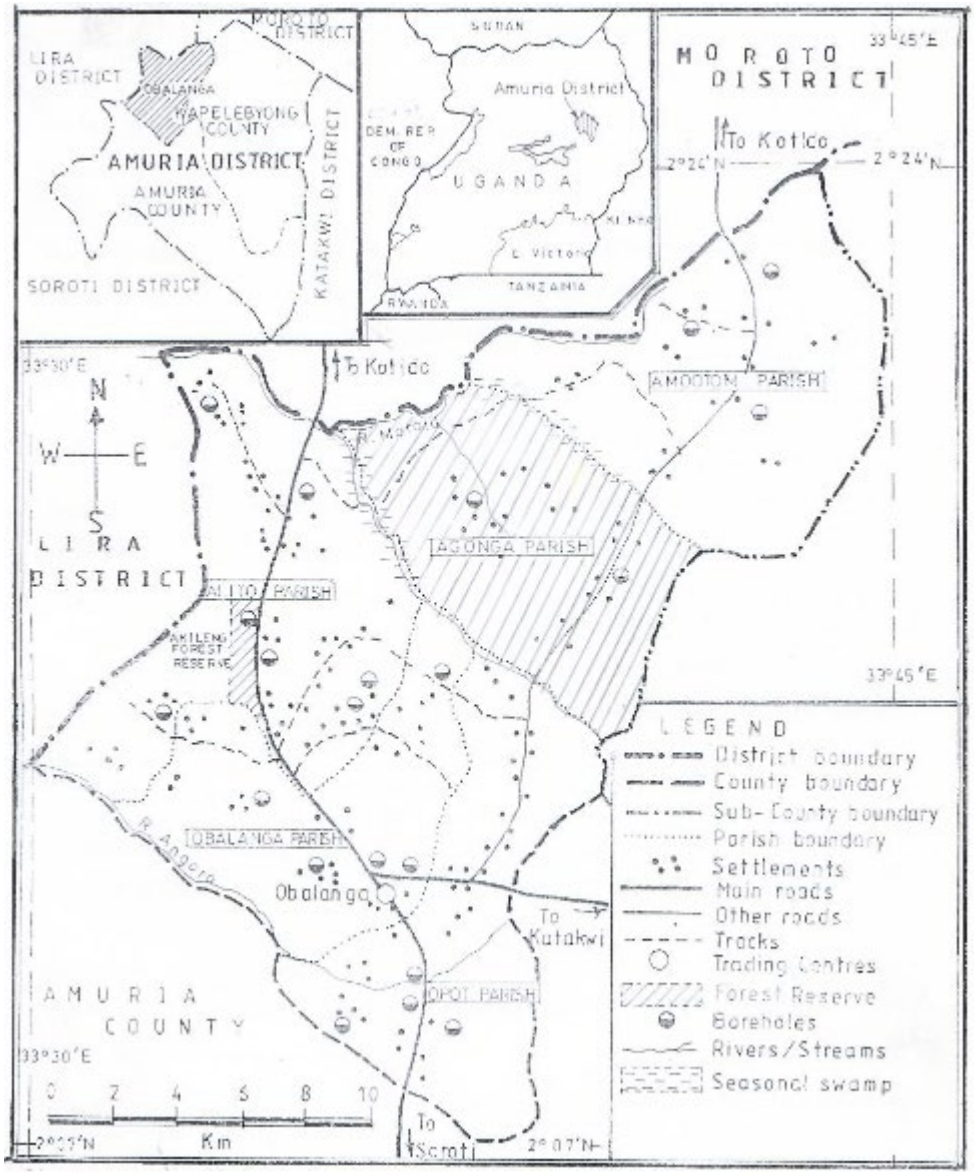


Fig. 1: Location of project area (Obalanga, Okungur/Amootom and Alito), Kapelebyong district, Uganda

Sampling and data collection

The study targeted 60 farmers in 12 registered farmer groups in the sub-counties of Obalanga, Okungur and Alito, Kapelebyong district. The files of these groups were accessed from the respective sub-counties and a meeting was arranged with all group chairpersons to brief them on the research objectives. Thereafter, five members in each group were interviewed in their respective villages (homesteads). A village is the lowest administrative unit in Uganda under the local government structure. A semi-structured questionnaire was administered to each farmer in the field (parkland). The questionnaire elicited information on the number and identity of trees, source of knowledge on tree preservation or planting on farm, benefits derived from trees, management of trees and mode of harvesting tree products. Thereafter, the voucher specimens of the trees were collected, pressed and identified at Makerere University Herbarium. The diameter at breast height (dbh) of all the trees in 1 ha. parkland was measured using a dbh meter (800-647-5368, Jackson, MS, Germany). The tree stamps were not included in the measurement.

Data analysis

Qualitative data was collated, analysed using descriptive statistics and presented using figures and tables. The diversity of tree species in the parklands was computed using the Shannon weaner index using he formula $H' = -\sum_{i-1}^{s} pi \ln pi$ where p is the proportion (n/N) of individuals of a particular species (n) divided by the total number of individuals (N), ln is the natural log, R is the sum of the calculations, and *s* is the number of species. Shannon's equitability (E_H) was calculated following Krebs (1999) procedure by dividing H by H_{max} (here $H_{max} = \ln S$) using the formula $E_H = H / H_{max} = H / \ln S$. Equitability assumes a value between 0 and 1 whereby 1 represents complete evenness. The dbh of individuals in each species were grouped into diameter classes at increments of 10 cm. This was presented using frequency histograms for both diameter and class distributions following Peters (1996). Thereafter, the regeneration status was assessed from the shape of the histogram.

Results and discussion

Diversity of tree species

The study documented 42 tree species (Table 1). Only 9 species (21.4%) were deliberately planted in the parklands. This low tree planting ethos is attributable to the relative abundance of the indigenous trees and limited access to tree planting material. Similarly, Buyinza *et al.* (2005) found that local communities in the Lake Kyoga basin prefer preserving indigenous trees to planting. The trend is however, in contrast to Boffa *et al*. (2005) who reported that 50% of the tree species in agricultural landscapes of Kigezi sub-region in Western Uganda are planted deliberately.

The Shannon diversity index of tree species in the parklands of Kapelebyong is 3.23 with an equitability (evenness) of 0.86. This diversity index (H'=3.23) is greater than 2.0 which according to Magurran (2004) denotes high diversity. The high equitability index shows that the tree species are evenly distributed in the parklands. The mean tree density in these parklands is 5.7 trees ha^{-1}. This density is lower than the 15-42 mature trees/ha previously reported in some districts of Uganda (Byakagaba *et al.* 2011). The prevalent species include *Combretum adenogonium, Vitalleria paradoxa, Combretum collinum* and *Mangifera indica.* The presence of trees in the parklands underscore their ability to enhance resilience to environmental calamities such as climate change (Reppin *et al.* 2020). On the basis of prevalent tree species (Boffa 1999), the parklands in Kapelebyong can be described as *Combretum* spp-*Vitalleria paradoxa* parklands.

Nearly all the tree species in these parklands are indigenous or naturalized. Only Eucalyptus spp. and *Grivellia robusta* species were the exotic species encountered. This trend emanates from the limited availability of exotic tree planting materials and the poor tree planting culture. The latter stems from the perceived relative abundance of the indigenous trees and their associated products. However, elsewhere Boffa *et al.* (2005) reported that 69% of the species planted in Kigezi, western Uganda were exotic.

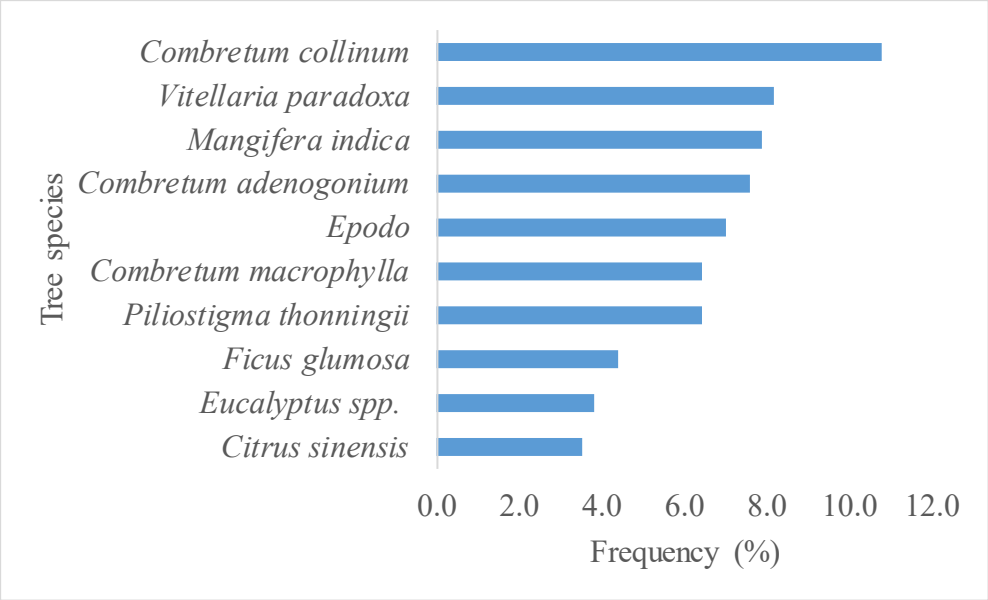


Figure 1: The frequent trees in the parklands of Kapelebyong district, Uganda

Uses of parkland trees

The farmers reported diverse uses of trees in the parklands (Figure 1). Provisioning services such as firewood, timber, and fruits are the most prominent uses. This highlights the dependence of the community on the parklands as a livelihood buffer (Boffa, 1999). This is in tandem with Buyinza *et al*. (2015), who reported that tree species are maintained on farms to meet the immediate needs of the household (Buyinza *et al*. 2015). In Burkina Faso, Neya *et al*. (2020) report that the carbon payment system promoted by Reducing Emission from forest Degradation and Destruction (REDD+) initiative is profitable and compensable to smallholder farmers' effort to plant and keep trees on farms. However, this program is yet to benefit many smallholder farmers in Uganda.

Table 1: Parkland tree species and their uses in Kapelebyong district, Uganda

Scientific name	*Local name (Ateso)*	*Uses*
Acacia hockii De Wild	Ekisim	Fi, Fm
Albizia coriara Oliv.	Eteka	Ti, Fi
Albizia zygia (DC.) J.F.Macbr	Ebata	Ti, Wb, Fi
Anacardium occidentale L.	Ekasnat	Fr, Oi, Fi
Annona senegalensis Pers.	Ebwolo	Cr, Fr, Sh
Azadiracta indica	Abach	Me, Fi, Ir
Melia sp.	Elira	Ti
Balanites aegpytiaca (L.) Delile	Ecomai	Lv, Fi, Ch
Bridelia Schleronuera	Erieco	Fr, Po, Fi
Carica papaya	Epapalu	Fr
Carissa spinarum L.	Emuriei	Fr, Fm, Me

Citrus sinensis	Emucuga	Fr
Combretum adenogonium Steud. ex A.Rich.	Emeng	Po, Fi, Sh, Ca
Combretum collinum Fresen	Ekulony	Po, Fi, Sh, Bm
Combretum macrocalyx (Tul.) Jongkind	Ekoboi	Fi, Sh, Ch, Wb, Bh, Ti, Po,
Combretum molle R. Br. ex G. Don	Ekwooro	Fi, Ch
Erythrinia abyssinica	Engosororoi	Fi, Ab, Fm, Ra
Eucalyptus camadulensis	Ekalitusi	Ti, Fi
Ficus sp.	Emidit	Fi, Sh, Ma, Fi, Fr
Ficus glumosa Del.	Ebiong	Ma, Ti, Sh, Fr
Ficus platyphylla Del.	Ebule	Gu, Ma, Sh, Ti, Fr
Ficus sycomorus L.	Eboborei	Sh, Ti, Fi
Gardenia ternifolia Schumach. & Thonn.	Ekoroi	Fm, Po
Grewia mollis Juss	Eparis	Fr, Po, Fi, Ch
Grivellia robusta	Egrivellia	Ti, Fi
Harrisonia abyssinica Oliver.	Ekerei	Ne, Bm, Cr, Fm
Lonchorcarpus laxiflorus Guill. & Perr.	Ekaikai	Fo, Fi
Mangifera indica	Emiebe	Fr, Ma, Sh, Wb, Fi, Cr
Onzora insignis	Etiling	Ti, Po, Fi, Cr
Bauhinia thonningii Schum.	Epapai	Pa, Fi, Bh, Sh, Sa, Hu
Pseudocedrela kotschyi (Schweinf.) Harms	Eputon	Ti, Bm
Psidium guajava	Emapara	Fr, Sh
Mitragyna stipulosa (DC.) Kuntze	Eutdolei	Fi, Sh
Schelerocarya birrea	Ejikai	Ti, Fr
Tamarindus indica L.	Epeduru	Fr, Me, Fi, Ch, Ab, Sp
Vachellia sieberiana	Etirir	Fi, Fm, Ti
Vitellaria paradoxa	Ekungur	Oi, Ch, Fr, Fi, Ne
Vitex doniana Sweet	Ekwarukei	Fr, Fi, Ma, Ti
Senegalia senegal (L.) Britton	Ekodokodoi	Fm, Ti, Po
	Epodo	Ti, Sh, Bm
Protea madiensis Engl.	Ebalangait	Fi, Sh, Sa
Persea Americana Mill.	Ovacado	Fr, Sh.
Combretum superba	Ekokobot	Po, Ch, Fi, Ma
Artocarpus heterophyllus	Efene	Fr, Sh

KEY: Fi = Firewood, Fr = Fruits, Ch = Charcoal, Sh = Shade, Po = Poles, Ma = Manure, Sa = Soda ash, Bm = Building materials, Fm = Fencing materials, Ti = Timber, Oi = Oil, Ne = Nector,
Me = Medicine, Ab = Aesthetic beauty, Sp = Spice, Pa = Paint for fish nets, Cr = Crafts, Wb = Windbreak, Fo = Fodder, Gu = Gum, Ra = Rain indicator, Ca = Clean air, Lv = Leafy vegetable, Ir = Insect repellant.

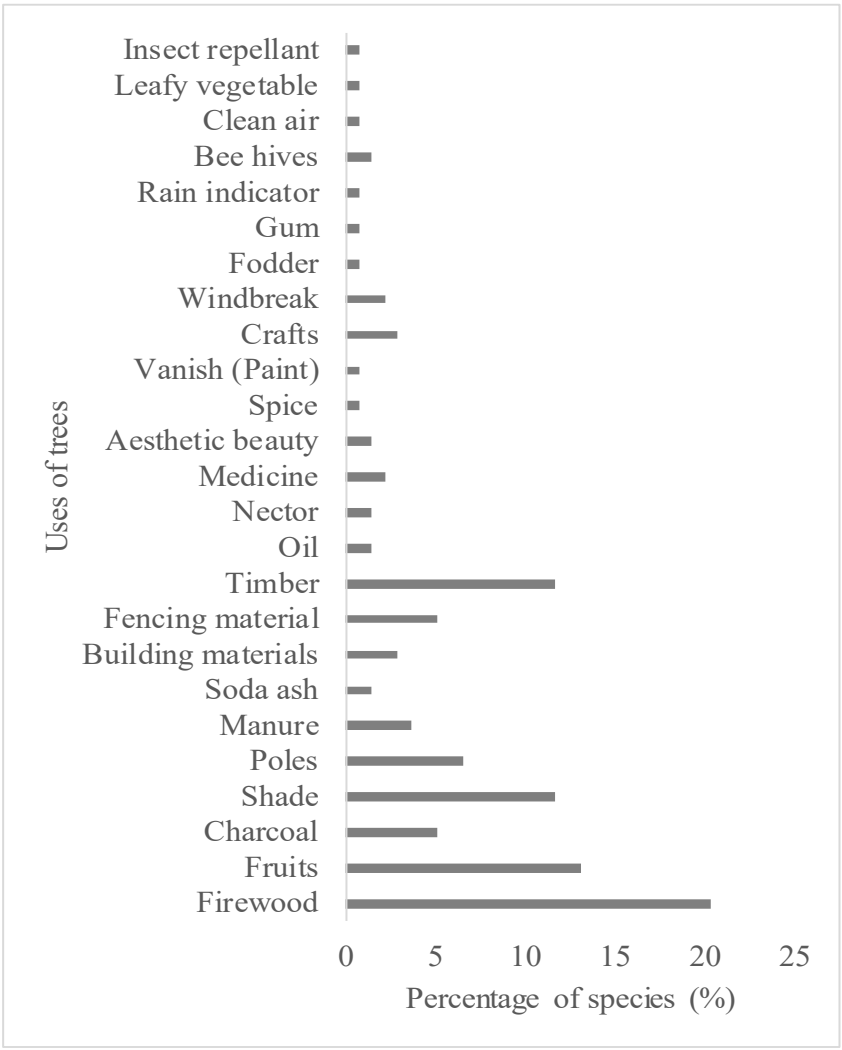


Figure 1: Uses of trees found in the subsistence parklands of Kapelebyong district, Uganda

Knowledge to preserve trees on parklands

The knowledge to preserve and/or plant trees on farms was acquired in various ways (Figure 2). Most farmers learnt this practice from their parents because this is traditionally an agricultural community. The knowledge is passed from one generation to another orally. For this reason, parklands are referred to as a traditional land-use system (Boffa, 1999). Their management therefore requires integration of indigenous knowledge to provide prescriptions that are relevant to the present scenarios (Boffa, 1999). In figure 2, more farmers preserved trees on farmlands as a result of own initiative and after training than those obliged by by-laws. This reveals that awareness creation is effective in promoting parkland conservation as opposed to enactment of by-laws. It also affirms Boffa's (1999) assertion that "farmers are rational decision makers who choose to conserve and regenerate trees in their fields if this brings higher benefits".

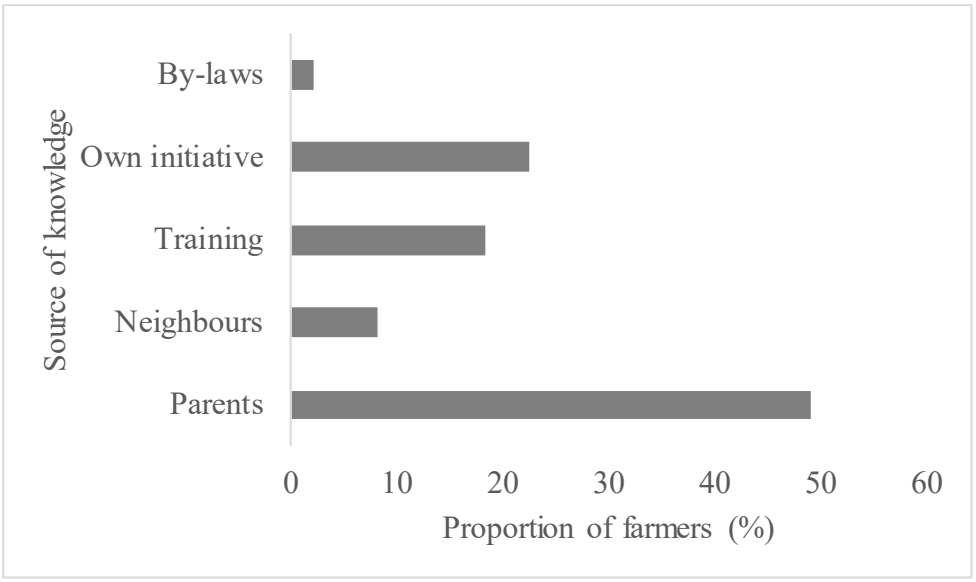


Figure 2: Source of knowledge on tree preservation in the parklands of Kapelebyong district

Tree management measures

Weeding and pruning are the prevalent tree management practices in the parklands of Kapelebyong district (Figure 3). Weeding is applied when crops are in the field while pruning can be done with or without crops. Pruning offers two-fold benefits; first to reduce shade and minimize competition with crops and secondly, to provide harvestable materials such as firewood. The other tree management measures include spraying with insecticides, watering during the dry season and application of manure. These measures are however, not widespread but limited to fruit trees such as *Citrus sinensis* and *Psidium guajava.* In West Africa, Boffa (1999) reported that tree pruning is an attractive option to improve crop production around tree canopies. Leaky (2010) opined that management of trees on-farm restores the productive capacity of farmlands and promotes local enterprises. This in turn reduces poverty and enhances food security.

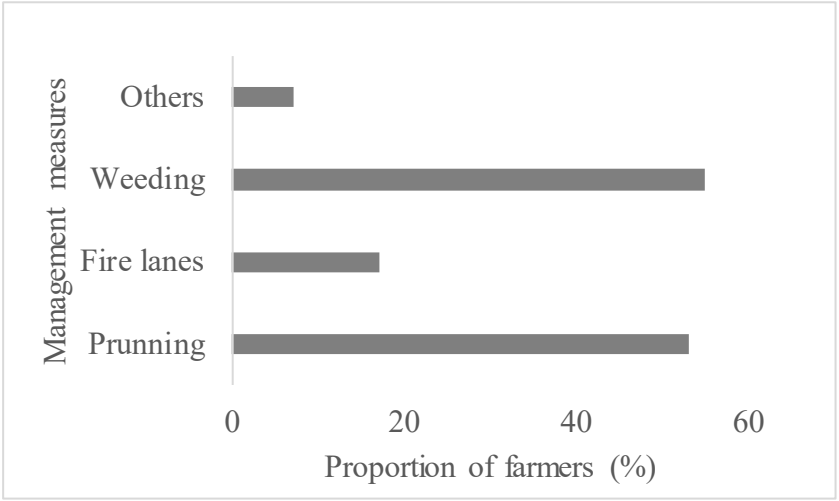


Figure 3: Management of tree species in the parklands of Kapelebyong district, Uganda

Harvesting techniques

The pruning of branches and twigs is the prominent technique of harvesting trees in the parklands (Figure 4). The low prevalence of debarking and digging roots points to the prudence of farmers and perhaps limited knowledge on the use of tree barks and roots.

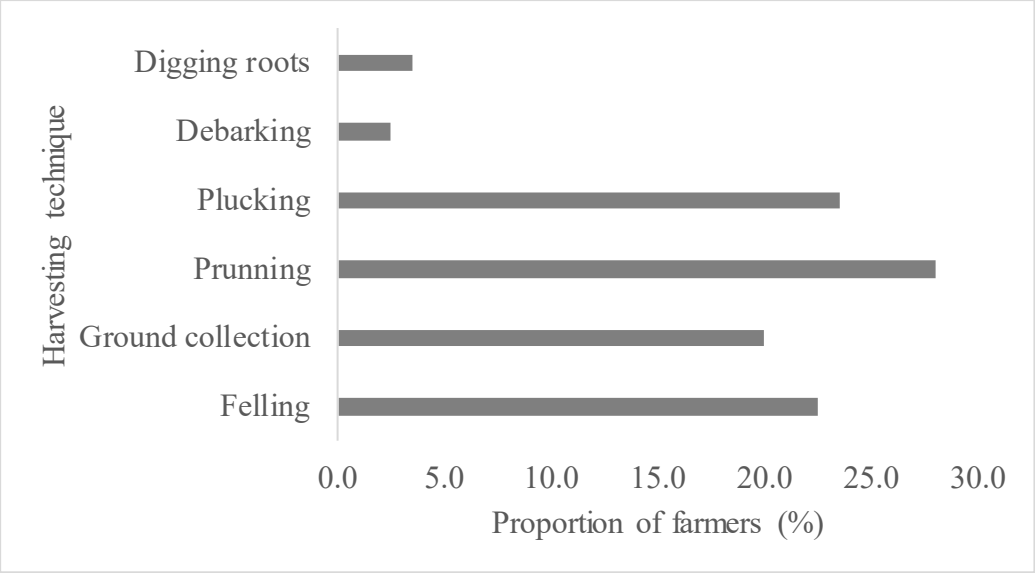
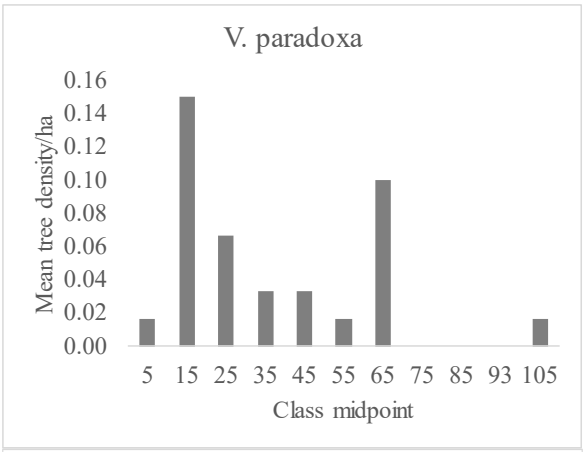
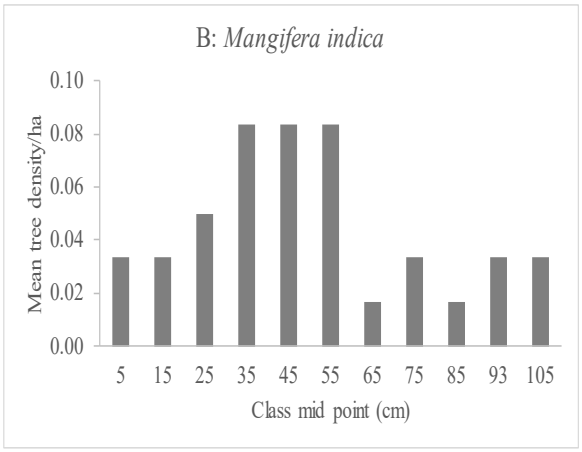


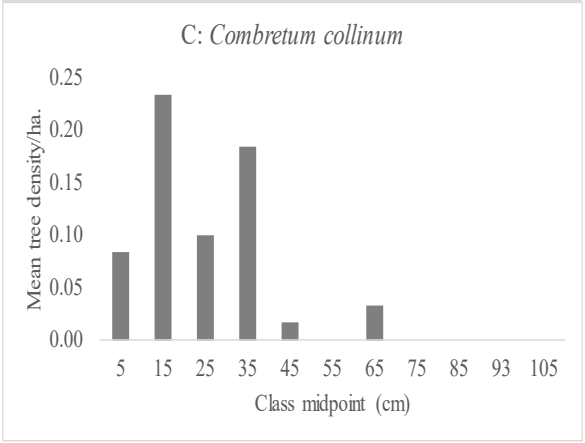
Figure 4: Techniques of harvesting tree products in the parklands of Kapelebyong district

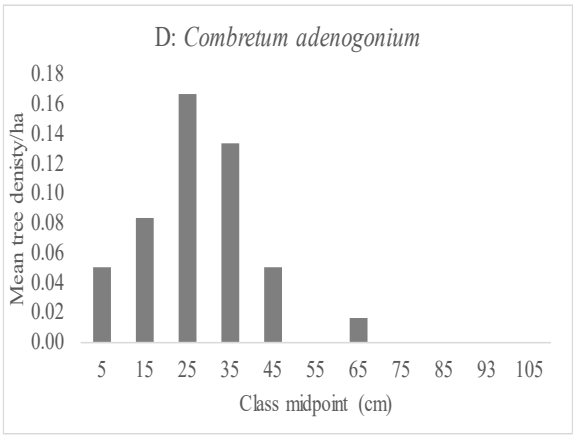
Class size distribution

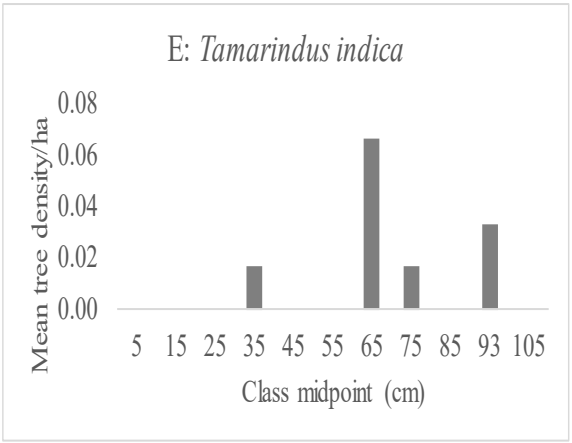
The histograms in figure 5 (A-J) present the class size distribution of ten tree species in the parklands of Kapelebyong district. These are the most frequent tree species in these parklands (Table 1).

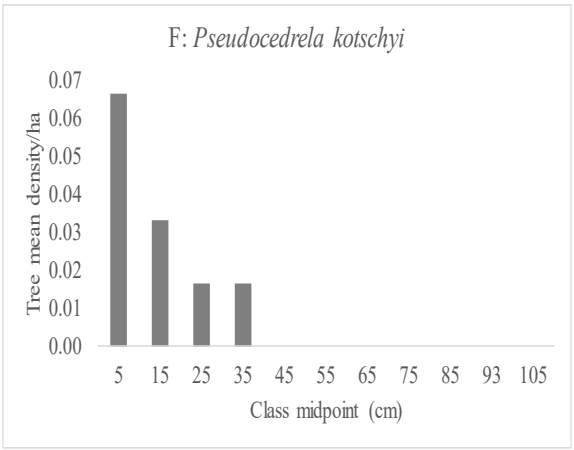

V. paradoxa
Mean tree density/ha
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5 15 25 35 45 55 65 75 85 93 105
Class midpoint


B: Mangifera indica
Mean tree density/ha
0.10
0.08
0.06
0.04
0.02
0.00
5 15 25 35 45 55 65 75 85 93 105
Class mid point (cm)


C: Combretum collinum
Mean tree density/ha.
0.25
0.20
0.15
0.10
0.05
0.00
5 15 25 35 45 55 65 75 85 93 105
Class midpoint (cm)


D: Combretum adenogonium
Mean tree denisty/ha
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5 15 25 35 45 55 65 75 85 93 105
Class midpoint (cm)


E: Tamarindus indica
Mean tree density/ha
0.08
0.06
0.04
0.02
0.00
5 15 25 35 45 55 65 75 85 93 105
Class midpoint (cm)


F: Pseudocedrela kotschyi
Tree mean density/ha
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
5 15 25 35 45 55 65 75 85 93 105
Class midpoint (cm)

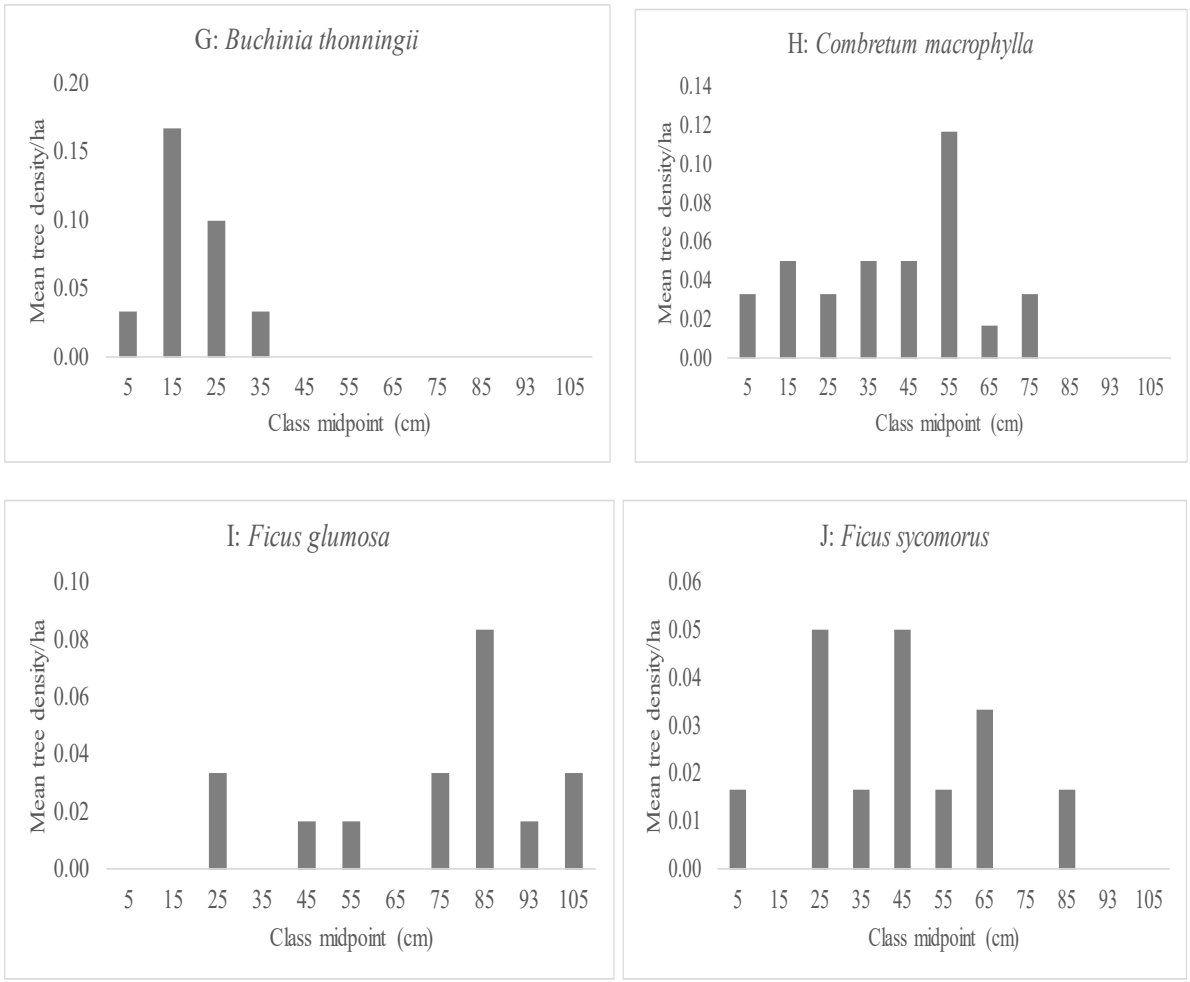


Figure 5 (A-J) Class size distribution of ten trees commonly found in the subsistence parklands of Kapelebyong district.

The histograms 5 (A-J) show that the tree species in the parklands of Kapelebyong have variable numbers of individuals in the class size distributions. This ultimately influences their population structures and regeneration trends. The high numbers of individuals of *P. kotyschi, V. paradoxa, C. collinum* and *B. thonningii* in the lower diameter classes show that they have a positive regeneration potential. On the contrary, *F. glumosa* and *T. indica* with more individuals in the higher diameter classes have poor regeneration potential. The suppressed regeneration in these species is due to destruction of seedlings by wild fires during the fallow periods in the dry season (December to February). In Burkina Faso, Nikiema (2005) opined that reduced regeneration in parklands is due to shorter and suppressed fallow periods but this could not be ascertained in the present study.

Conclusion

The parklands of Kapelebyong district have a high diversity of tree species and equitability (evenness). The trees act as a livelihood buffer because they provide diverse products to the farmers. The majority of the trees in the parklands are indigenous species preserved during opening of the land. Some of the prevalent tree species have healthy regeneration trends while others are not. In cognizance of the status of these parklands, it is important to develop mechanisms to incentivize farmers to maintain agroforestry parklands. There is also need to improve forestry extension services and information dissemination and access to affordable and quality planting material. Additionally, the effective management of these parklands can be reinforced by research that quantifies the impact of trees on crop productivity, adds value

to tree products and estimates biomass carbon sequestration potential. The latter will provide information to assess the viability of the small holder parklands in the carbon payment system promoted by Reducing Emission from forest Degradation and Destruction (REDD+) initiative.

Acknowledgement
We are grateful to the Institute for Global Environmental Strategies (IGES) through the Satoyama Development Mechanism (SDM) for the financial support to this research through a project on revitalizing the role of agroforestry parklands in biodiversity conservation. We also extend our sincere gratitude to the farmer groups and individual farmers who participated in the study.

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