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Research Article

Validation of Farmer Perceived Soil Fertility Improving Tree Species in Agropastoral Communities of Bushenyi District

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In sub-Saharan Africa, including Uganda, there is declining soil fertility and limited on-farm use of inorganic fertilizers due to poverty and limited subsidies for inorganic fertilizer use. Thus, integration of soil fertility improving tree species (SFITs) in farming systems remains a plausible option to sustaining soil productivity. However, knowledge of the effects of many of the locally growing farmer perceived soil fertility enhancing tree species on to soil chemical and nutrient contents are thus still lacking, and this has constrained decisions on their adoption and scaling up. The objectives of this paper were to identify farmers' preferred soil fertility improving tree species in agropastoral communities of Kyeizooba subcounty Bushenyi district, and characterize their litter content and assess their effect on selected soil chemical properties. Semistructured questionnaires were administered to 333 randomly selected agropastoral farmers. Litter and soils under canopy soils were sampled from three different environments: Under canopy radius (A), canopy edge (B), open pasture land up to thrice the canopy radius (C). Results revealed *Eucalyptus* as the most common tree species on livestock farms, followed by *Erythrina abyssinica*. The highest litter content was recorded for *Markhamia lutea* (240 g/cm^2 under its canopy) followed by *Croton macrostachyus* (90 g/cm^2), and 19 g/cm^2 *Erythrina abyssinica*. Nitrogen was higher ($P = .02$) in *Erythrina abyssinica* litter, K and carbon in *Croton macrostachyus* litter ($P = .03$). These results give evidence that of soil improvers *Erythrina abyssinica, Croton macrostachyus,* and *Markhamia lutea* may positively affect soil fertility. Farmers' indigenous knowledge and or valuation of important tree species can be relied on, and thus, their indigenous knowledge need to be incorporated during identification of tree species for promotion in farming systems.

1. Introduction

In sub-Saharan Africa, Uganda inclusive, most farmers cannot afford inorganic fertilizers due to high poverty levels and due to budgetary constraints that limit government effort to subsidize the agriculture sector [1, 2]. Integration of soil fertility-improving trees in farming systems remains a plausible option to sustaining soil productivity under declining fertility in the region [3–5]. Unfortunately, a few of the locally perceived soil fertility-enhancing tree species have been documented and or evaluated for such purposes. Moreover, diversity in sociocultural settings and agroecological zones influence species adoption and or valuation by farmers [6]. Such factors may thus limit adoption of the few already evaluated soil fertility improving trees by farmers outside studied regions.

Previous studies in Uganda have concentrated on different socioeconomic and ecological values of trees such as *Tamarindus indica* [7] and others [8, 9]; some attempts on soil fertility and carbon sequestration abilities of some tree species retained on livestock farms have been elucidated [8, 10], but no empirical studies specifically evaluating the soil fertility improving effects of such trees and farmer perception of their influence to this effect. In addition, there is limited information documenting and characterizing the soil fertility-enhancing effects of these species.

Given the soil fertility and/or productivity declining trend [1, 2, 10] visa vie need for enhanced agriculture production to support increasing population [11], identification of locally adapted SFITs is essential, and this study provides such information.

Given the dearth of knowledge to support decisions and strategies to guide the adoption of locally growing SFITs trees, this study was undertaken to determine the litter content and soil characteristics of the farmer perceived soil fertility-improving tree species on livestock farmers in Kyeizooba subcounty, Bushenyi district. Thus, objectives of this study were to make an inventory tree species found in the livestock farms, to identify and document the tree species farmers perceive as soil fertility improvers, to determine the tree foliar litter quantity and nutrient content variation, under the canopies, canopy edge, and open pasture land, of the farmer perceived soil fertility improving tree species to the nearby open pasture land, and to characterize the effect of the most preferred soil fertility improving tree species on soil chemical properties.

2. Materials and Methods

2.1. The Study Area. The study was carried out in Kyeizooba subcounty in Bushenyi district in Western Uganda (Figure 1). Bushenyi district is located between altitudes 910 and 2500 m above sea level and has an average temperature less than 20°C. It receives a bimodal rainfall (September to December and February to April) between 1000–1200 mm per annum. The soils are grouped under the sandy clay loams with alluvial parent rock. Livestock is the major source of income. The most common tree species are *Eucalyptus* species, *Markhamia lutea*, *Annona senagalensis, Mangifera indica*, *Jatropha caricus,* and *Prunus africana* that provide fuelwood, timber, poles, and other wood needs to the people [8, 12].

2.2. Sampling Procedure and Data Collection. Based on the 2002 population census [11], there were 2014 livestock farmers in Kyeizooba subcounty. From this list, 333 (16.5%) farmers were randomly selected. This study was carried out in two phases; in the first phase, semistructured questionnaires were administered to 333 livestock farmers randomly selected from the subcounty to solicit their perception on tree species planted and retained on their livestock farms and how they are utilized, including which ones they consider to enhance soil fertility. In the second phase, tree litter and under canopy soils from the farmer perceived soil fertility improving tree species (SFITs) and from the nearby open pasture land were sampled to collect data on litter nutrient composition and quantity variation from under the canopy of the farmer perceived SFITs to the nearby open pasture land for laboratory characterization and analysis to determine their soil fertility enhancing characteristics. A total of nine livestock farms with at least 3 of each SFITs, located in the same soil type, same landscape position, same aspect, and more than 3 m canopy radius (canopy size was used as proxy for age) were selected. In addition, the selected farms had to have had no tillage, fire, or inorganic fertilizer use in the last ten years, and a stocking density of at least two cows per acre. This was based on the fact that fertilizer, tillage, and fire applications in management, livestock densities, and age of individuals affect the soil fertility-enhancing effects of tree species [13, 14]. The trees considered also had to be isolated from other tree species by at least 8 times the radius of its canopy to minimize the influence of other tree species on their soil fertility-enhancing ability [15, 16].

Individuals of the farmer perceived soil fertility-enhancing tree species were identified on the selected livestock farms and tagged using permanent water proof marker. Three environments were demarcated for this study by establishing radial transects from the tree trunk, that is, under canopy $(0 - r)$ (where r is the canopy radius), canopy edge (B)(r-$2r$), and open pasture land ($2r$-$3r$).

2.3. Sampling of Litter. Tree litter was collected from the three environments (under canopy, canopy edge, and open environments) around each of the tagged trees. A total of ten litter traps each measuring 0.25 m^2 were placed at random points to trap falling litter along each environment each sampled tree. The litter collected from each environment was packed in litter bags and transported to the laboratory for further analysis. Sampling of litter was done for the individual trees for each of the SFITs.

Overall, collection of litter samples were undertaken once every month, and this continued for three months beginning from June to August 2008 when it was a dry season in the study area. The dry season was preferred as the most appropriate season for taking litter samples, because it is when most trees shade their leaves and little under growth below the tree canopy and expected high nutrient content in tree leaf litter [17].

Ten (10) soil samples (0–15 cm) which were randomly taken and used to make composites from each of the three environments (A, B, and C) for each of the individual SFIT for chemical analysis.

Chemical analysis was done at Makerere University Soil Science Laboratory. The litter samples were oven dried at 70°C to a moisture content of 1-2% following Okalebo et al., [18]. The litter samples for the farmer perceived SFITs were then prepared using standard approaches for chemical analysis of P, C, K, N, and Ca. The concentration of total nitrogen was determined using the digest method as described in Okalebo et al. [18]. The concentration of phosphorus from the digest solution was then determined using the Olsen method as described in Okalebo et al. [18]. This method was preferred because of its suitability for a diverse litter, soil types, and pH. The concentration of carbon was determined by oxidation with excess aqueous potassium dichromate mixed with sulphuric acid, followed by titration against ferrous ammonium sulphate following Okalebo et al. [18]. The concentration of calcium was determined by complete oxidation using the kjeldahl procedure followed by spectrometric analysis [18] using about 0.3 g of the oven-dried ground litter material. Digestion was then carried out at 360°C for 2 hours, and thereafter potassium, calcium and magnesium were determined.

The soils were then prepared for pH and different nutrient analysis following Okalebo et al. [18]. Soil total

Figure 1: Map of Uganda showing Kyeizooba subcounty in Bushenyi district.

nitrogen was determined using soil samples of particles less than 0.25 mm, 60 mesh. Available phosphorus, potassium, calcium (cation), and organic carbon content of soils were also determined. To determine soil pH (expressed as the inverse log of the hydrogen ion concentration in the soil), measurements were done on 2.5 : 1 water to soil suspension and a pH meter as described in Okalebo et al. [18].

The same soils of the studied trees were sampled two years later and analysed for the same parameters as for beginning (year zero). The soil samples were also analysed at Makerere University Soil Science Laboratory and following the same protocols as used for year 0 samples.

2.4. Data Analysis. Data from the questionnaire responses were coded and entered in Statistical Package for Social Scientists (SPSS version 16). Descriptive statistics were used to show most common tree species retained on livestock farms, the importance farmer's place on such tree species and the species farmers considered to be soil fertility improvers. Data for the nutrient contents in litter of each of the species (calcium, nitrogen, potassium, phosphorus, and carbon) were entered in GENSTAT Computer Programme version 7.22. A one-way analysis of variance (ANOVA) was then performed to compare the differences in the nutrient content in litter among the farmer perceived SFITs. The variability and the significance in different nutrient contents among the SFITs were taken at $P \leq .5$. Double difference (DD) and relative changes (RC) were computed for each parameter (soil pH, calcium, total nitrogen, potassium, available phosphorus, and organic matter). The double-difference estimator compared changes in value of a given parameters at year 0 and two years later using (1) rather than simply comparing values at one point in time [19]

$$\mathrm{DD} = \left(Y_{p1} - Y_{p0}\right) - \left(Y_{np1} - Y_{np0}\right), \tag{1}$$

where Y_{p1} is the value of a given parameter under canopy or canopy edge two years after the first sampling, Y_{p0} is the value obtained after the first sampling, Y_{np1} is the value the parameter for the open pasture two years after the first sampling, and Y_{np0} is the value of the open pasture obtained after the first sampling. The relative change (RC) was also computed using the simple formula in:

$$\mathrm{RC} = \frac{\left(Y_{p1} - Y_{p0}\right)100}{Y_{p0}}. \tag{2}$$

3. Results and Discussion

3.1. Tree Species on Livestock Farms and Their Uses. The main tree species grown on livestock farms in Kyeizooba sub-county included *Eucalyptus* tree species (71.9%), *Erythrina abyssinica* (41.6%), and *Croton macrostachyus* (20.3%) (Table 1).

Trees that are grown on livestock farms of Kyeizooba subcounty provide a wide range of goods and services (fuelwood, construction materials, medicine, soil fertility improvement, and shade). The growing of trees on-farm for provision of household needs by small-scale farmers is characteristic in Africa [20–24]. The results of this study show that *Eucalyptus* species are the most common in livestock farms in Kyeizooba subcounty in Bushenyi district although *Markhamia lutea*, *Croton macrostachyus*, *Pinus caribea*, and others species also exist. This result reinforces findings of species inventory done elsewhere in Bushenyi District by Nakakaawa et al. [8]. In an on-farm inventory of tree species associated with carbon sequestration in Bushenyi District [8], *Eucalyptus* was reported among the most common species. Among others, *Eucalyptus* species are used for fuel wood, timber, and poles for domestic use and for income. Its dominance in livestock farms in Kyeizooba subcounty (as revealed by the results of this study), generally in Bushenyi district [8] and elsewhere in farms in Uganda [25], illustrates the role played by *Eucalyptus* tree species in peoples livelihood needs satisfaction. However, *Eucalyptus* species are reported to deplete soil

Table 1: Tree species found in livestock farms and their uses in Kyeizooba subcounty Bushenyi district.

Tree species	%	Uses of species	%
Eucalyptus tree species	71.9	Fuel wood	100
		Poles	75
		Source of income	30
		Timber	4
Erythrina abyssinica	41.6	Soil fertility enhancement	82
		Shade	100
		medicinal	2
Croton macrostachyus	20.3	Soil fertility enhancement	78
		Shade	94
		Fuelwood	40
Markhamia lutea	16.7	Soil fertility	89
		Shade	65
		Timber	81
Eurphobia tree species	11.3	Fencing	100
		Medicinal	15
Ficus tree species (*Ficus natalensis* and *Ficus ovata)*	11.9	Shade for animals	93
		Fuelwood	54
		Fencing	98
		Boundary marking	98
		Animal fodder	15
		Soil fertility improvement	16
Grevillea robusta	7.8	Timber	76
		Source of income	72
		Fuelwood	41
		Soil fertility improvement	68
Mangifera indica	2.6	Fruits	93
		Shade for animals	15
Pinus caribeae	0.4	Provision of timber	100
		Fuelwood	2
		Source of income	98

nutrients, increase soil erosion, and is allelopathic to other crops or vegetation grown under it [26, 27].

In the case of Kyeizooba Sub County, the need for domestic and commercial benefits of the species to farmers may have lead the later to downplay the species associated negative effects. Additionally, the adoption of *Eucalyptus* by farmers may have been aided by the species' easy mode of propagation and establishment. *Eucalyptus* tree species being the most dominant on livestock farms of Kyeizooba subcounty other than soil-fertility trees may have arisen from a number of factors. First, small-scale farmers expect to get most of their basic needs like fuel wood and construction materials that may not be suitably obtained from trees that improve soil fertility. Secondly, the beneficial effects of trees on soil fertility are often only noticeable after several years [28]. Third, small-scale farmers often cannot afford to invest in tree planting and tending without receiving an immediate returns [29].

About 93% of the respondents said that trees retained on their farms improved soil-fertility. Of these, 42% mentioned *Erythrina abyssinica.* Other tree species mentioned as soil fertility improvers were *Croton macrostachyus, Markhamia lutea*, *Ficus* sp, and *Grevillea robusta* (Table 1). *Erythrina abyssinica, Croton macrostachyus*, and *Markhamia lutea* were mentioned as the top most three soil fertility improving species on livestock farms in Kyeizooba subcounty in Bushenyi district. Scientific evidence elsewhere has shown that *Croton macrostachyus, Erythrina abbysinica*, and *Markhamia lutea* being grown as soil fertility improving trees and able to enhance soil fertility [30–36]. However, there is no single study which has tested the performance of these particular trees on soil quality. Tree effects on soil fertility may differ from area to area due to soil type [37]. In Kyeizooba subcounty in Bushenyi district, farmers pegged their perception of a tree species to be soil-fertility improving based on improved pasture growth and or higher crop yield under the species canopies or in the fields where the tree species were removed. Trees can improve the nutrient balance of a site by reducing unproductive nutrient losses from erosion, and leaching, and increasing nutrients inputs

Table 2: Average surface tree litter densities in the three environments under SFTI.

SFTI type	Location	Mean tree foliar litter (g/cm^2)
Erythrina abyssinica	Under canopy	19
	Canopy edge	4
	Open pasture land	0
Croton macrostachyus	Under canopy	90
	Canopy edge	4
	Open pasture land	0
Markhamia lutea	Under canopy	240
	Canopy edge	25
	Open pasture land	0

Table 3: Variation in the nutrient content of litter for the farmer perceived soil fertility improving tree species retained on livestock farms in Kyeizooba subcounty bushenyi district.

Nutrients	Tree species					
	Erythrina abyssinica	*Croton macrostachyus*	*Markhamia lutea*	Grand mean	LSD	*F*-value
Nitrogen g/Kg	20.4	18.1	17.3	18.6	1.9	0.017*
Phosphorus g/Kg (10^{-3})	0.29	0.33	0.28	0.30	0.12	0.509
Potassium cmol/Kg	8.3	17.1	7.1	10.8	7.1	0.026*
Calcium cmol/Kg	6.9	8.0	6.4	7.1	3.1	0.483
Carbon g/Kg	405.7	431.3	429.7	422.2	18.0	0.023*

* Significant differences at $P \leq .05$ for the level of nutrient content among the tree species.

through nitrogen fixation, in addition they can also take up some of their nutrients from the subsoil and deposit them in surface soils through leaf litter and to decay [29, 38].

3.2. Quantity and Nutrient Composition of Litter of the Farmer Perceived Soil Fertility-Improving Tree Species on Livestock Farms. Table 2 gives the amount of litter collected from the three SFTIs. *Markhamia lutea* had the highest quantity of litter averaging 240 g/cm^2 under its canopy and 25 g/cm^2 at its canopy edge. It was followed by *Croton macrostachyus* that had an average litter quantity of 90 g/cm^2 under its canopy and 4 g/cm^2 at its canopy edge, and the least *Erythrina abyssinica* had 19 g/cm^2 and 4 g/cm^2 under its canopy and canopy edge, respectively.

Differences in litter production between species observed in this study could be attributed to the type of leaf, canopy type and diameter and the size of the trees [39]. The observed patterns of litter loads under isolated tree crowns may have important consequences for nutrient cycling and habitat in scattered tree ecosystems. The higher surface foliar litter densities under canopies that normally correlates positively with higher nutrient recapitalization from the tree is in agreement with observations by many scientists [17, 40, 41].

3.3. Nutrient Content in Litter of Farmer Perceived Soil-Fertility Improving Tree Species. In addition to litter quantity, litter quality and soil biophysical conditions would also affect rate of nutrient cycling [42], and whereby tree canopies have effects on all conditions above. Considerable differences were observed in tree litter nutrient concentrations for nitrogen, potassium, calcium and carbon content of litter among the farmer perceived SFITs (Table 3).

The concentration of phosphorus and calcium were similar ($P < .05$). The concentration of carbon, potassium, calcium and phosphorus were higher in litter from Croton macrostachyus, while nitrogen was higher in litter from Erythrina abyssinica trees. The ratios of carbon to phosphorus (C : P) and carbon to nitrogen (C : N) were higher in litter from Markhamia lutea (Table 4).

The results of the current study revealed that C : N ratios were highest for *Erythrina abyssinica* followed by *Croton macrostachyus* and least in *Markhamia lutea,* while C : P ratios was least in *Croton macrostachyus* and highest in *Markhamia lutea.* For all the species, litter C : N ratios were below 30, which is critical level above which net nitrogen immobilization occurs [43]. Net nitrogen mineralization begins when C : N ratios fall below 19 [44], while according to Powlson and Jenkinson [45], C : N ratios are not unerring measure of nitrogen availability; rather, it is any factor that increases the rate of decomposition/nitrogen demand that narrow C : N ratio. Since canopy type and size have an influence on weather conditions underneath, it will inevitably have an effect on decomposition.

As noted by Stevenson and Cole [46], organic matter with C : P ratios greater than 300 induce immobilization and less than 200 induce net mineralization. Thus, the rate of nitrogen mineralization would occur in the order *Erythrina abyssinica* > *Croton macrostachyus* > *Markhamia lutea* in the current study. Secondly, the C : P ratios in these species litter were less than 200, thus phosphorus net mineralization was possible. According to Palm and Sanchez [47], nitrogen mineralization is also influenced by lignin, polyphenols, and carbohydrates in addition to C : N ratio. Other studies, for example Berg and Ekbohm [48], have also shown that organic matter and nutrient content regulate early stages

Table 4: Nutrient ratios for the farmer perceived soil fertility improving tree species on livestock farms in Bushenyi district.

Nutrient ratios	Tree species		
	Erythrina abyssinica	*Croton macrostachyus*	*Markhamia lutea*
Leaf litter C : P ratio	142.4 : 1	131.2 : 1	157.6 : 1
Leaf litter C : N ratio	20.22 : 1	24.10 : 1	25.07 : 1

Table 5: Selected chemical soil property contribution of SFTI (0–15 cm soil depth).

SFTI	Cluster	Ca cmol/Kg	N g/Kg	SOM g/Kg	P g/Kg (10^{-3})	K cmol/Kg	pH
Erythrina abyssinica	Under canopy	14.0	1.2	−16	5.2	1.81	−0.135
	Canopy edge	3.5	3.0	−7	2.8	−0.87	0.115
Croton macrostachyus	Under canopy	34.5	0.73	−66	26.8	0.87	0.068
	Canopy edge	−8.0	−0.72	−190	−8.2	−1.76	−0.186
Markhamia lutea	Under canopy	12.8	3.2	152	−15	2.04	0.067
	Canopy edge	−3.1	−0.59	−44	−3.8	−0.2	0.07
	P (tree species)	.11	.181	.998	.333	.997	.673
	Lsd (.05)	13.75	0.721	158	15.45	3.323	0.4918
	P (cluster) (.05)	.009	<.001	.004	.187	.044	.04
	Lsd (cluster)	13.75	0.721	158	15.45	3.323	0.4918

of species litter decomposition, while the later stages are influenced by among others by lignin. Furthermore, species litter decomposition is mediated by soil microorganisms, temperature, pH, moisture content, and other plant species within niches [15, 16] conditions which are also influenced by the tree canopy. The higher nitrogen concentration in *Erythrina abyssinica* litter and its narrower C : N ratio makes it a better improver of soil nitrogen, while higher litter K content in *Croton macrostachyus* would improve soil K better than other tree species in this study. The high leaf litter concentrations of N, P, and K and probable high litter decomposition rate have a great potential for soil improvement a similar find by Mwiinga et al. [49] and Gindaba et al. [50].

3.4. Effect of Farmer Perceived SFITs on Selected Chemical Soil Properties. The soil (0–15 cm) below the tree canopy tended to increase in Ca, total N, K content, and pH compared to canopy edge ($P < .05$) (Table 5). Ca, N, OM, K, and pH reduced significantly at the canopy edge ($P < .05$).

The results of soil nutrient content in year 0 and after two years of farmer perceived SFIT on soil-fertility based on six important soil-fertility parameters are summarized in Table 6. Apart from pH and Ca for *Makharmia lutea,* all parameters showed an increment in their relative change (Tables 6 and 7). The double difference estimator shows that the three SFTIs had significant effect on the 0–15 cm soil properties except available P, but the type of SFTI did not affect considerably the change in these properties ($P < .05$).

Percentage relative changes of soil fertility parameters within a period of two years indicated higher positive change in all mean values of all parameters and for all clusters under the three tree species (Table 7). Similarly, soil fertility enrichment under trees has been reported for various leguminous as well as a few nonleguminous trees and shrubs [51].

Similar higher positive mean values of soil fertility parameters were observed by Yeshanew et al. [52], under canopies *Croton macrostachyus* trees as compared to adjacent open land in traditional agroforestry system in north western Ethiopia. The observed improvement in exchangeable soil calcium and pH under canopies of the above trees could be attributed to the factor that trees are able to mine subsoil nutrient deposits like Ca and deposit them on the top soil through litter fall [29].

The observed increment of soil nitrogen under *Erythrina abyssinia* tree canopy which is nitrogen fixing is in agreement with previous studies elsewhere [31, 33, 34]. The ability of *Erythrina abyssinia* tree in particular to improve soil nitrogen is also reflected in high nitrogen content in its leaf litter. Results on previous study of Gindaba et al. [35] do agree with the findings of this study that *Croton macrostachyus*, increases soil nitrogen, which was attributed to tree leaf and root litter. Since *Croton macrostachyus* is not nitrogen-fixing plant the only way it could have improved soil nitrogen is by absorbing N from the subsoil and depositing through litter fall [51, 53].

Martín et al. [54] observed that temperature, humidity, and aeration affect decomposition and thus nitrogen dynamics. Under the tree the canopy modifies these conditions [55], consequently having indirect influence on soil nitrogen. However, recent studies have shown that effects of tree species on soil nutrient availability can be better predicted from the mass and nutrient content of litter produced, hence total nutrient return, than from litter decay rate [56]. The contribution of these trees to soil nutrient depends more on amount of nutrient returned in their leaf litter, which is also affected by litter nutrient content. Hence, it can be safely argued that higher soil nitrogen in *Erythrina abyssinia* litter is

Table 6: Variability in soil nutrients among and within the soil improver tree species different environments in Kyeizooba subcounty in Bushenyi district in Uganda in a period of two years.

SFTI	Location	Year 0						Year 2					
		pH	SOM (g/Kg)	N (g/Kg)	P (g//Kg) (10^{-3})	K (cmol/Kg)	Ca (cmol/Kg)	pH	SOM (g/Kg)	N (g/Kg)	P (g/kg)(10^{-3})	K(cmol/Kg)	Ca (cmol/Kg)
Erythrina abyssinica	A	4.26	69.3	1.5	5.67	2.9	20.0	4.76	84.9	3.8	12.73	7.2	30.8
	B	4.30	64.5	1.4	4.78	2.2	20.9	4.51	81.1	2.8	9.41	3.8	21.1
	C	4.32	58.5	1.5	4.71	1.7	21.4	4.35	75.6	2.6	6.53	4.2	18.2
Croton machrostachyus	A	4.95	57.7	1.4	8.06	3.7	23.5	5.98	90.3	4.0	50.02	9.9	81.2
	B	4.71	49.3	1.4	6.95	3.3	22.7	4.94	69.5	2.6	13.94	6.8	37.8
	C	5.22	54.3	1.4	5.32	3.5	24.4	5.47	9.34	3.4	20.47	8.8	47.6
Markhamia lutea	A	4.59	54.4	1.6	5.46	2.5	21.2	4.93	73.3	2.8	10.52	6.8	33.6
	B	4.76	60.1	1.9	5.99	3.3	24.5	4.57	59.4	2.2	8.74	5.4	21.0
	C	4.83	52.6	1.5	6.83	4.7	22.8	4.61	56.3	2.4	13.39	7.0	22.4
($P < .05$)		.00	.02	.27	.16	.14	.04	<.001	.01	.03	.05	.16	<.001
LSD (trees)		0.34	7.40	0.3	1.80	1.5	2.1	0.42	13.2	0.7	16.41	3.6	13.9

Table 7: Relative change in selected soil chemical properties.

Type of tree	Location	Relative change for the soil top soil (0–15 cm) properties					
		pH	SOM	N	P	K	Ca
Erythrina abyssinica	A	11.6	23.6	161.1	4.81	135.0	53.0
	B	5.7	27.5	98.3	4.53	90.0	5
	C	0.8	29.3	71.1	3.24	171.0	−16
Croton machrostachyus	A	20.5	55.0	187.1	5.79	198.0	260.0
	B	4.9	41.1	85.5	4.64	151.0	64.0
	C	4.7	72.6	135.2	5.59	157.0	96.0
Markhamia lutea	A	7.8	39.9	79.9	4.45	241.0	60.0
	B	−3.2	−0.1	21.7	3.73	118.0	−15.0
	C	−3.2	7.3	62.5	4.15	98.0	−3
LSD (SFTI)		11.07	23.75	42.53	0.848	149.6	74.8
P (SFTI)		.215	.006	.003	.11	.879	.003
LSD (location)		11.07	23.75	42.53	0.848	149.6	74.8
P (Location)		.06	.317	.005	.164	.598	.013
LSD (SFTI* location)		19.18	41.13	73.67	1.468	259.1	129.5

a contributing factor to soil nitrogen. Organic matter relative change was generally less under canopy in comparison to other areas (*Erythrina abyssinica* and *Croton macrostachyus*) while it is greater in subcanopies of *Markhamia lutea*. The probable explanation of differences in changes between organic matter and total soil N could be due to differences in nitrogen concentrations in sources of organic matter [57].

In this study, available *P* was not considerably improved by any of the studied SFTI. However, in the second year, *Croton macrostachyus* trees reflected higher values ($P = .05$) of available *P*, under canopies as compared to soils in nearby vicinity. A similar study by Gindaba et al. [35] in Ethiopia observed that *Croton macrostachyus* trees enhance soil available *P* which was attributed to high *P* concentration in tree foliar and root litter. The observed nonsignificant differences in soil available *P* between under tree under canopies and open pastureland could also be due to high soil acidity [58].

Soil acidity is a crucial issue in wet regions African tropical soils, whereby soil acidity limit crop production [59]. In acidic soils like those of Kyeizooba subcounty an increment in soil pH as observed under tree canopies would have an effect on nutrient supply especially available phosphorus which is usually limiting in African tropical soils.

4. Conclusion and Recommendations

The dominant tree in Kyeizooba subcounty is *Eucalyptus* tree species. *Erythrina abyssinica*, *Croton macrostachyus,* and *Markhamia lutea* are also grown on livestock farms and are perceived as soil fertility improvers. Evaluation of the above tree species used as soil improvers revealed that *Erythrina abyssinica* had higher nitrogen content in its leaf litter, while litter of *Croton macrostachyus* had higher Carbon and potassium content. The three tree species, *Erythrina abyssinica*, *Croton macrostachyus* and *Markhamia lutea,* used as soil improvers reflected relatively positive values on soil fertility parameters tested in this experiment although in some cases not significant. This knowledge will act as a guide for further research and scaling up of these species for adoption in the subcounty and elsewhere in similar agroecologies in Uganda. The findings of the current study reinforce the need for evaluation of tree species values to farmers within their context before scaling up for adoption, as has been recommended before [6]. The indigenous knowledge of the farmers and or valuation of species of importance can be relied on, and thus need to be incorporated during identification of tree species for promotion in farming systems.

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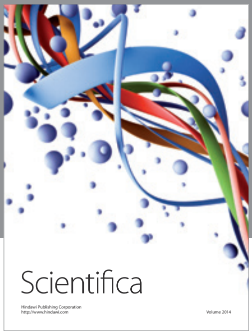

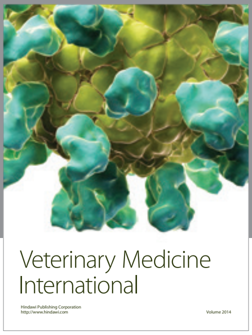

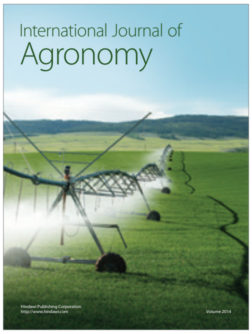

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