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Farmers' planting and management of indigenous and exotic trees in Botswana: implications for climate change mitigation

Abstract

Natural woodlands provide majority of rural population with energy source, food, building material and fodder for livestock. However, current developments and population growth have exerted enormous pressure on the woodlands and possible extinction of some species. Human activities, such as deforestation, agriculture actives, and uncontrolled wildfires, have increased environmental degradation around villages. Despite effort by government to lure communities to tree planting initiative the uptake is unsatisfactory. The study focused on exploring constraints and potential of tree planting and management of both indigenous and exotic trees by local farmers in Botswana. Data were collected through structured and semi-structured household questionnaires and 350 respondents were interviewed. Farmers highly appreciate the potential benefits of products and services from tree planting and are willing to take part. About 98% of the respondents agreed that indigenous trees are the main source of biofuel energy and approximately 73% of the respondents concurred to that trees contribute significantly to their food and financial needs. Nevertheless, farmers highlighted some constraints that hinder the adoption of tree planting initiative among them long maturity of trees, limited information on indigenous trees, unfavorable conditions for exotic species and termites as major constraints. Local conditions were identified that favour the adoption of tree planting and agroforestry opportunities. The fact that farmers already leave and grow both indigenous and exotic trees on farms and homesteads and they are knowledgeable on the importance of tree gives hope for future adoption.

Keywords: natural woodlands, constraints, agroforestry, indigenous trees, Botswana.
JEL Classification: Q00, Q01, Q05.

Introduction

In Botswana, more than 80% of the population live in rural areas engaged mainly in agriculture: this is mainly based on subsistence farming, which involves mainly pastoral farming and dry-land arable farming. Despite the fact that there is abundance of the land in Botswana, the production of food crops has not kept up with the increasing human population mainly due to unpredictable droughts, infertile soils and very low rainfall. Natural woodlands are an integral part of daily lives in rural communities around the country and they depend on the natural woodland for a variety of products, such as fuel wood, poles, fruits, roots, leaves, insects and honey (Legwaila et al., 2011, Neudeck et al., 2012), moreover certain trees and shrubs are valued for different medicinal properties (Mothanka and Makhabu, 2010). Utilization of natural woodlands varies considerably among groups living in similar or slightly different environment. These differences have been explained from territorial difference and different levels of availability of food and alternative sources of energy. Although one of the primary demands made on natural woodlands is for fuel wood, in the context of the rural home one is dealing with the multiple uses of woodland resources. The natural vegetation is also exploited in an indirect manner in form of providing grazing for livestock, which, in turn, supply meat, hides, milk and other products.

However, Botswana, like many other developing countries, is faced with serious problem of overexploitation of its natural resources, like the natural woodlands. As traditional pastoral systems are replaced by sedentary farming, trees and shrubs are often cut to clear land for cultivation and to obtain fuel wood and livestock grazing for expanding rural populations. This loss of tree cover around settlements and lands has led to: increased wind/water erosion, increased loss of top soil, decrease in crop yields and lower income to farmers.

One way to mitigate adverse effect of deforestation and to reclaim degraded forest lands, ensure sustainable use of marginal land, protect good quality land (Khan, 1986) and fulfil the rural need for economic and noneconomic benefits from trees to sustain their rural livelihood, tree planting on farm lands is the most feasible and viable under the present circumstance (Zubair and Garforth, 2006). According to Amanor (1997), trees have been used in farming system unconsciously for maintaining soil productivity and to have favourable effects on crops. The role of nitrogen fixing trees for improving soil fertility in croplands and pasture is as important as has the resistance of some trees to drought, the role of windbreaks in protecting cropland and pasture, the contribution of high protein tree fodder to livestock production and commercial potential of several kinds of trees crops.

Moreover, there is a need to introduce technologies and sound strategies which focus on the mainte-

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nance or introduction of both indigenous and exotic trees and shrubs into agricultural systems, to conserve and improve the soil and supply a variety of tree products, such as dry-season folder, food, fuel wood and building poles. However, even though agroforestry can increase productivity and improve sustainability, it is not a solution for every land situation. Trees are not necessarily a cure for all environmental problems, including desertification. In some cases the very advantages of agroforestry may be associated (e.g., with selection of wrong species for a particular situation). In the dessert country like Botswana, woodlots and plantations yield poor economic returns due to high establishment and maintenance costs. Trees in woodlots are also prone to high mortality rates due to drought, insects and disease attacks, increasing the financial risks associated with this approach. Therefore, there is a need for careful planning before any technology can be implemented in any particular situation.

This work is aimed at gathering data on the constraints to and opportunities for tree planting through agroforestry as a land use system since research has little or no information on the system for the study area. This study would, therefore, serve to improve the system as well as pave way for future research work in agroforestry, in particular, tree planting in Botswana. In view of the subsistence farming and the associated problems of declining food production and woodland resources, this study was planned to critically assess the factors which are a constraint to the planting and management of both indigenous and exotic trees in the country.

Botswana's forest resources furnish multiple direct and indirect benefits to communities in Botswana. The benefits include wood and non-wood products, food and medicine, environmental protection, habitats for plants and wildlife, shade and aesthetic beauty as well as opportunities for recreation, cultural and spiritual activities. The derivation of these products is under immense pressure from the increasing population and human activities, such as land clearance for human settlement and agriculture. These factors coupled with frequent and wild forests fires, and adverse climatic conditions contribute significantly to the decline of Botswana forest resources hence there was a need to come up with reforestation/afforestation measures.

Botswana has measures in place to promote reforestation by bringing tree seedlings closer to the communities through Department of Forestry and Range Resources (DFRR) with twenty one (21) established nurseries across the country. The average annual production of these nurseries is 500.000 tree seedlings for selling at subsidized prices to the public to plant (DFRR, 2014a). In addition, the DFRR facilitates the establishment of backyard nurseries so as to bring the tree seedlings even closer to the communities, and at the same time economically empowering the community. Other activities aimed at promoting reforestation are: National Tree Planting (NTPD and District Tree Planting Days held annually, community tree planting in woodlots, agroforestry projects, around home tree planting, parks, land reclamation projects and school tree planting. These reforestation efforts are supported by Botswana National Tree Seed Centre from 1998 to date (DFFR, 2014b).

Efforts to protect endangered tree species and preserve biodiversity for future use, six forest reserves, namely, Chobe, Kasane, Kasane Extension, Kazuma, Maikaelelo, and Sibuyu, all with a total of 401.529 ha (about 0.8% of Botswana's land area) were established in the Chobe District in the late 1960s and early 1970s. These forest resources in the forest reserves are protected from veld fires through established external and internal firebreaks which are maintained annually to allow natural regeneration. Community involvement through Community Natural Resource Management projects and at the same time economically empowering them has contributed positively in sustainable management of forest resources.

A National Forest Policy that emphasizes integrated conservation and management throughout Botswana has been developed and approved by Parliament. Review of the fragmented Forest Legislations to make it compatible with the National Forest Policy is in progress to merge them into one instrument. Currently, Forest Act (1968) has also been amended, so far as it relates to the requirements of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The desirability of boosting tree planting on both farmland and communal land is recognized, both in literatures and through government supporting documents and initiatives such as Forest Act (1968), Agricultural Resource Conservation Act as well as National Tree Planting Day (NTPD) which date back from 1985. NTPD was introduced to arouse awareness and educate the public on the importance of tree planting in order to reduce further extinction of valuable trees species and enhance suitable management and utilization of other natural resources. Despite all this, the uptake has been low than anticipated in many projects. As such, less is known about factors influencing farmer's decision on tree planting, perception, constraints and potential of planting and managing trees by farmers in Botswana. Therefore, the study sought to assess factors which constrain tree planting in farming system and identifying potential of tree planting as per local farmers understanding and perception. The main objective was to explore the constraints and potential of tree planting and management of indigenous and exotic trees by local farmers. The specific objectives include identification constraints that hinder adoption or tree planting in farmlands or communal area by farmers, determination of farmers perception on potential benefits of tree planting and identification of the conditions and local practices that favour the adoption of agroforestry systems.

Materials and methods

The study was carried out in seven districts in Botswana, namely, Kgalagadi, Kanye, Goodhope-Mabule Tonota, Palapye, Nkange, and Kasane. The districts were purposively sampled on the basis of various factors which include diverse ecological conditions and population densities, presence of agro-based activities like pastoral, arable and tourism areas among others. The selected districts have rainfall range of 200 to 600 mm, respectively (Anon, 2000) Sampling of the households was done using multistage stratified random sampling technique beginning with stratification sampling procedures as outlined by Lee-Ann and Martin (1997). Using this procedure, at least 40% of the divisions with relatively homogeneous characteristics in each district were sampled to form a stratum. This ensured heterogeneity was well captured and represented. Similar procedure was followed for selection of administrative locations and sub-locations. A total of 50 households were sampled from each district. Data collection was done using structured and semi-structured household questionnaires. The information collected included proportions of land size per household, household land area under trees, tree planting practices, tree preferences and tree planting constraints. The generated data was coded and entered in the computer using spread sheet of MS-Excel. Statistical package for social sciences (SPSS) were used in analyzing the data.

Botswana has a land area of 581.730 km^2 and is situated in the centre of the southern African, sharing boarders with South Africa, Namibia, Zimbabwe and Zambia. Most of the country is flat, with some small hills in the eastern areas. The natural vegetation in Botswana covers an area of about 525.600 km^2 (90%) of Botswana's land area of 581.730 km^2 (Totolo, 1997). About 77% (449.000 km2) of Botswana's land surface is covered by the Kalahari sands, commonly referred to as the 'sandveld', while the remaining 23% (133.000 km2) in the south-eastern, eastern and north-eastern parts of the country comprise the 'hardveld' land system with sandy loam and loamy sand soils that support the arable agriculture industry (Map 1) (Anon, 2000). In Botswana, rainfall is unpredictable over space and time, and varies considerably from year to year. The rainfall varies over the country from an average maximum of 600 mm in the northeast to an average minimum of 250 mm annual rainfall in the south-west.

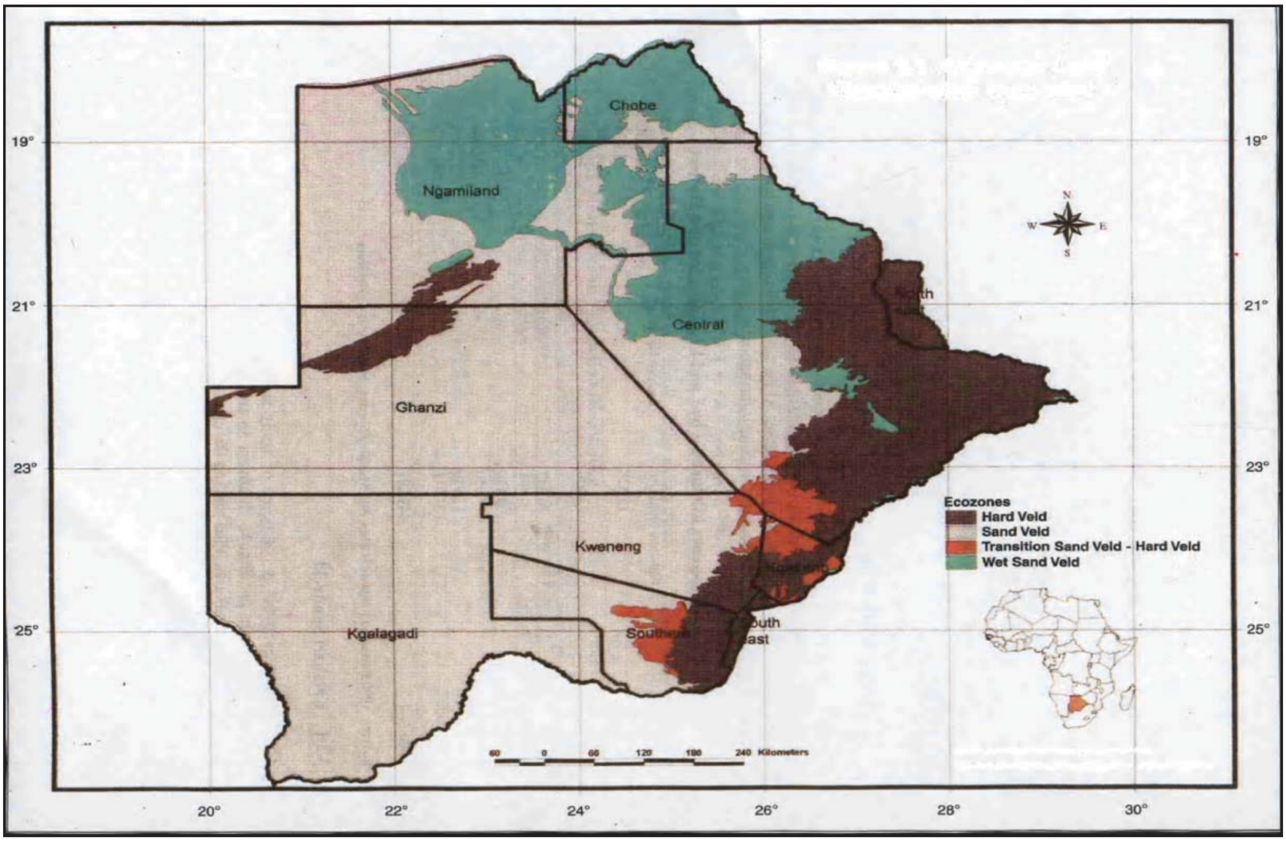

Fig. 1. Botswana land classification (Anon, 2000)

Results and discussion

A total of 350 households participated in the study which was segmented and distributed in seven districts, namely, Kgalagadi, Goodhope-Mabule, Tonota, Palapye, Nkange, Kasane and Kanye. More women (48.1%) participated in the study than men (41.9%) (Table 1). An average of 80.2% of the respondents were in aged class of 20-49 years (economical active group). This run contrary to the believe that only the aged remained in villages. Educational status of the respondents indicates that majority of the respondents (30%) have attended school to secondary level and a few of them had nonformal education at 2.6% (Table 1).

Table 1. Background characteristics of sampled population

Category	Frequency	Percent
Gender		
Male	163	46.6
Female	187	53.4
Age		
< 20	5	2.1
20-29	66	27.9
30-39	69	29.1
40-49	50	21.1
50-59	21	8.8
60-69	21	8.9
70+	5	2.1
Education		
None	85	24.3
Non-formal	9	2.6
Primary	66	18.9
Secondary	105	30.0
Tertiary	85	24.3
Total	237	100

The main source of income of the respondents in all the districts is employment trailed by farming. The farming system is based on extensive livestock production. Some respondents are combining farming as well as monthly income (employment). Some income source revealed by the respondents included old age pension, rented houses, selling fruits as well as selling edible wild plants (EWPs) when available (Figure 1).

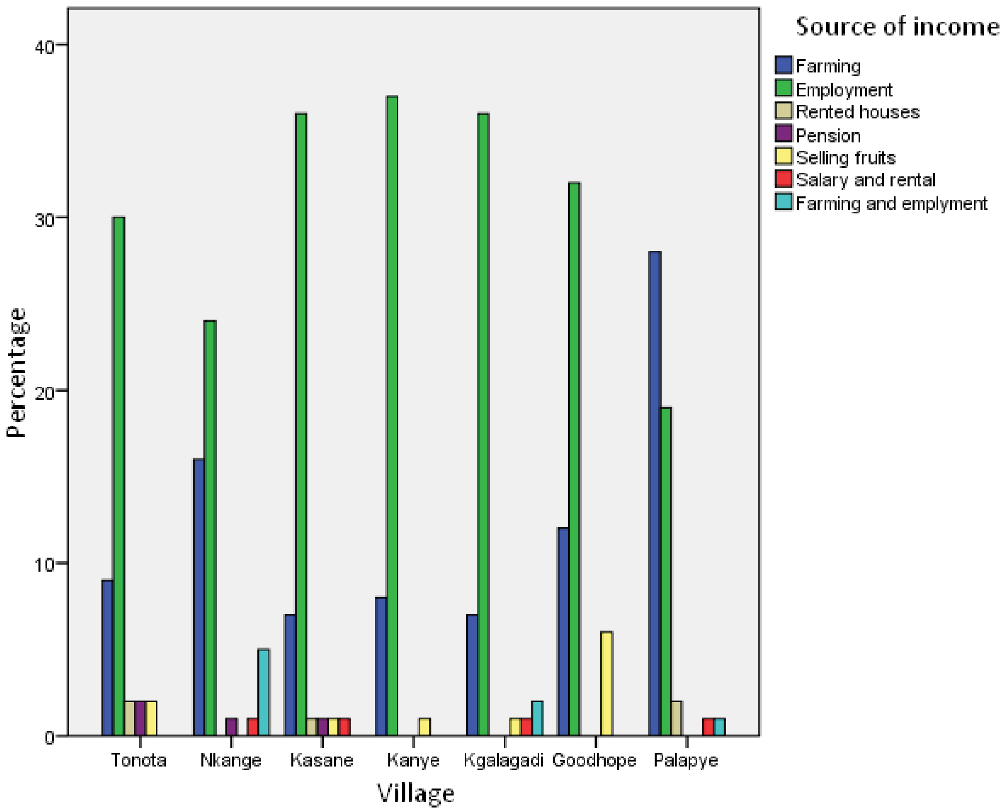

Fig. 1. Source of income of respondents

About 81 % of the respondents have planted indigenous and exotic trees in their yards, as they offer shade and fruits (Figure 2). Trees also play a very important role of acting as windbreaks around homes and also act as shields against wind. In addition, tree planting on plot boundaries have several advantages for livestock-farming: creation of a fence limiting the movement of animals, protection against the wind and harshness of the sun, occasional forage resource.

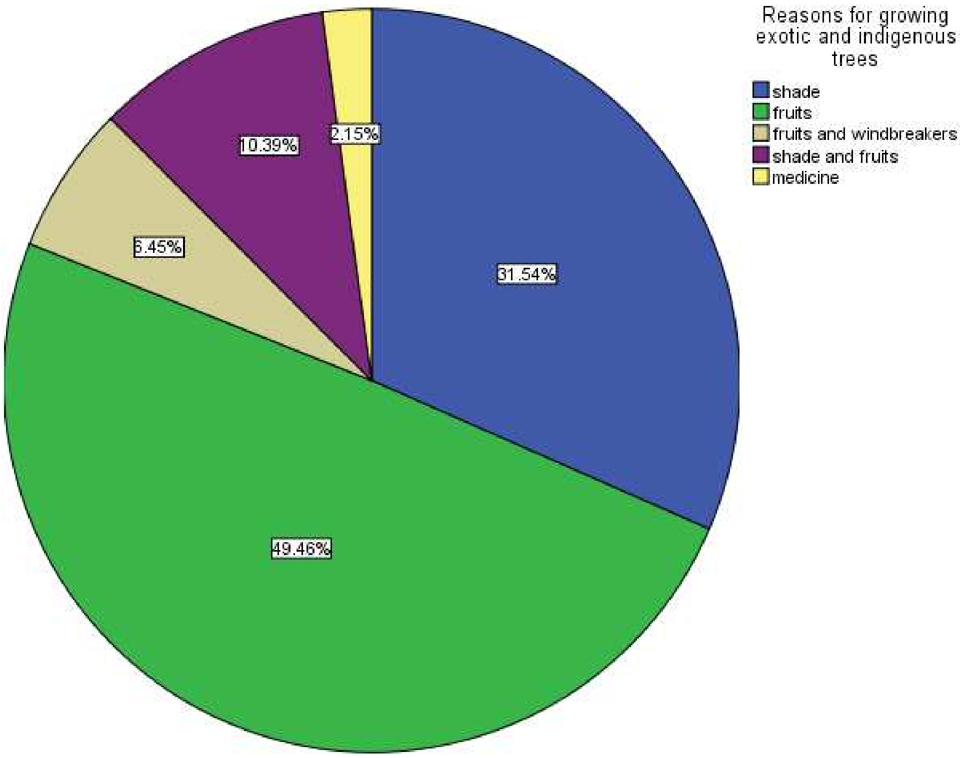

Fig. 2. Reasons for growing exotic tree and indigenous trees

The predominance of citrus, guava, pawpaw, mulberry and other fruits trees in nearly all homestead and farmland throughout the country indicates a preference for fruit trees. Most farmers, however, also tend few indigenous timber and shade species in their farm, such as *Combretum species, Sclerocaryabirrea* subsp. *caffra, Adansoniadigitata and Colophospermummopane* (J. Kirk ex Benth) J. Kirk ex J. Léonard (Appendix 1). Respondents showed that they grow trees for fruits (49.5%) mostly, followed by (31.5%) trees planted for shade and the least being for medicinal purposes at 2.15%, these results concur with those reported by Sale et al. (2014). Unlike annual crops, trees only need to be planted once, minimizing soil and nutrient loss, and are easy to integrate into an urban landscape. Table 2 presents the prevalent types of trees per district in the study area. The results on the benefits and constraints in Table 3 and 4 can be interpreted with the list of these trees.

Table 2. Common trees in their locality per district

Common names	Scientific names	Family names
Motsintsila	*Berchemiadiscolor*	Rhamnaceae
Mowana	*Adansoniadigitata*	Bombacaceae
Mogonono	*Terminaliasericea*	Combretaceae
Mokolwane	*Hyphaenepetersiana*	Arecaceae
Tsaru	*Phoenix reclinata*	Arecaceae
Mogotho	*Acacia erioloba*	Leguminosae
Mongana	*Acacia mellifera*	Leguminosae
Mosu	*Acacia tortilissubsp. heteracantha*	Leguminosae
Moduba	*Combretumzeyheri*	Combretaceae
Moporota	*Kigeliaafricana*	Bignoniaceae
Mogwana	*GrewiaBicolor*	Malvaceae
Mmupudu	*MimusopszeyheriSond.*	Sapotaceae
Morula	*sclerocaryabirreasubspcaffra*	Anacardiaceae
Mophane	*colophospermummopane*	Fabaceae

Table 2 (cont.). Common trees in their locality per district

Common names	Scientific names	Family names
Mochaba	*Ficussycomorus*	Moraceae
Moretlologawakgomo	*Ximeniacaffra*Sond. var. *caffra*	Olacaceae
Mopororo	*Lonchocarpuscassa*	Leguminosae
Moretlologawapudi	*XimeniaamericanaL.var.americana*	Olacaceae
Moselesele	*Dichrostachyscinerea subsp. Africana*	Leguminocae
Mokwa	*Pterocarpusangolensis*	Leguminosae
Lethajwa	*Diospyroslycioidessubsplycioide*	Ebenaceae
Mosese	*Burkeniaafricana*	Fabaceae
Mokusi	*Baikiaeaplurijuga*	Fabaceae
Morojwa	*Azanzagarckeana (F. Hooffm.) Excell&Hillc.*	Malvaceae
Mosesenante	*Markhamiazanzibarica*	Bignoniaceae
Mokutshumo	*Diospyrosmespiliformis*	Ebenaceae
Kowa/Mokowa	*Syzygiumguineense*	Myrtaceae
NKANGE		
Morula	*sclerocaryabirreasubsp. caffra*	Anacardiaceae
Mophane	*colophospermummopane*	Fabaceae
Mosu	*Acacia tortilissubsp. heteracantha*	Leguminosae
Morojwa	*Azanzagarckeana (F. Hooffm.) Excell&Hillc.*	Malvaceae
Mohudiri	*combretumapiculatum*	Combretaceae
Mokgalo	*ZiziphusmucronataWilld.subsp. mucronata*	Rhamnaceae
Motsiara	*Terminaliaprunioides*	Combretaceae
Moretlologa	*Ximeniassp*	Olacaceae
Motlopi	*Bosciaalbitrunca*	Capparaceae
Motswiri	*Combretumimberbe*	Combretaceae
Mokoba	*Acacia nigrescens*	Leguminocae
Mongana	*Acacia melliferasubsp. detinens*	Leguminocae
Mokgalo	*ZiziphusmucronataWilld.subsp. mucronata*	Rhamnaceae
Moselesele	*Dichrostachyscinerea subsp. Africana*	Leguminocae
Mogotho	*Acacia erolioba*	Leguminocae
TONOTA		
Mophane	*Colophospermummopane*	Fabaceae
Morula	*sclerocaryabirreasubsp. caffra*	Anacardiaceae
Mosu	*Acacia tortillis subsp. heteracantha*	Leguminosae
Mohudiri	*combretumapitilum*	Combretaceae
Mongana	*Acacia mellifera subsp. detinens*	Leguminosae
Mogwana	*Grewiabicolor*	Tiliaceae
Motswere	*Combretumimberbe*	Combretaceae
Motlopi	*Bosciaalbitrunca*	Capparaceae
Mokoba	*Acacia nigrescens*	leguminosae
Mokgalo	*ZiziphusMucronataWilld. subsp. mucronata*	Rhamnaceae
Mogonono	*Terminaliasericea*	Combretaceae
Mokgomphatla	*GrewiaschinziiK.Schum*	Tiliaceae
Moselesele	*Dichrostachyscinerea subsp. Africana*	Leguminocae
Moretlologa	*Ximeniasspkj*	Olacaceae
Mosetha	*Peltophorumafricanum*	Leguminosae
Morojwa	*Azanzagarckeana (F. Hooffm.) Excell&Hillc.*	Malvaceae
Mmupudu	*MimusopszeyheriSond.*	Sapotaceae
Motswere	*Combretumimberbe*	Combretaceae

In developing countries, woodfuel is the major source of cooking and heating where about 2 billion rely solely on fuel wood for cooking (FAO, 2005). From Table 3, approximately 84.5% of the respondents agreed that indigenous trees are the main biofuel energy, with only 7.5% disagreeing. The majority of respondents at an average of 98% from Kasane and Kgalagadi largely approved the contribution of indigenous trees as source of biofuel. Moreover, almost all the respondents in different districts concurred that indigenous tree firewood is the cheapest at an average of 91.6%, and with only 1.4% disapproving.

Indigenous fruits where labeled cheap nutritious than exotic fruits by 82% respondents, and 5.2% invalidating the factor (Table 3). The residents of Kanye and Kasane predominantly agreed, at 96% and 95.9%, respectively. Majority of the respondents, 60.2% agreed to the fact that indigenous fruits are less exported than exotic fruit importation. They stated that products from exotic trees are normally cheap and mostly available than products from indigenous trees. About 73.2% of the respondents specified that indigenous trees contribute significantly to their food and financial needs in their families. Rural communities around the world depend on various natural woodlands in different seasons to supplement both their dietary and income needs (Asfaw & Tadesse, 2001; Addis, 2009; Assefa and Abebe, 2011; Neudeck et al., 2012). Natural woodlands are of critical importance to the rural communities and source of income, more especially to those who live in areas unsuitable for crop production. Additionally, 77.7% of the respondents also stated that trees are a source of cut and carry fodder for their livestock, whilst 17.7 were uncertain and only 4.6% disagreed. The residents of the seven subdistricts emphasized that trees provide protection of infrastructure and crops, also, that trees shades are nice and cheap with an average response of 80.1% and 87.3%, respectively. From Table 3, almost 59.2% of the respondents have interest in making plantation and woodlots of different species in their yield, with only 15% uninterested. People in Kasane have clear interest in plantations/woodlots with an average of 88% respondents interested but Goodhoope residents are so skeptic about investment in woodlots/plantation. Chobe is the only district where the rainfall is just adequate to support more or less closed canopy forest vegetation (NFS, 1992). Furthermore, with valuable tree species such as *Baikiaeaplurijugaand Pterocarpusangolensis* the residents are keen to invest in plantations or woodlots.

Table 3. Percentage distribution of farmers benefits of planting and managing trees

Benefits	Villages	Disagree	Uncertain	Agree	Total
Indigenous trees are main source of biofuel energy	Tonota	0.60	2.00	11.50	14.10
	Nkange	1.70	2.90	9.20	13.80
	Kasane		0.30	14.10	14.40
	Kanye	0.30	0.30	13.80	14.40
	Kgalagadi	0.30		14.10	14.40
	Goodhope	1.70	0.30	12.40	14.40
	Palapye	3.70	1.40	9.50	14.70
	Total	**8.30**	**7.20**	**84.50**	**100.00**
Firewood from Indigenous trees is the cheapest alternative source of fuel energy	Tonota	0.30	2.30	11.50	14.10
	Nkange		0.90	13.00	13.80
	Kasane	0.90		13.50	14.40
	Kanye		0.30	14.10	14.40
	Kgalagadi		2.60	11.80	14.40
	Goodhope		0.90	13.30	14.10
	Palapye	0.30		14.40	14.70
	Total	**1.40**	**6.90**	**91.60**	**100.00**
Indigenous fruits are cheap, nutritious fruits than exotic fruits	Tonota	0.30	2.00	11.30	13.60
	Nkange	2.60	0.60	11.00	14.20
	Kasane	0.30	0.30	13.60	14.20
	Kanye		0.60	13.90	14.50
	Kgalagadi	0.90	5.80	7.80	14.50
	Goodhope	0.30	1.20	12.80	14.20
	Palapye	0.90	2.30	11.60	14.80
	Total	**5.20**	**12.80**	**82.00**	**100.00**
Less indigenous tree products are exported than exotic imports	Tonota	2.90	6.60	4.60	14.10
	Nkange	2.30	2.90	8.60	13.80
	Kasane	2.30	0.90	11.20	14.40
	Kanye		1.40	13.00	14.40
	Kgalagadi	0.60	7.80	6.10	14.40
	Goodhope	1.40	4.90	7.80	14.10
	Palapye	0.30	5.50	8.90	14.70
	Total	**9.80**	**30.00**	**60.20**	**100.00**
Indigenous fruits source of food and income to your family	Tonota	1.20	0.60	12.10	13.80
	Nkange	0.60	3.20	10.40	14.10

Table 3 (cont.). Percentage distribution of farmers benefits of planting and managing trees

Benefits	Villages	Disagree	Uncertain	Agree	Total
	Kasane			14.40	14.40
	Kanye		2.60	11.80	14.40
	Kgalagadi		4.00	10.40	14.40
Indigenous trees are main source of biofuel energy	Goodhope	3.50	7.20	3.50	14.10
	Palapye	2.90	1.20	10.70	14.70
	Total	**8.10**	**18.70**	**73.20**	**100.00**
Backyard garden and orchard are source of income	Tonota		0.30	13.60	13.90
	Nkange	0.30	0.60	13.00	13.90
	Kasane			14.50	14.50
	Kanye	0.90	1.40	12.10	14.50
	Kgalagadi	0.60	1.40	12.40	14.50
	Goodhope	2.30	6.60	5.20	14.20
	Palapye	0.30		14.50	14.70
	Total	**4.30**	**10.40**	**85.30**	**100.00**
Interest in plantation or woodlot	Tonota	1.20	4.90	7.50	13.60
	Nkange	4.60	3.20	6.40	14.20
	Kasane	1.20	0.60	12.70	14.50
	Kanye	1.20	5.50	7.80	14.50
	Kgalagadi		6.10	8.40	14.50
	Goodhope	4.60	4.90	4.60	14.20
	Palapye	2.30	0.60	11.80	14.70
	Total	**15.00**	**25.70**	**59.20**	**100.00**

Table 4 presents the results on the constraints to planting and managing trees by farmers. Farmers gave numerous reasons that are constraints towards adoption of agroforestry or tree planting in farmers or communal area in Botswana. Tree maturity or long rotation length is often cited by majority as one of the factors hindering adoption of tree planting (Kallio, 2013), the benefits are realized after a very long time. This was reiterated by the sampled resident, majority of the respondents 88.8% cited out that tree takes long time to reach maturity and produce as well as realizing profits, as such, they regarded trees to be of less commercial gain. Almost 75.1% of the respondents in sampled areas indicated that indigenous trees propagation is still a challenge as compared to them growing naturally. Information deficiency was highlighted as a predominant constraint, as 80.1% of the respondents concurred that they is less information about indigenous tree production, 10.1% was uncertain, whilst 8.9% disagreed to the factor. Furthermore, majority (average of 73.8%) of respondents agreed that limited information and service of indigenous trees contribute to reluctance of rural dwellers to adopt agroforestry initiative. Some are of the perception that indigenous trees grow well on their own, so there is no need for human management. Exotic trees adaptation to locally conditions is another factor unsettling locals from planting and managing them, this was depicted by 75.5% of the respondents, 16.9% was uncertain and merely 7.35% disproved the factor. Again, exotic trees was labelled less preferred in rural areas by average of 60.7% of respondents, 21.1% was uncertain and 17.9% invalidated the factor. Trees like agricultural crops suffer from pest damage. The problem is more critical when no chemicals or other methods are available to control their spread and damage. The major pest in the country is termites (Mutakela et al., 2003). Destruction of trees by termites and small stock animals, was highlighted as another factor hindering adoption of agroforestry and an average of 74% concurred to the factor as a barrier to planting and managing trees.

Table 4. Constraints to planting and managing trees

Constraints	Percentage
Trees grow slowly to reach maturity and production stage.	88.8
It is not easy to propagate indigenous trees than when they propagate naturally.	75.1
There is limited information on many indigenous trees about production and potential benefits and services of indigenous trees agronomically to rural dwellers.	75.5
There is poor adaptation of exotic trees when grown locally and most exotic trees grown locally are ornamental or fruit bearing and less preferred in rural areas.	60.1
Termites and small stock animals are the most destructive pests of trees in rural area.	74.0

Drivers of adoption of agroforestry practices by farmers. The following are the identified local conditions that favour the adoption of tree planting and agroforestry opportunities:

Farmers leave trees on farms: This is an old practice, which is some form of agroforestry, hence farmers are likely to adopt an improved version of this system since they are already familiar with the importance and benefits of trees. One, therefore, needs to simply educate and encourage farmers to utilize the full potential of this system. In the study area there is no taboo against tree planting. When agroforestry is introduced in the communities, it is likely that the introduced tree species will be accepted, as far as the usage and benefits of these trees are explained.

Knowledge on tree importance: Trees are used for firewood, shade, windbreaks, fodder, in the communities, which implies that local uses of the woody perennial already exist and it is in a high demand. Dead trees are the most common source of domestic fuel for the people in the study area. However, pressure on these trees will render extinction of some useful tree species for fuelwood. Communities have complained of shortages of fuelwood since women who are responsible for fetching firewood walk long distances to obtain some. It is, therefore, expected that the community will be able to obtain readily available source of fuel when agroforestry is practiced. The respondents also recognized the importance of trees are a source of cut and carry fodder for their livestock. Farmers have also identified some trees, which can be used as fodder, as motlopi (*Boscia Albitrunca*), farmers are the opinion that it has the same feeding value as alfalfa (Lucerne). It was also observed that fruit trees are grown in most of the home gardens and indigenous trees in some districts have been left and managed in agricultural fields.

Live Fencing of homes and demarcation of boundaries: In nearly all districts in the communities, live fencing was observed, which indicates that this form of agroforestry is already present. Trees are also used as demarcation of land units and farmers know the importance of using tree species for this purpose.

Presence of nurseries: Knowledge on raising tree seedlings is in existence in some villages. It is likely that some facilities for establishing nurseries can be obtained and they could be encouraged in the whole community.

Favorable climate for tree and crop growth: Apart from the decline of the amount of rainfall, farmers have not mentioned other climatic or environmental constraints, which affect the growth of either the crops or trees. However, the major concern of pests, especially termites attack, is still a major constraint that hinders tree planting by communities.

Existence of Government Extension and NGOs: In nearly all the districts, Government Forestry Extension and NGOs are supporting the community by educating farmers, which can eventually supplement the practice of agroforestry.

Fruit trees for subsistence and income: Farmers grow fruit trees not only within the vicinity of their community, but also in the field. This practice is seen as very favourable when future attempts are made for combining food crops with nonconventional tree species (timber species). Mango (*Mangiferaindica*), peaches and Sweet orange *(Citrus sinensis*) are the common fruit trees being cultivated in the country even though around the homesteads.

Farmers' interest in bee keeping: The farmers' interest can be beneficial when improved agroforestry systems are recommended.

Costs of farm inputs: Since farmers cannot afford the high costs of farm inputs, such as fertilizer and pesticides, introduction of low-input demanding system like agroforestry will be a relief to them. It was, therefore, suggested that agroforestry is in the greater potential stability of responding to drought and heat stress, nutrients cycling and improved moisture balance and in the greater variety of products it yields.

Implications for climate change mitigation

The Green House Gas (GHG) mitigation potential of Sustainable Land Management (SLM) in agricultural lands is very large (Liniger et al., 2011). In humid zones of Africa, retaining shade and understory trees in cacao can provide vast carbon stores. Mature cacao agroforestry systems in Cameroon store 565 tons of CO_2eq per hectare. Even in semi-arid lands, agroforestry systems like intercropping or silvopasture, with 50 trees per hectare, can store 110 to 147 tons of CO_2eq per hectare in the soil alone (Liniger et al., 2011). Agroforestry has the potential to sequester significant amounts of carbon for 2 reasons. First, the area currently in crops and pastoral systems is large. Second, although the density of carbon storage is low in comparison with forests, the woody biomass of agroforestry systems could provide a source of local fuel. This fuel would reduce pressure on the remaining forests in the area and, at the same time, provide a substitute for fossil fuel. These effects are important because the most effective way to use land for stabilization of atmospheric carbon is not through reforestation but through the substitution of wood fuel for fossil fuel (Hall et al., 1991). Takimoto et al. (2008) reported that *F. albida* parklands stored more C than improved agroforestry systems (live fence and fodder bank) or abandoned land. Similarly, Garrity (2010) indicated that the carbon sequestration potential of agroforestry systems varies greatly from under 100Mt to over 2000Mt of carbon dioxide equivalent per year particularly the use of *Faidherbiaalbida* in Malawi and Niger.

Forests would continue to hold the carbon accumulated, but they would accumulate no additional carbon after that time. In contrast to the temporary effect of reforestation, the sustainable use of wood fuels provides a solution that could last indefinite. The biophysical and spatial potential for carbon sequestration in Africa is high; the socio-political conditions related to land usage, ownership and permitted land management practices are not, constituting a serious dilemma for carbon storage on the continent – and a similar dilemma for biofuel projects. The primary problem within this dilemma is land tenure, and no clear way ahead exists, despite the well-intentioned recommendations in the afforestation and reforestation carbon sequestration literature for the development and implementation of Western notions of property rights, along with improved governance, local participation, and sustainable development (Kauppi and Sedjo, 2001). Land tenure will be the most fundamental issue regarding how trees are to interact with African landscapes.

Lal (2004) noted that afforestation, the establishment of tree plantations, has a large potential for SOC sequestration in the tropics. Deans et al. (1999) reported SOC accumulation under 18-year plantation of *Acacia Senegal* in northern Senegal at the rate of 0.03%/yr under the tree canopy and 0.02%/yr in the open ground, corresponding to SOC sequestration rates of 420 and 280 kg C/ha/yr for a soil bulk density of 1.4 Mg/m3. Johnson (1992) reported a > 35% increase in soil C following the afforestation and reforestation of cultivated soils. The use of woody perennials, such as cocoa plantation in Ghana and Cameroon, coffee plantation in Burkina Faso, indigenous fruit trees in South Africa, oil palm plantation in Cote' de voire, exotic tree species in Ethiopia, rubber plantation in Nigeria and Ghana, Cashew and teak plantation in Nigeria were covered (Ofori-Frimpong et al., 2010). Cocoa planted at low plant density and under shade stores more carbon per unit area of soil than an equivalent area of cocoa planted at high density without shade. In addition to C sequestration in biomass and soil, tropical plantations are needed for timber, and more importantly, as fuel wood for cooking. Thus, the area under tropical plantations has increased drastically since the 1960s, from 7 Mha in 1965 to 21 Mha in 1980, 43 Mha in 1990 (Evans, 1992) and 187 Mha in 2000 (FAO, 2003). In western Nigeria, Ekanade et al. (1991) reported that the SOC pool under forest was 29 g/kg and that under cocoa was 19 g/kg. Similar observations were made by Adejuwon and Ekanade (1988) in Oyo state, Nigeria. Also in southern Nigeria, Ogunkunle and Eghaghara (1992) observed that the SOC concentration under 10-year old cocoa plantation was 25 g/kg compared with 35 g/kg under forest. In Nigeria, Aweto (1987) reported that the SOC concentration was 14 g/kg under primary forest and 12 g/kg under a 18-year old rubber plantation. The SOC concentration under rubber increased over time. In Kade, Ghana, Duah-Yentumi et al. (1998) reported that the SOC concentration of a soil under 40-year old rubber plantation was lower than that under virgin forest or 20-year old cocoa. Both rubber and cocoa received no fertilizer or manure.

Conclusion

Farmers in the communities have indigenous knowledge on trees and their importance, since a high percentage of the farmers interviewed already knew the concept of agroforestry and were ready to adopt the system based on its multiple benefits. When introducing tree species, however, farmers have suggested multi-purpose species adaptable to their locale. Traditional values, such as taboos regarding tree planting, are absent in the communities. Land for crop production in the area is largely by inheritance and allows for tree planting. The introduction of agroforestry in the area would, however, not be a new idea since on their farms; farmers have been practicing the act of keeping trees together with food crops. Also the practice of growing fruit trees and live fencing species makes the system not entirely new. With the interest expressed by communities to plant fruit trees and fodder, management of the components of the system is assured. The study conducted indicated that there is a high opportunity for the conscious introduction of tree planting and agroforestry in the study areas. However, the inadequate education on tree propagation, water as well as the poor marketing system and road networks are possible threats to the realization of the full benefit of the system. Lack of inputs serves as limiting factor to the adoption of tree planting and agroforestry in the study area since farmers interested in tree growing are constrained by these.

References

1. Addis (2009). Edible wild and semi-wild plants of Hamar and Xonso (South Ethiopia) with emphasis on their Ethnobotany and nutritional composition of selected species. PhD Thesis. Addis Ababa University, Addis Ababa, Ethiopia.
2. Arnold, J.E.M. (1991). *Community Forestry: 10 years in review*. FAO Community forestry.

3. Asfaw, Z. and Tadesse, M. (2001). Prospects for sustainable use and development of wild food plants in Ethiopia. *Economic Botany*, 55, pp. 47-62.
4. Deans, J.D., O. Diagne, D.K. Lindley, M. Dione and J.A. Parkinson (1999). Nutrient and organic matter accumulation in *Acacia senegal* fallows over 18 years, *Forest Ecology Management*, 124, pp. 153-167.
5. Duah-Yentumi, S., Ronn, R., and Christensen, S. (1998). 'Nutrients limiting microbial growth in a tropical forest soil of Ghana under different management', *Applied Soil Ecology*, Vol. 8, Nos 1-3, pp. 19-24.
6. Department of Forestry and Range Resources (2014b). Government tree nurseries. DFRR.
7. Department of Forestry and Range Resources (DFRR) (2014a). Backyard tree nursery list in Botswana. DFRR.
8. Ekanade, O., F.A. Adesina and N.E. Egbe (1991). Sustaining tree crop production under intensive land use: An investigation into soil quality differentiation under varying cropping patterns in western Nigeria, *Journal Environmental Management*, 32, pp. 105-113.
9. FAO (2003). State of the World Forests. FAO, Rome, Italy.
10. Food and Agriculture Organization (FAO) (2005). The State of the Worlds Forests. Accessed from: http://www.fao.org//docrep/007/y557e/y557e00.html.
11. Garrity, D.P. (2010). Hope is Evergreen. Our Planet May: 28-30.
12. Hall, D.O., Mynick, H.E., Williams, R.H. (1991). Cooling the greenhouse with bioenergy, *Nature*, 353, pp. 13-12.
13. Kallio, M.H. (2013). Factors influencing farmers' tree planting and management activity in four case studies in Indonesia. Vikki Tropical Resource Institute (VITRI). Department of forestry Science. University of Helsinki. Finland.
14. Kauppi, P., Sedjo, R. (2001). Technical and Economic Potential of Options to Enhance, Maintain and Manage Biological Carbon Reservoirs and Geo-engineering. Chapter 4 in IPCC Third Assessment Report. Cambridge University Press, Cambridge, London.
15. Lal, R. (2004). Carbon Sequestration in Dryland Ecosystems Environmental Management, Vol. 33, No. 4, pp. 528-544, 2004, Springer-Verlag New.
16. Liniger, H.P., R. MekdaschiStuder, C. Hauert and M. Gurtner (2011). Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).
17. Legwaila, G.M, W. Mojeremane, M.E. Madisa, R.M. Mmolotsi and M. Rampart (2011). Potential of traditional food plants in rural household food security in Botswana, *Journal of Horticulture and Forestry*, Vol. 3 (6), pp. 171-177.
18. Mothanka and Makhabu (2010). Medicinal and edible wild fruits of Botswana as emerging new opportunities. *Journal of Medicinal Plants Research*, Vol. 5 (10), pp. 1836-1842.
19. Mutakela, P.S., Mokgwathi, S.W. and Tsheboeng, K. (2003). *Assessment of community woodlots in Botswana.* Ministry of Agriculture. 59 p.
20. Neudeck, L., Avelino, L., Bareetseng. P., Ngwenya, B.N., Teketay, D. and Motsholapheko, M.R. (2012). The contribution of edible wild plants to food security, dietary diversity and income of household in Shorobe village, Northern Botswana, *Ethnobotany Research and Application*, 10, pp. 449-462.
21. Norwegian forestry society (NFS) (1992). Chobe forests inventory and management plan. Gaborone, Ministry of Agriculture, Botswana.
22. Ofori-Frimpong, K., Afrifa, A.A., Acquaye, S. (2010). Impact of shade and cocoa plant densities on soil organic carbon sequestration rates in a cocoa growing soil of Ghana, *African Journal of Environmental Science and Technology*, Vol. 4 (9), pp. 621-624.
23. Ogunkunle, A.O. and Eghaghara, O.O. (1992). 'Influence of land use on soil properties in a forest region of Southern Nigeria', *Soil Use and Management*, Vol. 8, No. 3, pp. 121-125.
24. Sale, Aladi, F. John, O.O. (2014). Farmers perception of opportunities preferences and obstacles of growing multipurpose trees on farmland in kogi state, *European Scientific*, Vol. 10, No. 14, ISSN, pp. 1857-7881.
25. Takimoto, A., Nair, P.K.R., Nair, V.D. (2008). Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel, *Agriculture, Ecosystems & Environment*, 125, pp. 159-166.
26. Totolo, O. (1997). Multiple-use of indigenous forests and woodlands in the SADC region, *Journal of Forestry Association of Botswana*, 1 (1), pp. 19-31.
27. Zubair M., Garforth, C. (2006). Farm level tree planting in Pakistan: the role of farmers' perceptions and attitudes, *Agroforestry System*, 66, pp. 217-229.