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Farmers' preferred trees carbon sequestration capacity in Lake Victoria's rural landscapes

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ABSTRACT

This study identified the carbon sequestration potential of the most valued trees species by farmers in Mayuge district, Uganda. Composite soil samples were collected 1.5 to 2 m away from the tree trunk for carbon content and bulk density at two different soil depths (0-15 cm and 15-30 cm). Soil samples were collected from eight trees of each species, 8-10 years old, on a lixic ferralsol within a radius of 5 km, occurring in different land-use types including land which had been under fallow for 8-10 years. Soil carbon stock did not significantly vary between the different trees and averaged 31.54 Mg ha^{-1} and 27.05 Mg ha^{-1} for 0-15 cm and 15-30 cm soil depth, respectively. The effect of land-use and depth on soil carbon stock varied with tree species ($p<0.05$). Implications of these findings to future studies in Agroforestry as well as to communities in the Lake Victoria rural landscapes are discussed in this paper.

Key words: Agroforestry, carbon density, *Eucalyptus,* land use, *Maesopsis eminii,* Uganda

RESUMÉ

Cette étude a identifié le potentiel de séquestration du carbone des espèces d'arbres les plus appréciées par les agriculteurs dans le district de Mayuge en Ouganda. Des échantillons de sol ont été recueillis de 1,5 à 2 m du tronc d'arbre pour déterminer la teneur en carbone et la masse volumique apparente à des profondeurs de sols de 0-15 cm et 15-30 cm. Des échantillons de sol ont été prélevés sous huit espèce d'arbres de 8 à 10 d'âge sur un sol ferralitique dans un rayon de 5 km, et sous différentes utilisation des terres, y compris sous jachère pendant une période de 8 à 10 ans. Le stock de carbone dans le sol n'a pas varié de façon significative entre les différentes espèces d'arbres et en moyenne 31,54 Mg ha^{-1} et 27,05 Mg ha^{-1} a été observé pour la profondeur de 0-15 cm et 15-30 cm, respectivement. L'effet de l'utilisation des terres et de la profondeur sur le sol des stocks de carbone varie avec les espèces d'arbres ($p < 0,05$). Les implications de ces résultats dans le cadre des études avenir dans le domaine d'agroforestie tout comme celui des études communautaires sur les flancs du Lac Victoria sont discuteés dans cet article.

Mots clés: Agroforesterie, la densité de carbone, *Eucalyptus,* Utilisation de terre, *Maesopsis eminii,* Ouganda

INTRODUCTION

Soils and forest vegetation are known as the major terrestrial carbon storage systems (Buringh, 1984; Batjes, 1996). The recognized importance of these two carbon pools in mitigating climate change has led countries to study their carbon stocks and initiate the assessment of enhancing and maintaining carbon sequestration of these resources. Carbon sequestration is recognized as one of the key processes of atmospheric greenhouse gas (GHG) reduction (IPCC, 2007). For the soil pool, carbon sequestration contributes to soil fertility enhancement (Rao *et al*., 2007) through the moderation of cation exchange capacity (CEC), water holding capacity, soil structure, resistance against erosion, nutrient retention and availability and buffering against sudden fluctuations in soil pH (Lal, 2005). Soil C sequestration is done directly and/or indirectly (Soil Science Society of America, SSSA, 2001). Direct soil C sequestration occurs by inorganic chemical reactions that convert CO_2 into soil inorganic C compounds such as calcium and magnesium carbonates. Indirectly, soil carbon sequestration is done through afforestation/reforestation which are seen as potentially attractive mitigation strategies, as wood production, soil fertility enhancement and carbon (C) storage combined (Pacala and Socolow, 2004; Fisher *et al.*, 2011). Through this process, C sequestration occurs as plants photosynthesize atmospheric CO_2 into plant biomass which can indirectly be sequestered as soil organic carbon (SOC) during decomposition processes. The amount of C sequestered at a site therefore reflects the long-term balance between C uptake and release mechanisms and depends on the type of tree (amount and quality of biomass input provided by tree), the type of soil and their managements (Woomer *et al*., 1994; Jackson *et al*., 2000; Jobba´gy and Jackson, 2000; Woomer *et al*., 2000; Sauerbeck, 2001; Wright *et al*., 2001; Lal, 2005).

On-small scale farmers' gardens, the type of trees found or those which are grown is generally dictated by farmers' preference and expected potential benefits from the trees. Therefore, building carbon stock on farmers' garden requires the full participation of farmers. This is important because most of the land where trees are managed is outside protected areas and on private land. Secondly, farmers are key stewards of plant management and make decisions regarding which species to maintain or to destroy on their private land. To enhance and encourage wider on-farm tree planting, it is necessary that the species that farmers value most and which they are ready to manage are identified (Kahurananga *et al*., 1993; Dalle and Potvin, 2004). To make an effective choice of species that can contribute to climate resilience, we need to also determine which species have the most potential to sequester carbon. This study was therefore conducted to identify the most valued trees species by farmers and the carbon sequestration potential of targeted indigenous tree species.

MATERIALS AND METHODS

This study was conducted in Mayuge district, particularly in the Kigandalo sub-county, located in the eastern region of Uganda, 120 km from Kampala the capital city and 40 km from Jinja town (Figure 1). The district is bordered by Lake Victoria in the south and is relatively flat with high ridges and isolated hills, undulating lowlands and perch vents. The hills are linear and of a convex nature with rolling slopes. The lowest points 1,200 m above sea level are located along the lake and the highest 1500 m above sea level is found in the northern part of the district. The rainfall is bimodal

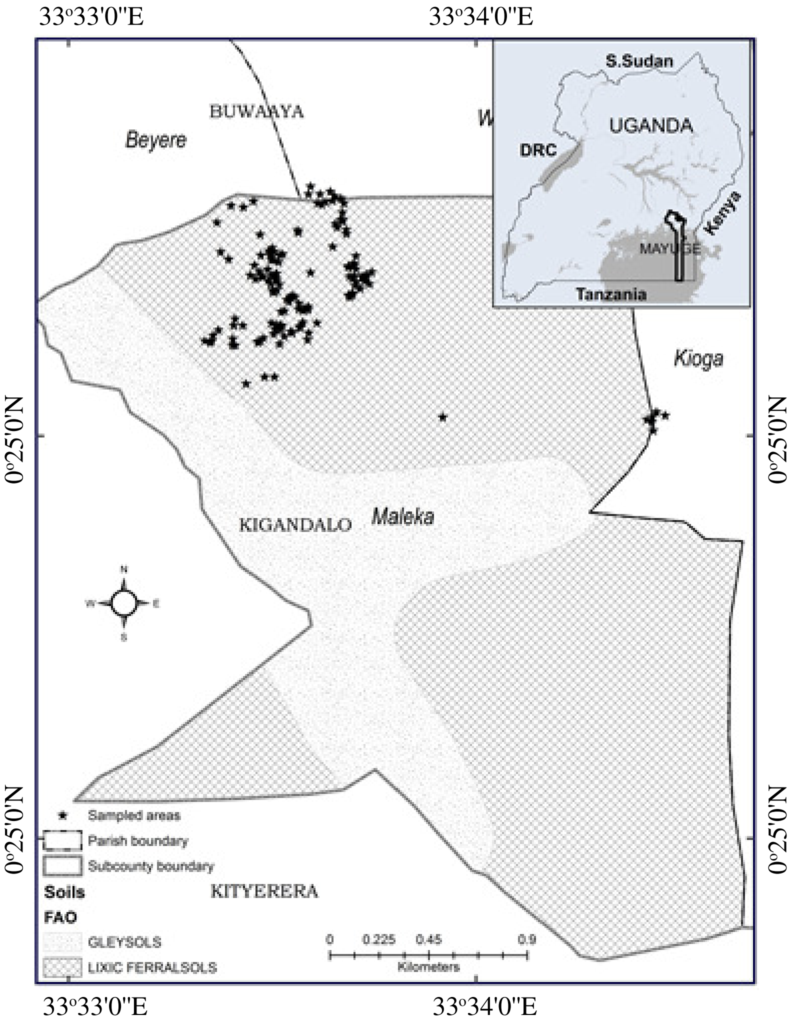

Figure 1: Sampled points on lixic ferralsols in Mayuge district - Uganda

with wet seasons occurring from April-June and August-November. The annual average rainfall is 1200 mm with an increasing rainfall gradient from the north (900 mm) to the south. The two rainy seasons are punctuated with a longer dry season December- March and short one July - August. These seasons enable farmers to have at least two growing seasons. Major crops grown include maize, cassava, groundnuts, cotton, cocoa, coffee, beans, sweet potatoes, finger millet and sunflowers. The soils are generally reddish brown sandy loam classified as lixic ferralsols in the upper well drained soils.

Identification of priority species preferred by farmers and which farmers are interested in propagating

An ethnobotanical survey was conducted from July to September 2012, in three villages Bukomya, Iwuuba and Nabukone, to identify priority species preferred by farmers and which they were willing to propagate. A total of 90 farmers were interviewed using a guided questionnaire in face to face interviews. This sample size was determined using Israel (1992) for the 2012 estimated population of the sub-county (62630 people), allowing for a 10% error. The focus of the interviews was to determine: the most preferred woody species (how often it was cited by farmers), existing tree management practices, existing constraints and opportunities in the context of tree management, as well as aspects of tree tenure. Respondents were also requested to list species that are becoming locally scarce and those which are becoming more abundant as well as factors contributing to these dynamics. This information is not reported in this study.

Determination of carbon sequestration capacity of the different farmers preferred trees

Priority tree species preferred by farmers were identified in the Kidangalo sub-county from the different land-use/cover in pre-selected villages. The land uses included fallow, households' compound, woodlot, annual crop garden, perennial (banana and coffee plantations), garden and along road sides. Three types of woodlots comprising of *Pinus* spp. (Pine), *Maesopsis eminii* (Musizi) and *Eucalyptus* plantations were considered. Farmers were asked about the approximate age of their plantations and trees on their farms. Efforts were made to only select tree species which were 8-10 years old. Eight replicates of composite soil samples and soil cores were collected between 1.5 to 2 m from the trunk of the different tree species at 0-15 cm and 15-0 cm soil depth in each land-use type. These samples were analysed at the soil science laboratory of Makerere University for the following parameters: carbon content and texture for the composite soil samples, bulk density and hydraulic conductivity analysis for the core samples. The carbon content was determined using Walkey and Black method described in Okalebo *et al*. (2002). Soil texture was evaluated using the Bouyoucos hydrometer method (Bouyoucos, 1962). The obtained data were used for textural classification using FAO classification (FAO-UNESCO-ISRIC, 1990). Bulk density was determined by the core method. Carbon stock per unit area was determined as a product of the carbon content and the mass of soil at each depth. In this study only carbon content, carbon stock, and bulk density are presented.

Data analysis

Variation of carbon stock under farmers' preferred tree across different land-use/cover was analysed using ANOVA in Genstat 13th Edition. The means were separated using the Least Significant Difference test at 95% confidence level.

RESULTS

Carbon sequestration capacity of the trees

Table 1 shows the bulk density and carbon content of soils under farmers' preferred trees in the study area. Bulk density and carbon content varied significantly with the type of tree species ($p<0.01$) and soil depth ($p<0.01$). Generally, bulk density ranged between 0.75 g cm^{-3} and 1.21 g cm^{-3} in the top 0-15 cm soil depth and 1.08 and 1.22 g cm^{-3} for the 15-30 cm soil depth. Bulk density did not vary significantly with tree species for the topsoil, but was relatively lower for *Senna* spp. (Gassia) and *Ficus sycomorous* (Mukunu) compared to other tree types. Soil carbon content varied with soil depth ranging between 1.25 % and 5.23 % within 0-15 cm soil depth; and between 1.14 % and 1.98 % for the 15-30 cm soil depth. It was high only for *Ficus sycomorous* (Mukunu) in the topsoil and moderate for other tree types. It was moderate for topsoil under *Milicia excelsa* and *Albizia coriaria* (Musita). *Senna* spp. (Gassia) and *Ficus sycomorous* (Mukunu) had high level of organic carbon for both soil depths. Soil under *Ficus sycomorous* (Mukunu) had the highest value of soil carbon content and soils under *Pinus* spp. had relatively the lowest value for 0-15 cm soil depth. For the 15-30 cm soil depth *Senna* spp. had relatively the highest value and *Persea americana* the relatively lowest value.

There was a linear relationship between organic carbon content and bulk density for the top 0-15 cm ($R^2=0.97$, $p<0.05$) (Figure 2). After removing the values of *Albizia* spp., *Ficus nantalensis*, *Ficus sycomorous* and *Senna* a significant linear relationship was obtained between soil carbon and bulk density ($R^2=0.39$; $p<0.05$).

Table 2 shows the amount of carbon stored in the different soil depths under each farmer's preferred tree.

Table 1: Bulk density and carbon content of soil below farmer's preferred trees

Name of the tree/soil depth (cm)	Bulk density (g cm^{-3})		Carbon content (%)	
	0-15	15-30	0-15	15-30
Coffea spp. (Mwanii)	1.15	1.20	1.46	1.29
Fallow	1.20	1.19	1.35	1.37
Senna spp. (Gassia)	1.04	1.09	2.65	1.98
Artocarpus heterophyllus (Fene)	1.06	1.17	2.52	1.72
Eucalyptus spp. (Kalitunsi)	1.10	1.15	2.17	1.58
Spanthodea campanulata (Kinalisa)	1.16	1.16	1.68	1.97
Antiaris toxicaria (Kirundu)	1.17	1.16	1.73	1.49
Mangifera indica (Muyembe)	1.13	1.15	2.32	1.67
Ficus sycomorous (Mukunu)	0.75	1.08	5.23	1.77
Markhamia lutea (Musambya)	1.14	1.15	1.87	1.66
Albizia coriaria (Musita)	1.11	1.14	2.05	1.75
Maesopsis eminii (Musizi)	1.18	1.21	1.48	1.67
Ficus nantalensis (Mutuba)	*1.07*	*1.14*	*2.63*	*1.22*
*Milicia excels*a (Muvule)	1.13	1.17	1.89	1.86
Albizia spp. (Nongo)	1.16	1.24	1.51	1.59
Persea americana (Ovacado)	1.16	1.21	1.67	1.14
Carica papaya (Mupapali)	1.12	1.20	1.92	1.21
Pinus spp. (Pine)	1.21	1.22	1.25	1.34
LSD (p=0.001)	ns	0.07	1.44	1.34

Table 2: Carbon stock in the different sampled soil layers

Tree species	Carbon stock (Mg ha^{-1})	
	0-15 cm	15-30 cm
Coffea spp. (Mwanii)	23.83	23.82
Fallow	23.82	24.19
Senna spp. (Gassia)	45.03	29.35
Artocarpus heterophyllus (Fene)	33.28	29.39
Eucalyptus spp. (Kalitunsi)	34.86	32.95
Spanthodea campanulata (Kinalisa)	30.15	25.87
Antiaris toxicaria (Kirundu)	31.69	29.61
Mangifera indica (Muyembe)	37.32	33.59
Ficus sycomorous (Mukunu)	34.84	25.16
Markhamia lutea (Musambya)	31.08	29.95
Albizia coriaria (Musita)	33.06	28.93
Maesopsis eminii (Musizi)	27.02	22.29
Ficus nantalensis (Mutuba)	43.95	32.87
Milicia excelsa (Muvule)	31.71	31.28
Albizia spp. (Nongo)	27.95	21.22
Persea americana (Ovacado)	26.75	21.18
Carica papaya (Mupapali)	32.16	24.44
Pinus spp. (Pine)	19.68	20.84
Average	31.57	27.05
p	ns	ns

There was no significant effect of type of tree species and soil depth on carbon stock. However, the amount of soil carbon beneath each tree was relatively higher in the 0-15 cm compared to 15-30 cm except for *Senna* spp. It ranged from 19.68 Mg ha^{-1} (*Pinus* spp.) and 45.03 Mg ha^{-1} (for *Senna* spp.) for the 0-15 cm soil depth; and between 20.84 Mg ha^{-1} and 33.59 Mg ha^{-1} for *Spanthodea campanulata*. On average the amount of carbon stock averaged 31.57 Mg ha^{-1} and 27.05 Mg ha^{-1} for 0-15 cm and 15-30 cm soil depth respectively.

Table 3 shows the relative change in carbon content and carbon stock compared to the control (fallow). The relative change was generally positive for all the trees except for *Ficus nantalansis* and *Persea*. More than 70 % relative change in soil carbon content was observed under *Ficus sycomorous* (Mukunu) followed by *Senna* spp., *Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba). *Senna* spp. (Gassia), *Ficus sycomorous* (Mukunu) and *Mangifera indica* (Muyembe) for the topsoil. In the subsoil the relative change in carbon content did not exceed 45% for all the trees studied. It is important to note that the relative change in carbon content was negative under *Pinus* spp. (Pine) for both soil depths. Sub-soils under *Carisa, Persea americana* (Ovacado), and *Ficus nantalensis*

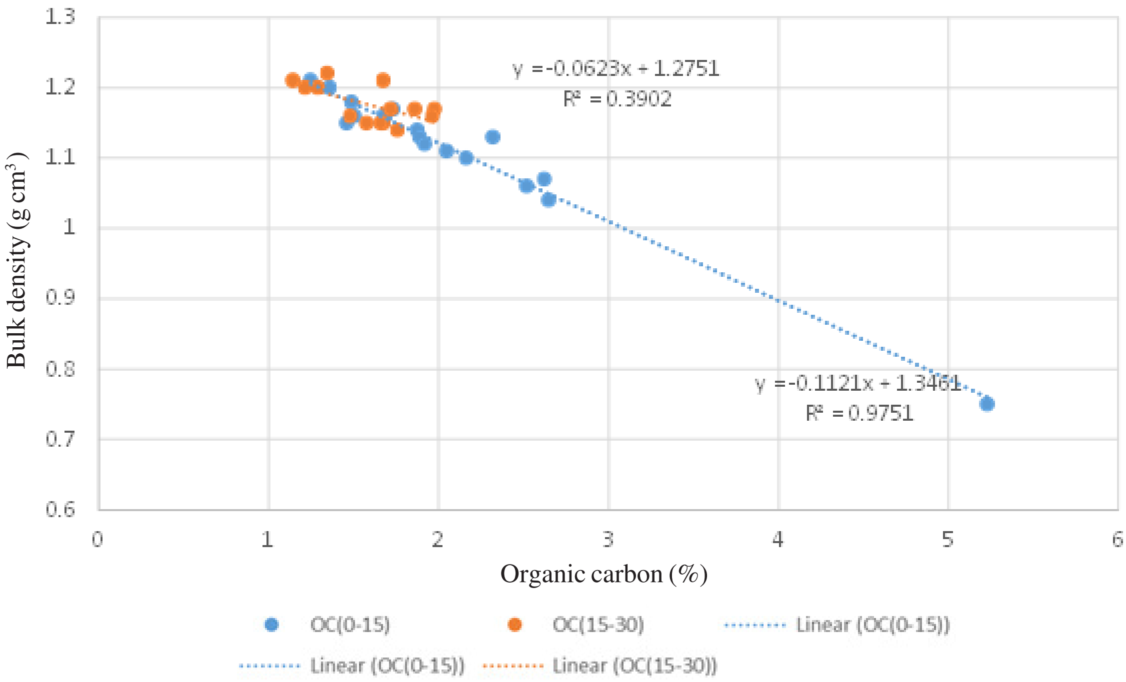

Figure 2: Relationship between soil organic carbon and bulk density

Table 3: Relative change in carbon content and carbon density compared to land under fallow

Name of the tree /soil depth	Relative change in Carbon content (%)		Relative change in Carbon density (%)	
	0-15	15-30	0-15	15-30
Coffea spp. (Mwanii)	1.46	1.29	0.04	-1.55
Senna spp. (Gassia)	96.3	44.53	39.71	21.50
Artocarpus heterophyllus (Fene)	86.67	25.55	46.36	36.20
Eucalyptus spp. (Kalitunsi)	60.74	15.33	26.58	6.94
Spanthodea campanulata (Kinalisa)	24.44	43.8	33.04	22.39
Antiaris toxicaria (Kirundu)	28.15	8.76	56.68	38.84
Mangifera indica (Muyembe)	71.85	21.9	46.25	4.00
Ficus sycomorous (Mukunu)	287.41	29.2	30.49	23.83
Markhamia lutea (Musambya)	38.52	21.17	38.80	19.58
Albizia coriaria (Musita)	51.85	27.74	13.45	-7.84
Maesopsis eminii (Musizi)	9.63	21.9	84.50	35.88
Ficus nantalensis (Mutuba)	94.81	-10.95	33.10	29.32
Milicia excelsa (Muvule)	40	35.77	17.33	-12.27
Persea americana (Ovacado)	23.7	-16.79	12.28	-12.45
Carica papaya (Mupapali)	42.22	-11.68	35.01	1.03
Pinus spp. (Pine)	-7.41	-2.19	-17.38	-13.86

(Mutuba) had a negative relative change for the carbon content and carbon stock in the 15-30 cm soil depth; This was subsequently reflected in the 15-30 cm carbon stock of *Persea americana* (Ovacado) and *Pinus* spp. (Pine). Soil under coffee, *Albizia* and *Milicia excelsa* (Muvule) had a negative relative change in carbon stock for the sub-soil.

Soil carbon stock under farmers' preferred trees and land-use types

Tables 4 and 5 show variation in soil carbon stock beneath each tree species at 0-15 cm and 15-30 cm soil depths. Four types of variation behaviors were observed: i) soil carbon stock variation with land-use and soil depth; ii) variation only with land use; iii)

Table 4: Carbon stock under farmers' preferred trees in different land-uses in Mayuge district (0-15 cm soil depth)

Tree species	Carbon stock (Mg ha^{-1})										
	Banana	Coffee plantation	Compound	Eucalyptus plantation	Fallow	Grassland	Maize	Musizi plantation	Pine plantation	Roadside	Prob
Coffea spp. (Mwanii)		23.85	26.24		21.40						ns
Senna spp. (Gassia)		54.36			35.70						0.01
Artocarpus heterophyllus (Fene)				26.81	43.72		29.31				0.001
Eucalyptus spp. (Kalitunsi)			29.35		34.96		34.76				ns
Spanthodea campanulata (Kinalisa)			22.42		39.82		35.10			23.27	ns
Antiaris toxicaria (Kirundu)			34.66		34.42		25.99				ns
Mangifera indica (Muyembe)		31.48			52.01						ns
Ficus sycomorous (Mukunu)	33.20	51.06	29.80		42.26					17.87	0.04
Markhamia lutea (Musambya)					27.28		34.89				0.01
Albizia coriaria (Musita)					30.44		35.68				0.08
Maesopsis eminii (Musizi)	26.81				31.98			25.71			ns
Ficus nantalensis (Mutuba)	29.71	70.38			33.13		42.26				0.01
Milicia excelsa (Muvule)	29.09	29.28			31.92					37.50	ns
Albizia spp (Nongo)	30.08	21.77			27.64						<0.01
Persea americana (Ovacado)	29.42		32.11			18.71					ns
Carica papaya (Mupapali)	30.87		35.19		30.41						ns
Pinus spp. (Pine)			15.81						23.55		ns
Grand total	29.93	40.72	28.03	26.81	34.42	18.71	31.62	25.21	23.55	26.77	

Table 5: Carbon stock under farmers' preferred trees in different land-uses in Mayuge district (15-30 cm soil depth)

Tree species	Carbon stock ($Mg\ ha^{-1}$)										
	Banana	Coffee plantation	Compound	Eucalyptus plantation	Fallow	Grassland	Maize	Musizi plantation	Pine plantation	Roadside	Prob
Coffea spp. (Mwanii)		21.67	25.96								ns
Senna spp. (Gassia)		24.68			34.03						ns
Artocarpus heterophyllus (Fene)				24.37	32.39		31.42				ns
Eucalyptus spp. (Kalitunsi)			28.38		34.96		35.50				ns
Spanthodea campanulata (Kinalisa)			26.81		22.74		29.72			24.21	ns
Antiaris toxicaria (Kirundu)			32.72		30.02		26.08				ns
Mangifera indica (Muyembe)		39.48			27.69						ns
Ficus sycomorous (Mukunu)	28.77	25.53			23.86					22.47	ns
Markhamia lutea (Musambya)					29.20		30.71				ns
Albizia coriaria (Musita)					29.85		28.01				ns
Maesopsis eminii (Musizi)	26.81							21.87			ns
Ficus nantalensis (Mutuba)	28.43	47.25	25.48		30.31						0.086
Milicia excelsa (Muvule)	24.72	24.98			32.26					26.90	ns
Albizia spp (Nongo)	28.87	19.50			18.03						0.002
Persea americana (Ovacado)	22.32					20.04					ns
Carica papaya (Mupapali)	21.15		27.73								ns
Pinus spp. (Pine)									20.84		ns
Average	25.87	29.71	27.18	24.37	29.31	20.04	27.51	21.87	20.84	23.34	

variation only with soil depth; and iv) no variation with land-use and soil depth. Soil carbon stock varied with land-use and soil depth beneath under *Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba) and *Albizia* spp. (Nongo). Soils below *Artocarpus heterophyllus* (Fene) had relatively high carbon stocks when occurring on fallow soils compared to other land-uses where this species was found. With *Artocarpus heterophyllus* (Fene), the topsoil under fallow conditions had also higher carbon stock than the sub-soil. Soil under *Ficus nantalensis* (Mutuba) had higher carbon stock under coffee followed by maize, fallow and the banana for the 0-15 cm soil depth. For soil depth of 15-30 cm, maize had higher carbon stock compared to all other land-use beneath *Ficus nantalensis* (Mutuba). Under *Albizia* spp. (Nongo) tree species, soil carbon stock varied significantly with land-use and soil depth (P<0.05). Beneath *Albizia* spp. (Nongo), soil carbon stock was highest under banana followed by fallow for the topsoil (p=0.002), and higher under banana compared to fallow and casasava which had similar soil carbon stock for subsoil (p=0.076).

Significant variation on soil carbon stock under different land-use types was observed beneath *Spanthodea campanulata* (Kinalisa), *Senna* spp., and *Markhamia lutea* (Musambya) (p<0.05). Beneath *Spanthodea campanulata* (Kinalisa), soil carbon stock was higher on fallow and maize gardens in the 0-15 cm topsoil compared to other land-uses (p<0.05). Soils carbon stock under *Senna* spp. varied significantly for the topsoil, and was higher on coffee plantation compared to the soil under fallow (p < 0.001). No significant difference in soil carbon stock was observed in the sub-soils under *Senna* spp. (p> 0.05). However, soil carbon stock beneath *Markhamia lutea* (Musambya) tree, in the topsoil, was higher under maize than under fallow (p<0.05). Under *Ficus sycomorous* (Mukunu) carbon stock was relatively higher on coffee plantation, followed by fallow compared to other land-use for the topsoil (0-15 cm) (p<0.05).

Soil under *Antiaris toxicaria* (Kirundu) did not show any significant variation due to the land-use where this tree species was found (p>0.05). Carbon stock under eucalyptus tree did not vary significantly across the land-use where it occurred and with soil depth (p>0.05). Beneath *Mangifera indica* (mango) tree, soil carbon stock did not vary with the type of land-use and soil depth, but showed a significant interaction between the effect of land-use and soil depth. Soil under mango tree tended to have more carbon stock in the sub-soils; while those found under fallow tended to have more carbon stock in the topsoil compared to the subsoil (15-30 cm). Beneath *Albizia coriaria* (Musita), soil carbon stock did not vary significantly with land-use, but varied significantly with soil depth (p=0.004). The interaction between soil depth and land-use was also significant (p=0.019). Soil carbon stock used under fallow was similar for the two soil depths, while under maize it was highest for the topsoil compared to the subsoil (p<0.01). Beneath *Maesopsis eminii* (Musizi), soil carbon stock did not significantly vary with land-use and soil depth. On the other hand, *Milicia excelsa* (Muvule) tree, no significant land-use type and soil depth effects were observed (p>0.05). Soil carbon stock under avocado and pawpaw varied only with soil depth (p<0.05) with the topsoil (0-15 cm) having more carbon stock than the sub-soil (15-30 cm). Carbon stock under *Pinus* spp.(Pine) plantation did not significantly change with soil depth (p>0.05).

DISCUSSION

Farmers preferred trees exhibited differentiated potential in carbon sequestration. High carbon stock potential was observed on *Ficus sycomorous* (Mukunu) followed by *Senna* spp., *Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba). *Senna* spp. (Gassia), *Ficus sycomorous* (Mukunu) and *Mangifera indica* (Muyembe). The change in carbon stock varied with land-use and soil depth for *Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba) and *Albizia* spp. *Albizia* spp. (Nongo), changed only with land-use for *Spanthodea campanulata* (Kinalisa), *Senna* spp., and *Markhamia lutea* (Musambya), and did not show any variation with land-use and soil depth for *Milicia excelsa* (Muvule), *Persea americana* (Ovacado), *Carica papaya* (Mupapalii), *Albizia coriaria* (Musita) and *Pinus* spp. (Pine). The magnitude of soil carbon stock observed in this study is relatively lower than the values observed in other regions of Uganda with similar soils (Nampiija *et al*., 2010; Twongyirwe *et al*., 2013). This is due to the variance in the dominant tree species in the different environment, and the fact that soil carbon stock is correlated with the age bracket of the tree considered, the type of soil, the initial soil carbon content and climatic conditions (Shi *et al*., 2013). Kaul *et al*. (2010) reported variance in maximum net annual carbon storage flux for the different categories of growing trees species in a forest environment. They estimated 1 Mg C $ha^{-1}yr^{-1}$ for slow-growing long rotation sal forests, 6 and 8 Mg C $ha^{-1}yr^{-1}$ for fast-growing short rotation Eucalyptus and poplar forests, and 2 Mg C $ha^{-1}yr^{-1}$ for moderate-growing short rotation teak forests, Twongyirwe *et al.* (2013) research was conducted in an intact forest while Nampiija *et al.* (2010) studied a relatively better managed soils of Rakai district in Uganda. However, the generally no effect of the tree species on the stock of carbon in the soil is a reflection of the variability induced by land-use. Most of the tree species tended to have high values of carbon stock when they were under coffee plantation and on fallow compared to other land-uses. This is mainly due to the relatively high input added to coffee because of its economic value, which can enhance its growth, hence increase the amount of litter fall and root growth. Similar observations on positive effect of fertilization related enhancement of C in tree biomass and soil C pool were made by Giardina *et al*. (2003). Some scholars have also noted negative effects of N addition (Jobidon, 1993; Luxmoore *et al*., 2008), and others observed no effects (Shujauddin and Kumar, 2003; Kim 2008). However, as reported by Nair *et al*. (2010), generally fertilization effects on tree plantations may be positive depending on the intrinsic fertility of the site, species, fertilizer doses applied, and the stage of stand development. At relative young growth stage tree fertilization is expected to stimulate growth (Lamp'l, 2012; VanDerZanden, 2014). Tree performance tend to be better under undisturbed conditions (fallow). In Nebraska for example, SOC concentration, in the 0-7.5 cm and 7.5-15 cm soil depths, under undisturbed shelterbelt was 55% more than that in the adjacent crop field (Sauer *et al*., 2007). The same authors further observed that for a period equivalent to a third of a century, soils of 0–15 cm depth sequestered more SOC than the crop field. This was mainly due to absence of soil disturbance, increased inputs by litter, reduced erosion, and deposition of windblown material.

Some trees did not induce change in soil carbon stock including *Pinus* spp. *(*Pine*), Milicia excelsa (*Muvule*), Albizia coriaria (*Musita*),* and *Carica papaya* (Mupapali). This corroborates observations by Parfitt and Ross (2010) that under *Pinus* spp. (Pine), grass is gradually shaded out by the unpruned trees, and completely disappeared after 6 years; and by year 9, soil microbial C and nitrogen (N), and net N mineralisation, decreased significantly compared with pasture. Close to the *Pinus* spp. (Pine) stem, soil C decreased significantly for three years. Research in Ivory Coast on *M. excelsa* trees showed that carbonate is also present in soils surrounding these trees (Braissant, 2005; Cailleau 2005; Verrecchia *et al*., 2006). However, it can precipitate in the soil pores if the pH increases up to 8.4 in the presence of calcium. For lower values of pH which is the case for soils of Mayuge and many soils in other parts of Uganda (Isabirye *et al*., 2004), carbonate ions present in the soil are pumped by roots in the same way as calcium or other nutrients, and enter in the xylem tissues or are leached out of the soil system (Cailleau, 2005; Verrecchia *et al*., 2006). In the tropical environment, litter is rapidly degraded by soil fauna, so C-oxalate stock is quickly consumed by oxalotrophic organisms. Since the oxalate is rapidly degraded, its quantity present in the soil at a given time, is extremely low. It is also possible that soil carbon build up was balanced by the loss for *Albizia coriaria (*Musita*), Carica papaya* (Mupapalii)*,* and more so for the latter since it depends on critical nutrient management practices due to its continuous growth, flowering and fruiting habit.

CONCLUSION AND RECOMMENDATIONS

High carbon stock potential was observed in *Ficus sycomorous* (Mukunu) followed by *Senna* spp. (Gassia)*, Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba)*, Ficus sycomorous* (Mukunu) and *Mangifera indica* (Muyembe). This potential varied with land-use and soil depth for *Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba)*,* but did not vary with land-use for nged only with land-use for *Spanthodea campanulata* **(**Kinalisa), *Senna* spp. (Gassia), and *Markhamia lutea* (Musambya), and did not show any variation with land-use and soil depth for *Milicia excelsa* (Muvule), *Persea americana* (Ovacado), *Carica papaya* (Mupapali)*, Albizia coriaria* (Musita)*,* and *Pinus* spp. (Pine). This study demonstrate that carbon stock can be improved by selective tree planting even on continuously cultivated land. It is therefore recommended that *Ficus sycomorous* (Mukunu) followed by *Senna* spp.*, Artocarpus heterophyllus* (Fene), *Ficus nantalensis* (Mutuba). Senna spp. (Gassia)*, Ficus sycomorous* (Mukunu) and *Mangifera indica* (Muyembe) be promoted on agricultural land and protected by byelaws in Mayuge district. Research is needed in other districts of Uganda and other countries to identify preferred tree species with high carbon sequestration potential.

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STATEMENT OF NO CONFLICT OF INTEREST

We the authors of this paper hereby declare that there are no competing interests in this publication.

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