Research Article

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Species selection in unfamiliar terrain: participants' preferences and practices around Mount Elgon, Uganda

Abstract

Efforts to restore the world forests and trees are obviously significant and still increasing. Selection of tree species in this context is based on prevailing challenges impacting on livelihood needs. A study was conducted around Mount Elgon between January 2018 and July 2020. The objectives were to; i) document the socio-economic factors of participants in tree multiplication and planting, ii) identify the farmers practices and choice of species used under farming contexts iii) assess the relationship between the participants socio-economic factors, practices and choices of tree species. A multi-stage sampling approach was followed to select a total of 150 participants. The participants were engaged through semi-structured and key informant interviews. Quantitative data were analyzed in MINITAB 19. Results show that tree multiplication and planting activities were dominated (84%) by a vibrant group of males between the ages of 15 and 40 years old. Up to 60% of this group were illiterate or inexperienced in tree planting and multiplication. Exotic trees (containing *Eucalyptus grandis, Grevillea robusta* and *Neolamarckia cadamba*) were highly valued for firewood, timber and small stems used to support food crops including *Musa* spp., *Phaseolus vulgaris* and *Solanum lycopersicum*. The indigenous species (mainly *Cordia africana, Maesopsis eminii*, *Albizia* spp. and *Ficus* spp.) were on the other hand treasured for shade in the coffee-banana farming systems as well as serving social-cultural benefits, counting medicine and rituals. The participants gender significantly influenced the choice of tree species adopted (P<0.001). For example, the men were more interested in timber and carbon related tree species while the women and the youths were generally involved in apiculture and fruit tree growing. With all the anticipated benefits and publicity about the exotic trees in this region, the participants have no choice but to follow the advice from the various tree planting campaigns. We recommend co-operation of the stakeholders especially during tree germplasm selection in order to meet performance expectations. The expectations include developing individual species breeding protocols based on site conditions for tree seed collection, seedling multiplication and planting.

Keywords: tree planting, tree seedlings, forest restoration, farmer-based restoration

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Introduction

In countries where indigenous forests and tree availability are shrinking, local people grow their own trees to sustain the supply of livelihood products and services including timber and firewood.[1-6] The planting and management of trees in the fields however, takes place especially if the benefits are predictable.[7] Accordingly, selection of tree species in this context is based on prevailing challenges impacting on livelihood needs, such as income, food and energy supply and restoring the environment.[8,9] For example, tree food such as fruit, nuts and leaves are often good potential sources of nutrients such as fat, fibers, protein, minerals and vitamins, and their consumption therefore, is important.[10] Also planting trees to sequester carbon dioxide mitigates climate change, but significant progress has been hindered by limited attention given to the quality of the germplasm used in afforestation/reforestation programs.[6] Stakeholders therefore, need to gather the necessary information to make tree choices that fit their farming contexts in order to optimize benefits.

Optimum and sustainable supply of tree benefits require reliable supply of quality germplasm. Quality tree germplasm incorporates aspects of productivity, fitness of purpose, viability and diversity.[3,11] Strategies for individual species productivity may however, vary based on functional use, biology, management alternatives and the planting sites. There is a need to raise awareness amongst stakeholders (including tree farmers and policy-makers) in order to demonstrate the value of using high quality germplasm.[12]

Although the notion of quality tree germplasm is highly promoted in forestry science and generally valued in the developed countries such as the US and Europe,[13,14] in the developing world it is not.[6] Limited awareness on the importance of quality tree germplasm coupled with absence of effective policy guidelines to regulate germplasm production in many countries are the likely reasons as to why tree germplasm is often collected in such a disorganized manner.[15-17] Indeed weaknesses in policies on tree germplasm supply include fragmentation of institutional mandates/functions and underfunding of institutions involved.[18] Often though, this is due to the stakeholders' lack of information on germplasm demand, coordination and planning during tree seedling production and management. Moreover, some actors' involvement is inclined towards the desire to make profit, while others are technically crippled to handle this business. Consequently, resources often get wasted when tree germplasm fail to germinate or seedlings flop in the field.[19]

Lillesø et al,.[20] blame tree seedling failure on actors in the developing countries to frequently collect tree germplasm from a relatively narrow range of maternal parents. In such countries there is generally two types of tree germplasm supply models, namely centralized and decentralized, with several variations depending on the source and the actors involved.[20] For example, in the Philippines, Koffa and Roshetko[21] found that most tree seed specialists collected seed from one to five trees while in Malawi, Namoto and Likoswe[22] reported that most nursery operators collected seed from between one and 26 mother trees. Moreover, earlier reports by Lengkeek et al,.[7] hinted on the use of a single mother tree by more than one third of tree nurseries around Mount Meru in Central Kenya. Further, after initial farm introductions, germplasm for the subsequent planting rounds was harvested from trees on the same farm or, less frequently, from neighboring farms. Such practices promoted genetic inferiority and compromised the quality of tree growth and resilience.[23] As a result, inferior tree seedlings failed in the field leading to farmer losses and frustrations.[6] There is a need to build systems to better estimate the tree germplasm demand and supply to enable the tree germplasm suppliers in developing countries make informed decisions.[6,12]

Due to a need to increase tree planting around Mount Elgon, the factors affecting the participants in production and management of tree plantings were investigated. The specific objectives were to; i) document the socio-economic factors of participants in tree multiplication and planting, ii) identify the farmers practices and choices of species used under farming contexts iii) assess the relationship between the participants socio-economic factors, practices and choices of species. The interaction of political and socio-economic factors at global and local scale affect tree breeding and management practices.[9,24,25] For example, the farmers' motivation to plant trees may be governed by an interplay of factors such as the need to improve their livelihood,[9] availability of land,[26] readiness of labor, nature of farm tenure-ship, accessibility to capital inputs as well as social status.[27] Likewise, the participants' socio-economic factors leading to species selection are as important as the drivers for tree planting or reforestation, and can help to guide efforts towards forest and tree restoration in unfamiliar terrain such as the areas surrounding Mount Elgon in Eastern Uganda. "Unfamiliar" because it is difficult and belligerent in all aspects of life including the landscape, environment and inter-person/community relationships. A terrain where livelihoods thrive on protected resources, farmland is vertical and extensively split into very small plots. Conflicts over land, trees and crop resources increase everyday leading to more divisions and confusion within the communities.[28]

Study location and methods

Study location

The study was conducted around Mount Elgon, covering five districts of Mbale, Manafwa, Bududa, Bulambuli and Sironko (Figure 1). Mount Elgon is an extinct 4321 m high Miocene volcano at the border of Uganda and Kenya.[29,30] It is partly associated with the Great Rift System and has rich soils, conducive for agriculture and tree farming.[31] The slopes are generally gentle (averaging less than 4^o), with natural terraces cut by sheer cliffs in the north, and steep slopes in the south and south-west.[30] The soils are of a volcanic origin and the types include; Acrisols, Ferralsols, Nitisols and Luvisols.[32] The area receives an annual average rainfall of 1800 mm, mostly occurring in the months of April–June and August–November.[29,33] However, significant changes in rainfall patterns have occurred in the past two decades.

Mount Elgon is an important area for biodiversity conservation. The biodiversity thrives on four broad plant communities including a mixed montane forest up to 2500m, bamboo forest and low canopy montane forests existing from 2000-3000m and moorland above 3500m asl.[34] About 1464 vascular plant species exists, of which 39 were recorded only from this area.[24] The area is also important for endangered and restricted species. For example, half of the total number of butterflies and up to 144 bird species of Uganda were recorded from this region. The bird species record includes the Jackson Francolin (*Francolinus jacksoni*), Bronze-naped pigeon (*Colomba delegorguei*), Hartlaubs Turaco (*Turaco hartlaubi*) and Tacazze sunbird (*Nectarinia tacazze*) which are restricted to this area.[33]

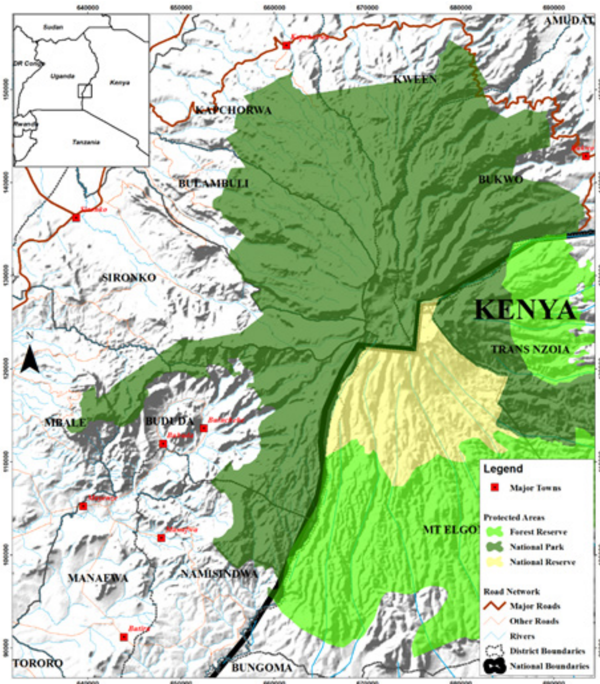


Figure 1 Location of the study districts around Mount Elgon. Data source: National Forestry Authority (NFA) GIS Unit, Kampala, 2019.

The Elgon region also serves as a major water catchment area for important water systems such as River Turkwell and Lake Turkana in Kenya, as well as Lake Victoria and the Nile River basin in Uganda.[35] The forests and trees within, refine water for more than 2 million people in both countries[30] and contribute medicine and shelter for the social cultural rituals of the Bagisu and Sabiny communities in Uganda.[36]

The Sabiny and Bagisu communities comprise a local population of about 1,500,000 people with high densities ranging from 400–800 people/sq.km, and growing at 5.6% per annum.[37,38] The Bagisu are heavily dependent on agriculture and extraction of forest and tree resources for subsistence and economic purposes. The Sabiny on the other hand, are nomadic pastoralists and supplement their livelihoods through hunting and gathering wild food resources.[26] Agriculture is practiced within a mixed farming system on very small landholdings, averaging less than one acre.[36]

Food crops such as maize (*Zea mays* L.) groundnuts (*Arachis hypogaea* L.), cassava (*Manihot esculenta* Grantz), sweet potatoes (*Ipomea batatus* L.), beans (*Phaseolus vulgaris* L.), Irish potatoes (*Solanum tuberosum* L.) and plantain (*Musa* L. spp.) are generally cultivated.[29,36] The cash crops comprise of cotton (*Gossypium herbaceum* L.) and coffee (*Coffea arabia* L.) as well as fruits such as guavas (*Psidium guajava* L.), Jackfruit (*Artocarpus heterophyllus* Lam), mangoes (*Mangifera indica*), avocado (*Persea americana* Mill.) and *Citrus* spp. Also an assortment of vegetables such as tomatoes (*Solanum lycopersicum* L.), onions (*Allium cepa* L.) and cabbages (*Brassica oleracea* L.) also contribute a significant portion of cash to farming livelihoods in this region.

Methods

Due to multi-stakeholder involvement in the tree multiplication and planting enterprises, the study employed both qualitative and quantitative methods. Initial visits to the study area were conducted to identify key stakeholder in the forest/tree based enterprises. Subsequently a few stakeholders were engaged in preliminary interviews and Focus Group Discussions (FGDs). A total of 18 (including six permanent and 12 temporary) nurseries were evaluated. Permanent nurseries were profit based, extensive and raised at least 10,000 tree seedlings a year. They consisted long-term structures including greenhouses, seed beds and a mother garden. Temporary nurseries on the other hand, were short-term, generally small in extent, numerous and restricted in terms of number of seedlings (between 150 and 2,000) raised at once. They consisted provisional structures constructed out of cheap and temporary materials, commonly grass and tree/banana leaves. Key informants including (tree farmers, seed collectors, seed processors, and other nursery employees) were engaged in guided interviews. The interviews and discussions generated new insights about tree multiplication and planting enterprises in the area. Development of data collection tools used in the main survey was completed during this process.

Qualitative data collection in the main survey

In order to understand the linkage between the participants' factors, practices and choices of species to multiply/plant, the following questions guided our quest into the tree multiplication and planting practices. The questions included; i) which practices are common among the tree farmers and nursery owners? ii) How does the social, economic and political differences of the participants (including tree farmers and seedling producers) influence the nature, practices and choice of species used? Such choices depend on the availability of the resources needed for production, infrastructure and markets as well as apparent costs and benefits. During this process, the common tree species and cost per seedling were recorded.

Key informants interviews (KIIs) drew participants from government and non-government based institutions. The government based institutions included; i) the National Forestry Authority (NFA), ii) Uganda Wildlife Authority (UWA), iii) National Forestry Resources Research Institute (NaFORRI), iv) Ministry of Water and Environment (MWE) and v) District Forestry Departments. The non-government participants were selected from i) the International Centre for Research in Agroforestry (ICRAF), ii)Mount Elgon Tree Growers Enterprise (METGE), iii) World Vision Uganda, iv) Mbale-Coalition Against Poverty (Mbale-CAP), v) International Union of Conservation for Nature (IUCN), vi) Eco-TRUST, vii) Saw-log Production Grant Scheme (SPGS) and ix) the Uganda Tree Growers Association (UTGA). All these participants at the time of the study, were very actively involved tree planting and forest restoration efforts around Mount Elgon. The interviews elicited information on tree seedlings multiplication practices as well as tree species choices by farmers around Mount Elgon. The informants were also engaged on tree seed collection processes, seedling production and distribution systems as well as planting challenges, and trends in choices of trees on farm.

The quality of seedlings of at least one important species per nursery was assessed for growth vigor, pest and disease incidence. A maximum of 20 and a minimum of five seedlings per species lot were randomly selected and assessed for growth vigor. Growth parameters such as the root and stem diameter, and seedling height were assessed using a caliper and diameter tape. The ratio of height to stem diameter provided information about the seedling's sturdiness, a critical quality aspect to achieving out planting performance (Ritchie 1984). Also the number of leaves for each of the seedling were counted. For pest and disease incidence, the ratio of infested to health parts was established.

A total of 30 most mentioned species were selected for ranking based on revenue projections, access to planting materials and ease to manage on farm. Out the 30 species, the farmers were asked to identify 10 species they knew best for each of the ranking criteria. The authors considered that expert knowledge of people can rank up to a maximum of 10 items, without losing the ranking quality.[38] For revenue projections and access to good planting materials, 10 and eight species were selected respectively. While with ease to manage and value for products and services, 14 and six species were selected correspondingly.

Quantitative data collection

A multi-stage sampling approach was followed to select participants during quantitative data collection. Selection of respondents followed a stratified random sampling procedure. Each study district formed a stratum from which a random sample of participants was drawn. For each district, an exhaustive list of actors in the tree multiplication and planting enterprises was generated. A total of 22 respondents were from Bududa District while Bulambuli District contributed 23 participants. Up to 27 actors from Manafwa District participated while 29 and 25 respondents were from Mbale and Sironko Districts respectively. From the lists, a random sample of 35 tree farmers, eight tree seed dealers, 15 nursery workers, 29 forest/tree products based business owners (nine carpenters, five timber dealers, eight fuelwood dealers, seven fruit traders) six forestry research technicians based in the region were interviewed using semi-structured questionnaires. Data on tree germplasm collection and multiplication, nursery management practices, and trends in tree planting on farms as well as benefits were gathered.

Data analysis

Participatory methods were used to analyze qualitative data. Bradley and Terry[39] approach was followed to analyze the ranking data of tree species, revenue projection, access to planting materials and value for products and services. A rank is a relationship between a set of items such that, for any two items, the first is either 'ranked higher than', 'ranked lower than' or 'ranked equal to' the second. Ranking should not be confused with rating, where the items are scored with absolute values on a scale for example, from 1-5.[38] The analysis yielded ranking estimates from each individual participant. The ranking estimates were used to create one combined ranking for all the respondents. For the sake of interpretation and comparisons of rankings, a decision rule was used to group and label tree species based on their ranking estimates following Turner and Firth.[40]

Quantitative data was summarized in Microsoft Excel and analyzed in MINITAB 19. Descriptive statistics (including means, standard error and standard deviations) were computed to determine the average family size, farming period and income of the participants per annum. Cash income was calculated from the sale of tree products, agricultural crops and livestock products while subsistence income was estimated as the value of products directly consumed by the participants' household, multiplied by the local unit price.[36] A Pearson Chi-square test was used to determine the degree of association between socio-economic factors of participants, practices and choice of species planted. From literature,[9,41-43] we anticipated a positive or negative association between the variables because tree based enterprises constituted an important source of livelihoods in the region.

Results

Socio-economic factors of participants

Majority (84%) of the participants were males between 15 and 40 years of age. Up to 60% of them were uneducated and lacked relevant training in tree seedling production, planting and on-farm management. Half of the participants were located in urban places, 35% were rural based, and 15% were operating by the roadside. Smallholder farmers comprised the most important participants in various tree based enterprises including fruit growing (45%), fuel-wood and timber processing (17%), tree seedling production and planting (16%), vegetable growing (13%), beekeeping (8%) and animal raring (6%). The tree nursery owners formed the second important category of participants operating on both, temporary (55%) and permanent (36%) basis (Table 1).

On average, smallholder farmers operated on less than one acre plots, with between two and 150 trees arranged based on farming context (e.g. trees scattered on farm, along the boundary, trees along the riverbanks, trees along the slope) to serve different purposes. The common species on farms included *Makharmia lutea* (Benth.) K.Schum. for boundary marking and timber supply. On the other hand, *Neolamarckia cadamba* (Roxb.) Bosser, *Cordia africana*, and *Maesopsis eminii* were also integrated for shade, while *Artocarpus heterophyllus, Magifera indica, Persea americana,* and *Prunus africana* were incorporated for firewood and timber as well as food and medicinal purposes (Table 2). *Eucalyptus grandis* was clearly favored for firewood and timber while *Calliandra calorthysus* was mainly grown to feed livestock and to guard against soil erosion down the slope.

Table 1 Socio-economic factors of participants in the tree multiplication and planting enterprises

Characteristics	Percentage (%)
Gender	
Male	84
Female	16
Age group	
15-35	40
36-45	25
46-55	20
56-66	15
Level of education	
Uneducated	20
Lower Primary	45
Upper Primary	20
Lower secondary	15
Upper Secondary	5
Tertiary (Vocational/University)	5
Location of business	
Rural farm	35
Urban center	50
Roadside	15
Nature of tree based enterprise	
Vegetable growing	13
Apiculture	8
Fruit farming	45
Tree production	16
Tree seed procurement	4
Forest management	1
Animal raring	6
Timber/ firewood business	17
Tree species preference	
Eucalyptus grandis	40
Neolamarckia cadamba	21
Cordia africana	3
Grevillea robusta	12
Maesopsis eminii	8
Fruit trees (e.g. P. americana, M. indica, A. heterophyllus & Citrus spp.)	16

Table 2 Trees planting contexts, and local use of around Mount Elgon, Uganda

Botanic name	Family	Farming context	Average cost per seedling (UGX)	Observation on farms and nursery	Local uses
Albizia glabberima (Schumach. & Thonn) Benth	Fabaceae	Trees scattered on farm	150	+	Firewood, charcoal, medicine, shade
Albizia zygia (DC.) Macbr	Fabaceae	Trees scattered on farm	160	+	Firewood, charcoal, medicine, shade for coffee
Albizia coriaria Welw. ex Oliv.	Fabaceae	Trees scattered on farm	180	++++	Firewood, charcoal, medicine, shade
Antiaris toxicaria (Rumph.ex Pers.) Lesch	Moraceae	Trees scattered on farm	50	++	Timber, firewood, toxins
Artocarpus heterophyllus Lam	Moraceae	Fruit orchards/ trees scattered on farm	450	+++++	Firewood, fruits, timber, shade
Calliandra calothyrsus (Meisn.)	Leguminosae	Hedgerows	240	+++++	Animal fodder, soil fertilizer, crop support, firewood
Carica papaya L.	Caricaceae	Fruit orchard/ trees scattered on farm	590	+++++	Fruit, medicine
Citrus sinensis (L.) Osbeck.	Rutaceae	Fruit orchard/ trees scattered on farm	660	++++++	Fruit, firewood
Coffea arabica L.	Rubiaceae	Coffee trees mixed with banana system	350	++++	Beverage, crop support, firewood
Cordia africana Lam	Boraginaceae	Trees scattered on farm	230	+++	Shade for coffee, firewood, timber, medicine
Dracaena fragrans	Ruscaceae	Boundary planting	50	+	Boundary demarcation, medicine
Erythrina abyssinica Lam. Ex DC.*1	Fabaceae	Trees scattered on farm	40	+	Medicine, firewood, animal shelter, crafts
Eucalyptus grandis Hill ex Maid.	Myrtaceae	Woodlots, riverbank planting	250	+++++	Timber, medicine, crop support firewood, poles
Ficus exasperata Vahl	Moraceae	Trees scattered on farm	40	++	Firewood, timber, charcoal, medicine
Ficus mucuso Welw. Ex Warb	Moraceae	Trees scattered on farm	23	+	Shade for banana and coffee, firewood, timber and medicine
Ficus natalensis Hochst.	Moraceae	Trees scattered on farm	48	+	Shade for banana and coffee, firewood, timber and medicine
Ficus sur	Moraceae	Trees scattered on farm	25	+	Firewood, charcoal, medicine, fruits
Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	Boundary planting/ woodlot	240	+++++	Timber, firewood
Khaya anthotheca (Welw.) C. DC	Meliaceae	Trees scattered on farm	200	++	Medicine, shade, firewood, timber
Maesopsis eminii Engl.	Rhamnaceae	Trees on farm/woodlots	270	++++	Timber, shade, firewood
Mangifera indica	Anacardiaceae	Fruit orchard	570	+++++	Fruit, timber, firewood, medicine
Markhamia lutea K. Schum.	Bignonaceae	Boudary planting/ Trees scattered on farm	290	+++	Boundary marking, timber, firewood, poles firewood
Mellia volkensii Guerke	Meliacea	Trees scattered on farm/ woodlots	210	++++	Timber, firewood, stakes
Milicia excelsa (Welw.) C. Berg.	Moraceae	Trees scattered on farm	250	++	Shade, ornamental, timber, firewood, medicine
Moringa oleifera Lam.	Moringaceae	Trees on farm	55	++++	Medicine, firewood crop-stakes
Neolamarckia cadamba (Roxb.) Bosser. Bosser, J.	Rubiaceae	Trees on-farm/woodlots/ along farm boundaries	150	+++++	Timber, firewood, crop-stakes
Persea americana Mill.	Lauraceae	Fruit orchard/ trees on-farm	400	++++++	Fruits, timber, firewood medicine
Pinus spp.		Woodlots	280	++++++	Timber, firewood, boundary marking
Polycias fulva (Hiern) Harms	Araliaceae	Trees on farm	30	+	Timber, firewood, craft
Psidium guajava L. (guava)	Myrtaceae	Fruit orchard/ trees on farm	450	+++++	Fruits, medicine, firewood
Sesbania sesban (L.) Merr.	Fabaceae	Fodder bank	25	++++++	Fodder, soil fertilizer, crop-stakes
Spathodea campanulata P. Beauv.	Bignoniaceae	Trees scattered on farm	20	+++	Shade, firewood, medicine
Syzigium cumini (L.) Skeels	Myrtaceae	Trees scattered on farm	350	+++	Fruits, medicine, timber firewood
Terminalia superba Engl. & Diels	Combretaceae	Woodlots	290	++++	Timber, firewood, crop-stakes

[+]Trees abundant on farm but seedlings rare/absent in nurseries, [++]Tree exists on some farms but rare in the nurseries, [+++]Exists on farm but forests provide the main source of planting materials, [++++]Common on farms and nurseries but the quality of seedlings was mostly low, [+++++]Common on farm and nursery with good and poor quality seedlings available, [++++++]High quality seedlings observed both on farm and nursery

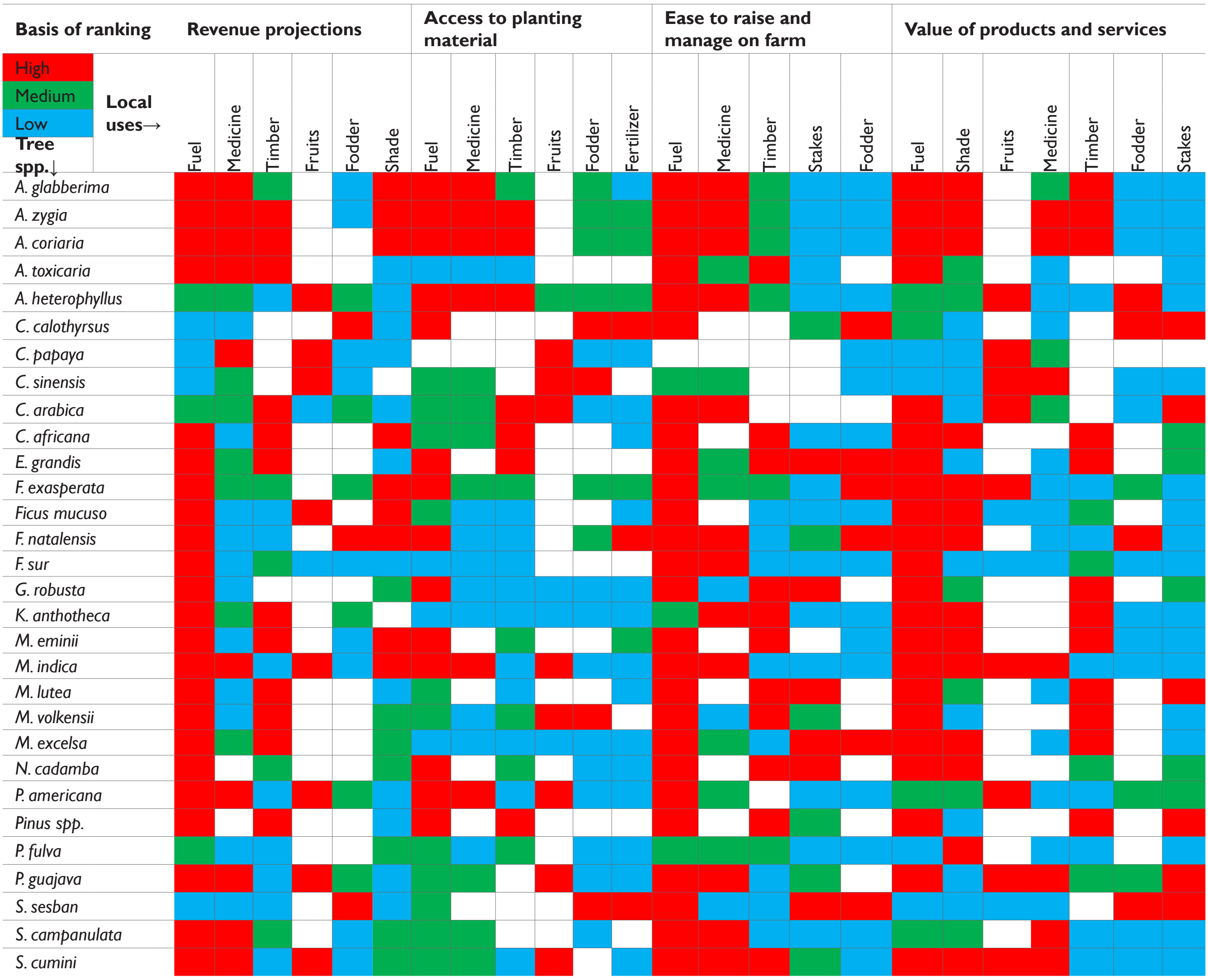
Participants' practices and choice of tree species

The participants highly ranked all woody tree species as viable sources of income earned mainly through the sale of firewood followed by timber and acting as shade respectively (Figure 2). This demonstrates that firewood, timber and shade were the most important reasons for planting trees on farms around Mount Elgon. About one quarter of the participants were involved in plantation establishment while only 12% were engaged in the tree product value chain development (Figure 3). Tree seedlings multiplication and planting was steered by convenience and nearly 40% of the participants determined tree seed quality from their color. Moreover, 38% of all the seed observed in tree nurseries were mixed (more than one species kept in one place) or contaminated (signs of fungal/ bacterial and pest infestation, debris and dirt observed).

From 16% to 42 % of the observed seedlings in the nurseries were diseased or infested with pests respectively. Only 10% of the seedlings exhibited uniform growth with about 30% of the leaves and 20% of the root collar diameter (RDC) appearing normal respectively (Figure 4). Majority (85%) of the rootstock was raised from market refuse and wild sources. The scions were largely (68%) collected from trees on farm and fruit trees were raised from both seed and stems. Mangoes, avocado and citrus were commonly grafted while others such as jackfruit, papaya and other fruits such as guavas were mainly propagated by seed.

The choice of species in large-scale nurseries was driven by economic benefit while the same in small-scale nurseries was driven by need for firewood, fruits, shade and supply of stems to support the under crops. Consequently, the commercial oriented nurseries raised mostly exotic trees ranging between 25,000 and 300,000 seedlings, valued between USD $2000 and USD$7, 000 a year. The most important economic species raised included *E. grandis* (80%), *N. cadamba* (60%), *G. robusta* (56%), *C. africana (*25%) and 10% *M. eminii* (Figure 5). This suggests that *E. grandis* was highly demanded or promoted in this region as a safeguard against firewood and timber shortage. Indigenous species were rare in large nurseries and about half of these nurseries raised at least one fruit species, indicating that fruit growing too, is important to local livelihoods in this region.

Figure 2 Rankings of 30 species by nine local uses and four qualities followed during selection of species to plant. The columns are a representation of the species ranking for a specific local use and qualitative values from the actors' perspective. The species are labelled based on their relative position within the rankings. Species ranked highest and whose position for a specific use was significantly different are shaded red while the average ones are covered in green. The rest of the lower ranked species are shaded blue. The blanks mean there was no ranking done for that specific tree, use and quality.



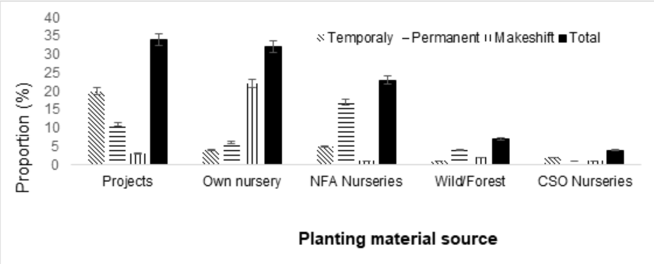


Figure 3 Sourcing of planting materials by nursery type.

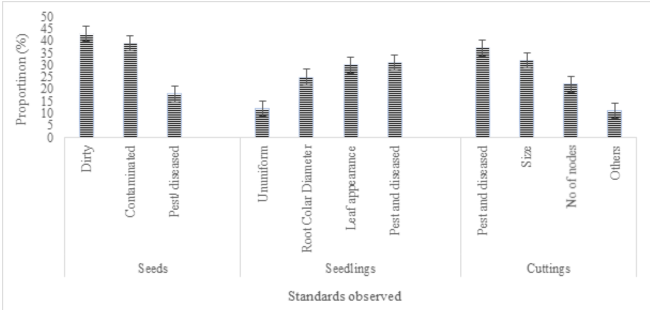


Figure 4 Appearance of tree seedlings in nurseries.

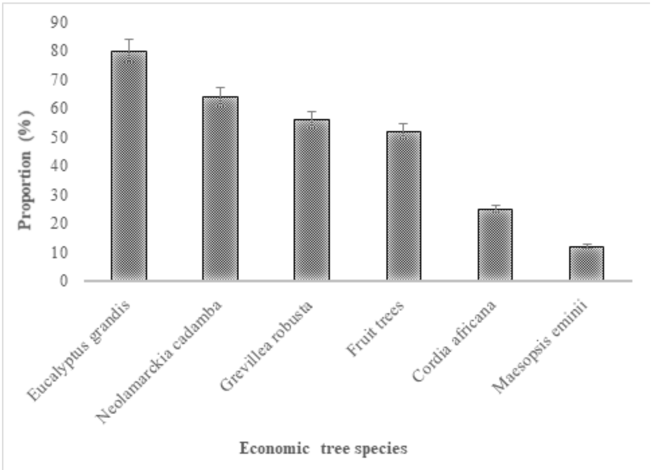


Figure 5 Tree species commonly encountered in nurseries around Mount Elgon.

Participants associations, practices and choice of tree enterprises

The participants selected fruit growing, beekeeping, eco-tourism, carpentry and carbon farming among the lucrative tree based enterprises in the region. Gender bared a positive effect on the choice of enterprise (χ^2=27.432, DF=4, P<0.001). For example, the men were more associated with timber and carbon farming while the women and youths were more associated with fruit growing (selecting high yielding and fast growing varieties) and beekeeping (Fig. 6). Both men and women were however, involved in tree nursery business, producing a wide array of exotic and indigenous tree seedlings and a few indigenous species including *Khaya anthotheca* (Welw.) C.DC. *Albizia coriria* Welw. ex Oliver, and *Milicia excelsa* (Welw.) C. Berg (Figure 6).

Exotic tree species were multiplied in higher numbers compared to their indigenous counterparts, and Forestry/tree restoration projects (χ^2=37.6875, DF=4, P=0.0001) were the most important source of seed for temporary nurseries (Table 3). The other small-scale nurseries relied on wild sources (χ^2= 57.03, DF=4, P=0.0001) including forests and woodlands as well as naturally scattered trees in villages. On the other hand, government nurseries such as the National Forestry Authority (NFA) were an important source of seed for permanent nurseries (χ^2=20.36, DF=4, P<0.001) although, some participants within these government institution relied on natural regeneration (wildings) as also a source of planting materials.

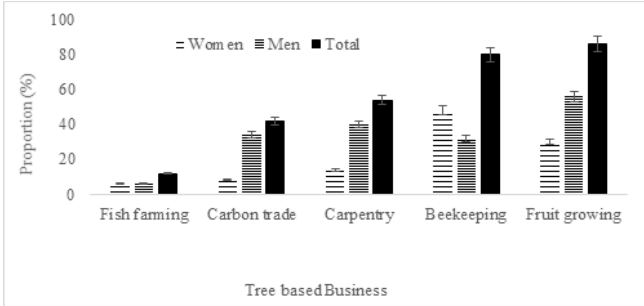


Figure 6 Participants' level of involvement in tree-based enterprises.

Table 3 Chi-Square Goodness-of-Fit Test between the seed source and type of nurseries around Mount Elgon, Uganda

Source of seed	Observed	Expected	Contribution
Projects	3	5.8	1.3517
Own sources (On-farm)	22	5.8	45.2483*
Government (NFA)	1	5.8	3.9724
Wild/Forest (RMNP)	2	5.8	2.4897
NGOs (ICRAF, IUCN)	1	5.8	3.9724
Makeshift χ2=57.0345, DF=4, P<0.001			
Tree restoration projects	11	7.8	1.3128
Own nursery	6	7.8	0.4154
Govt. nurseries	17	7.8	10.8513*
Wild/Forest	4	7.8	1.8513
NGO nurseries	1	7.8	5.9282
Permanent χ2= 20.36,DF=4, P<0.001			
Tree restoration projects	20	6.4	28.9000*
Own nursery	4	6.4	0.9
Govt. nurseries	5	6.4	0.3063
Wild/Forest	1	6.4	4.5563
NGO nurseries	2	6.4	3.025
Small-scale χ2=37.6875, DF=4, P<0.001			

*Important contributor to Chi-square value

About 58% of the nurseries followed some basic "standards" (an unvarying practice geared towards producing uniform and consistent planting materials) while 42% did not. For example, some nurseries did not have any systematic way of obtaining and storing seed. Others purchased seed from unknown sources leading to inferior and low quality seedlings and low survival rates in the field. Although the seed management practices varied between the untrained participants (χ^2=9.53846, DF=4, P=0.049), technical knowhow in the nurseries was only valued during seed treatment (χ^2= 10.0741, DF=4, P=0.039).

Discussion

Socio-economic characteristics of participants

In a study on women and youths participation in agroforestry around Mount Elgon, Galabuzi et al,.[26] observed that conjugal relationships, which peaked during the circumcision rituals, often increased school dropouts, explaining the low literacy levels among the women and youth farmers. In the current study the actors were largely uneducated possibly due to a similar reasons. Among the Bagisu and Sabiny communities, maturity, courage and strength as social-cultural constructs are perhaps valued more than education among the male and female members of their community, peaking during circumcision ritual.

According to Smith,[44] smallholders produce food and non-food products on a small scale with limited external inputs, cultivating field and tree crops as well as livestock, fish and other aquatic organisms. However, they are not always full-time smallholders.[45] Many, in fact most, poor families earn their incomes in multiple ways, and productivity on farms is viewed in the overall context of total family income. In the current study, smallholders comprised the most important participants probably due to the small nature of their farming plots, tree planting in this context only makes sense if the trees were integrated with other components on farm. The farmers argued that integrating multipurpose tree enterprises promised more returns than a single venture. For example, practicing apiculture in a coffee- *Grevellia robusta* system produced honey, coffee and timber at different times in a year. Also, *C. calothyrsus* was planted in a similar way across maize and bean fields to improve the soil nitrogen status and provide animals with fodder, boosting crop and animal production in the region.

The tree nursery operators formed the second major category of actors possibly because tree multiplication and planting is a lucrative business in the region. Unlike for Mulugo et al,.[9] who observed that tradition leveraged women over ownership of land and the naturally growing trees, the women and children in the present study were mostly engaged as laborers in the nurseries, working to earn money. Several tree nurseries were temporary and employed mostly women and children as workers, probably because they formed a very important labor force on farms around Mount Elgon.[46] However, tree farming was not indicated among the lucrative enterprises possibly due to a scramble for land to feed the growing population in the region. Previous studies[28,36,47-49] in this region also uphold the same view. After all, tree based enterprises require land as a major capital investment.

Participants' practices and choice of tree species

According to Sibelet et al,.[50] the farmers in Costa Rica, select tree species to plant on their farms based on pressing needs such as timber and fruits, but also pay special attention to native tree species (such as *Psidium guajava* and *Ocotea floribunda*) that provided habitat and resources to wildlife. In Uganda dominance of multipurpose trees such as *Ficus* spp. *Warburgia ugandensis* and *Prunus africana* was observed on farms in central Uganda.[9,51,52] Although Buyinza et al,.[53] reported about *Albizia* spp. and *C. africana* among the important tree species planted in coffee and banana systems around the Mount Elgon region, in the current study we also add fruit tree species among the important choices especially for smallholders. This also perhaps explains why almost half of the nurseries produced at least one fruit tree species indicating that fruit trees were highly valued and formed a very important source of revenue for tree farmers in this region. Moreover, the planting materials for selected fruit tree species were readily available and yielded products (firewood, fruits) that were highly needed and easily marketed locally.

Although a significant number of figs and other indigenous species such as *C. africana, Albizia* spp*., Antialis toxicalia, M. eminii, Milicia excelsa, Spathodea campanulata, Canarium schweinfurthii*) were reported before on farms in this region,[54] the present study includes *E. grandis, N. cadamba* and *G. robusta* among the currently planted important trees on-farms around Mount Elgon. This finding is also consistent with earlier reports[38] on *E. grandis* as a major source of firewood and timber in the region. The new species species are easily germinated, grow faster and provide reliable shades for coffee and bananas.[53] Further, Buyinza et al,.[54] observed that smallholders around Mount Elgon operated with between two and thirty trees on farms while Galabuzi et al,.[26] reported that the species in local nurseries were a reflection of species on-farm or the reverse was true. In a similar way, Roshetko[16] observed that most farmers and organizations in Indonesia obtained tree seed from farmland and a similar pattern was observed in the Philippines.[21] The farmers in the current study relied on wild sources for both the planting materials and products for highly valued tree species. Lengkeek et al,.[7] further reported that the farmers in East Africa, use poor quality tree planting materials. Although Galabuzi et al,.[26] reported that a significant proportion of tree seedlings died in the field probably due to a failure to match species to specific planting sites by farmers, the current study also includes the use of low quality seedlings among the factors for high seedling mortality in the field. As such, training in tree species site matching should become part of a conservation strategy for Mt. Elgon region.[38] Also training in the identification and production of quality planting materials should also be prioritized.

The National Forestry Authority (NFA) through the National Forestry and Tree Planting Act (2003) is responsible on all matters of tree seed. The NFA through its National Tree Seed Center is therefore, expected to collect and supply good quality tree seed. However, tree seed gathering according to this study was still steered by convenience and the seed for exotic tree species still dominated their indigenous counterparts possibly due to a recent tree planting revolution in Uganda[55] and lack of effective policy guidelines on tree germplasm production and management.[15,16] Germplasm of most indigenous tree species is still collected from the most accessible sections of forests without consideration for quality of the trees, and continues to be deployed indiscriminately in the landscape resulting in low productivity of trees established on farms from such germplasm.[12] With all the anticipated benefits and publicity about the exotic tree species growth attributes, smallholders have no choice but to follow what they are told. Around Mount Elgon, smallholders are always eager to solve eminent problems such as soil erosion and landslides. Also the need to sustain energy and food supply, all become pressing to the extent that any development intervention in attempt to solve the problems, is welcomed with expectation to reap maximum benefits. In this study we observed that exotic species became popular among the farmers in the region following the publicity about their growing advantage over the indigenous species.

Participants' relationships of practices with choices of trees

Studies[9,54,25] have identified the importance of collaborative relationships between socio-economic, political and cultural factors with use and management of trees in farming systems of Uganda. For example, Mulugo et al,.[9] found that the age and family size of the farmers influenced the tendencies towards timber harvesting and decisions to collect tree wildlings respectively. However, Buyinza[43] observed that the size of landholding affected the tree species seedling diversity on farm and a negative relationship between education and intensity of tree germplasm extension services was established. Although Gram et al,.[38] found local knowledge to be gender blinding as no differences were observed in the rankings of species and ecosystem services by men and women, the current study points at gender to be among the important factors influencing the actors' choice of tree germplasm. This suggests that within a single household, the choice of species by men and women as well as youths and elderly varied. Similar trends were also reported in related studies[8,52] with more men recorded to be involved in fruit, timber and carbon tree species planting. The women were more attracted to fodder, soil and water conservation tree species probably because they form a critical labor force for crop and animal production around Mount Elgon.[24,26,36,54]

According to Karrfalt,[56] accreditation of nurseries helps to reduce and control production of poor quality tree germplasm. Nyoka et al,.[14] further argued that certification is a quality assurance process which guarantees that farmers are consistent with high quality planting material. In the present study most of the nurseries produced low quality seedlings possibly due to lack of a pure seed source, lack of technical personnel, and lack of a pest and disease management strategy. Moreover, key quality management infrastructure such as a ventilated seed store, permanent seedbed a functional greenhouse were also absent in most nurseries. As reported by Mbora and Lillesø[57] and Lillesø et al,.[20] findings in Kenya, the present study also found half of the fruit planting materials collected from market refuse. This finding is further consistent with reports of Asare and Pedersen,[58] in Uganda. Probably lack of a central place for seed collection or lack of effective policy guidelines for seed collection are responsible for this practice.[7,16,17]

Forest restoration and tree planting projects were a very important source of seed for temporary nurseries possibly because such projects were in most cases designed to provide free planting materials. Accordingly, some farmers ventured into nursery business only because of a readily available source of inputs. As expected, most temporary nurseries relied more on wild sources probably because these sources were free or cheaper or the participants cared less about the quality of seedlings produced. Government (NFA) was the most important source of seed for permanent nurseries probably because of general trust in public organizations. However, confidence in NFA sources by some nurseries was thin, citing lack of professionalism and corruption by staff. Lack of professionalism and corruption is a serious problem in the forestry and tree sector in Uganda, where quality is compromised for profit.[59-64]

Conclusions and policy implications

Tree germplasm production and management was dominated by an illiterate group of participants with need for specialized training in tree seed collection, multiplication and management. Smallholder farmers comprised the most important participants with varying interest in indigenous and exotic tree species.

Tree seedlings were raised mostly from seed, although stems and roots collected from various sources were common especially for fruit trees. Trees on-farm formed the most important source of planting material and seed collection was steered by convenience, explaining the high levels of seed contamination, poor quality of seedlings and low survival rates in the field.

All tree nurseries lacked at least three of the following qualities; i) pure seed source, ii) ventilated seed store, iii) permanent seedbed, iv) functional greenhouse, v) pest and disease management strategy and vi) technical personnel. To be effective, these qualities were required to embrace and decentralize the process.

We recommend that the stakeholders should co-operate during selection of seed sources to meet performance expectations. The seed/seedlings are likely to respond differently to unique planting sites. Moreover, development of quantified regeneration indices should be based on the physical and climatic conditions associated with specific sites to guide selection of appropriate qualities required for site adaptation.

Development of effective policy guidelines should be prioritized to streamline tree seed sourcing and seedling production in Uganda. The policy should spell out the minimum standards for establishment/running of a tree nursery and promote capacity building on seed sourcing, networking and information sharing among the actors, and provide a conducive environment, sanctions and discipline to errant actors.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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