Women's agricultural knowledge and its effects on soil nutrient content in the Nyalenda urban gardens of Kisumu, Kenya

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Abstract. In Kisumu up to 60% of the inhabitants practice some form of urban agriculture, with just under 50% of the workers being female. On average, women spend more hours a day in the gardens than men. To increase yields, women's knowledge has to be considered in agricultural management. However, women face greater obstacles in land ownership, investment, and farm inputs due to social and cultural constraints as consequence of their gender. This case study aimed to determine what agricultural knowledge the women farmers there hold, where they get their knowledge, what motivates them in their choice of agricultural management and finally how their choices influence the soils nutrient content. Soils were sampled in Nyalenda, one of Kisumu's informal settlements where urban gardening is practiced, to determine soil nutrient contents in the form of total C and N, available N and P, and exchangeable K, Mg and Ca in the soil. Two prevailing practices were compared: 1) applying manure only, and: 2) applying manure while intercropping with cowpeas. Interviews and focus group discussions were organized to determine what knowledge the women farmers possess, and where they acquired their knowledge. Soil analysis showed that agricultural management had significant effects on nutrient presence and availability. Intercropping led to significantly lower total soil nutrient contents than when only manure was applied. However, due to socio-economic factors, such as poverty, intercropping was applied in a way that did not increase soil nutrients but diversified revenue. The knowledge of the female vegetable growers was found to be limited to practical and sensory knowledge. This shows that in addition to socio-economic and cultural context, gendered knowledge differentiation has to be acknowledged and used in agricultural training when aiming to improve soil nutrient status and agricultural yields.

Introduction

This paper concerns a case study conducted in the urban gardens of Kisumu, Kenya. The study is part of an interdisciplinary study on soil nutrients and women entrepreneurship in Kenya and Burkina Faso and seeks to link women's knowledge on agricultural practices and their motivations in choosing specific practices with the nutrient content of their soils. Urban gardening is part of the practice of urban agriculture, which encompasses all agricultural activities practiced within municipal borders (FAO, 2012). Urban gardening, also called market gardening, is a phenomenon found in most cities in the developing nations and ranges in scale from sack gardening next to houses to several acres being used for food production. For the urban poor the urban gardens provide employment opportunities and are a source of affordable vegetables. These vegetables are less expensive than those imported from the rural areas due to the lack of transporting costs. Limited infrastructure makes it difficult for some types of produce to be transported from the rural areas. By growing such vegetables within the municipality the costs are reduced and the lower costs of these vegetables allow the urban gardens to contribute to urban diet diversity and food and nutrition security (FAO, 2012; Gallaher et al., 2013). Urban gardening is hailed by many as possible way to increase local food and nutrition security, as well as provide employment, however, there are also many concerns surrounding urban gardening, including some concerning health risks and environmental degradation (Cofie et al., 2003; FAO, 2012).

Opposition to urban agriculture comes mainly from the sectors of public health, environment and urban planning. In terms of urban planning, land used for urban agriculture may be more productive or valuable when used for other enterprises (Mougeot, 2000). Furthermore, urban agriculture is also often practiced on public lands (Mougeot, 2000). When undertaken on private lands it often concerns farmers whose previous rural land has been overtaken by urban sprawl, now finding themselves in the (peri-)urban sphere (Mougeot, 2000). When urban gardening is practiced on public lands the farmers often work on the roadside, or on riverbanks and floodplains (Mireri et al., 2007; Mougeot, 2000). Agriculture practiced on locations like roadsides especially, risks pollution from vehicle exhaust and industrial waste (FAO, 2012; Mireri et al., 2007). As a result, products from these sites can have contaminants that can threaten the health of the consumers as well as the producers. Urban agriculture is also considered to be an intense form of agriculture that causes soil degradation. Often confined to small areas, there is little room for urban farmers to rest the soil or rotate the crops, and products like mineral fertilizer are expensive for the poorer segment of the urban farmers that are most likely to resort to these practices (FAO, 2012; Mougeot, 2000).

With over half a million inhabitants Kisumu is Kenya’s third largest city. Unemployment in Kisumu is high, in 2013 the unemployment rate in Kisumu was determined to be 40% (Mireri, 2013). Over 60% of Kisumu’s inhabitants live in informal settlements (Mireri, 2013; Obade, 2014; UN-Habitat, 2005). It is estimated that up to 60% of the inhabitants of Kisumu practice some form of urban agriculture, including livestock keeping. Agriculture has been practiced on the periphery of the city since its founding in 1901, but as the city grew the boundaries between the urban areas and the rural areas have grown vague. Most of the original agricultural areas have fragmented and now fall within the municipal boundary, as such these areas have been reclassified as urban gardens (Anyumba, 1995). Most of the urban gardens are located on the edges of the informal settlements.

Mireri (2013) found that approximately 47% of those working in the urban gardens in Kisumu is female, and that on average the women spend more hours a day on the farms than men. Women are culturally expected to take responsibility for family food provision and practicing urban agriculture allows many women to do so while also performing their other duties. Women are expected to clean the house, provide food and watch over any children. As urban agriculture sites are relatively near the home it is an accessible option to women who also have many other daily tasks (Doss et al., 2018; Mougeot, 2000; Poulsen et al., 2015; Simiyu and Foeken, 2013). Many of the women farmers work on a subsistence basis (Kabira, 2007; Kameri-Mbote, 2006; Kiriti-Ng’anga, 2015a; Kiriti-Ng’anga, 2015b; Mireri, 2013) and any excess produce is sold by the women to pay for expenses such as their children’s school fees (Mireri, 2013; World Bank, 2009). Gender inequality makes it difficult for these women to move beyond subsistence agriculture. Women face greater obstacles than men in regards to land ownership, investment, and farm inputs due to historical, social, cultural and financial constraints as a consequence of their gender (Alunga and William, 2013; Dolan, 2015; Kabira, 2015; Kameri-Mbote, 2006; Kiriti-Ng'anga, 2015a; Kiriti-Ng'anga, 2015b). As a consequence of these obstacles, few modern techniques are applied in the urban gardens. Lack of access to capital and knowledge limits these women to traditional techniques and sensory knowledge passed down within families (FAO, 2012).

Due to a lack of equal access to technologies such as fertilizers, women consistently have yields that are on average 20-30% less than men in developing countries (FAO, 2006). At the same time, there is evidence of gender differentiated access to knowledge. The results of a food security survey held by the African Women's Studies Centre and the Kenyan National Statistics Bureau in 2013 showed that women respond differently to food security issues and consider challenges differently than men. For example, up to 80% of men believe that a small, uneconomical area of land is a hindrance to achieving food security, whereas only 20% of women consider this to be a major hindrance (KNBS/AWSC, 2014*)*. There is further research that suggests that women could potentially produce up to 20% more on the same surface area than men if given equal access to resources (Saito et al., 1994). However, there is also research showing that due to a lack of education and training, women farmers use practices that are less environmentally friendly and can lead to a more rapid degradation of the soil (Doss et al., 2018).

This raises the question of what knowledge women working in urban agriculture have on agricultural practices, and how their practices affect their soil. In close partnership with local partners from scientific institutions and NGO's, Nyalenda, a location in one of the urban gardens of Kisumu, Kenya was selected as representative of the area and farmers groups in the urban gardens of the city, and characteristic for the urban gardening situation that can be found throughout other cities of Kenya and (sub-)tropical Africa in general. With an approach that combines semi-structured interviews and focus group discussions with women food entrepreneurs (WFE's) working in Nyalenda, and soil analysis of their urban garden plots, we aimed to determine how the agricultural knowledge and motivations of women farmers influences their soil's nutrient status as reflected by the total soil C and N, available soil N and P and exchangeable soil Na, K, Mg and Ca in the Nyalanda urban gardens. The methods used were designed to triangulate and provide complementary information.

Materials and Methods

Kisumu is a city of approximately half a million inhabitants on the northern shores of Lake Victoria. The city is the headquarter of the Kisumu district and the Nyanza Province (Mireri, 2010). Temperature averages at 22 ^{0}C year-round and annual rainfall averages between 1000 and 1400 mm. There is a short rain season in November and December and a long rain season lasting from April until June. The city lies on Quaternary sediments and Tertiary Volcanic deposits. Due to the tropical climate, deeply weathered soils can be expected in this area, but the parent material is relatively young and rich in nutrient bearing minerals (Orodho, 2006).

There are several informal settlements in Kisumu, including Nyalenda. Nyalenda lies on the southern edge of the city and is one the largest of the cities six informal settlements, both in number of inhabitants and surface area covered (UN-Habitat, 2005). Divided over two blocks, A and B, Nyalenda houses nearly 50.000 people within an area of 8.1 km^2. Existing infrastructure, access to electricity and access to sanitation are limited in the informal settlements (UN-Habitat, 2005). All along the southern edge of Nyalenda there are active vegetable farms adjacent a river and wetland area. One of the groups active in these urban gardens is the Mesopotamia group. The group consists of 14 members, 8 women and 6 men, who cultivate an area of 3-4 ha. Most Mesopotamia members have inherited their land and some rent extra plots within the area; the group is diverse in age and experience.

The decision to work with the Mesopotamia group was made after various meetings with local NGO's and scientists in conference with the Mesopotamia group itself in January 2016. The Mesopotamia group is seen by the scientists gathered at the conference as representative for many of the urban gardening groups in Kisumu, and especially those working on the border of the Nyalenda informal settlement. The Mesopotamia group had previously been informed by government extension services that their soil might be lacking in N. In response to this apparent lack of N at least 5 group members changed their practices, they started to intercrop the local staple crop Sukuma Wiki, a kale (*Brassica oleracea var. Sabellica*) with a legume with nitrogen fixating root nodules, cowpeas (*Vigna unguiculata L. Walp*) (Likoko and Jonkman, 2016).

The four fields selected for soil sampling were all used to grow kales, in two of the fields the kales were intercropped with cowpeas. All four sampled fields are centrally located in the urban gardens, limiting the differential influence the nearby river might have on fields lying closer or farther away from it. The soil on these fields were classified as Vertisols (FAO, 2014), characterized by the presence of heavy clay which shows shrinking and swelling behaviour. All samples were collected in May during the dry season. On each of the four fields 12 samples were collected from the topsoil (0-15 cm) to limit the influence of spatial variability, 48 samples total. All samples were subsequently dried at 70^{o}C, sieved at 2 mm and stored for analysis.

2.1 Interviews and Focus Group Discussions

The four fields sampled are owned by two female members of the Mesopotamia group, each member owning two of the fields. One of the women grows exclusively kales on her fields and the other woman intercrops the kales with cowpeas on her fields. Both women used manure as fertilizer, however the farmer who grows exclusively kales ploughed the manure into the soil while the intercropping farmers applies the manure as a topdressing. The two women that own the sampled fields, along with the 6 other female members of Mesopotamia, were interviewed to determine what agricultural knowledge the women have, where they get their information and how this influences their management choices. The eight women varied in age and experience, capturing a broad spectrum of views and knowledge. The semi-structured interviews used open questions to determine what knowledge women farmers had about the effects of fertilizers on crops and soil, where they received this information, and to what degree and with whom they shared this knowledge. A set list of questions was use for the interviews to gather complementary and comparable information on the women's knowledge and views. The interview were conducted with the aid of an interview guide including an introduction, opening questions, key questions and a summary (adapted from Woodhouse, 1998; Curry, 2015a).

Interview questions:

Opening questions:

- *Can you describe what you do on your field on a typical day?*
- *How do you fertilize you fields?*

Key Questions:

- *What do you know about what the soil needs for growing crops?*
- *What do you know about the effect of fertilizer on the soil?*
- *What methods to fertilize your fields do you know?*
- *How do you know this? Where did you get your knowledge?*
- *Did you ever see differences in crops or the soil when you or somebody else changed their methods?*
- *Did you ever share this information with others?*

- *Is there an opportunity to share knowledge within the farmers group?*
- *Do you feel your knowledge is valued by others?*
- *Is it easier to share knowledge with other women?*

In addition to the interviews, two focus group discussions were held with members of the Mesopotamia group. One focus group discussion was held with 6 female participants and another with 11 participants, 6 women and 5 men. A women's only discussion was held with the 6 women participating to go more in depth on the knowledge of women. The focus groups discussions were based on questions used in the interviews and the methodology proposed by Curry (2015b), Krueger & Casey (2002) and Johnson & Mayoux (1998). The discussions were aimed at determining the extent of agricultural knowledge in the Mesopotamia group as well as their information sources and the relative importance of these to the farmers. Both focus group discussions had the same format and started with a short opening and introduction followed by an explanation of the goal and guidelines for the discussion. The opening was followed by a set of discussion questions and an exercise. The discussion was closed with a short summary. Due to the open platform and the presence of multiple participants the focus groups discussions provided more in-depth answers and clarifications, to support the information from the interviews.

Focus group discussion questions and exercise:

- *What does your day on the farm look like?*
- *How do you take care of your fields and crops? How do you decide on this?*
- *How do you know what you have to do to take care of your fields and crops? Where do you get this information?*
- *Can you rank the sources of information on validity and give a short explanation about their final ranking?*
- *When do you share your knowledge, to whom and why?*

2.2 Laboratory analyses and data processing

The analysis of the samples is to determine how soil nutrient contents were influenced by the management choices of the women farmers. Water extracts of the soil samples were created (ratio 1:2.5) and used to determine pH and EC. These water extracts were then filtered and available P, K, S, Ca and Mg measured using a Perkin Elmer Optima 8000 ICP-OES Spectrometer. Available NH_4^+, NO_x, PO_4^{3-} and SO_4^{2-} in the extracts were determined on a Skalar SA-40 continuous-flow analyzer. Total organic and inorganic C in the extracts were measured using a Shimadzu TOC/TN analyzer.

Filtered $BaCl_2$ extracts were used for the determination of exchangeable Fe, Mn, Mg, Ca, Al, and K with ICP-OES (Schwertfeger and Hendershot, 2009). Extracts were prepared using 100 ml $BaCl_2$ 0,125 M and 4 grams of milled soil sample (<2 mm). CEC was calculated as the sum of the values for exchangeable Ca, Mg, K and Na in $cmol_c$/kg.
Total C and N were determined with 50 mg of soil (<2mm, milled) by using a Elementar Vario EL cube CNS analyzer. Total P, K, Ca, S and Mg were determined by measuring HNO_3/HCl extracts with ICP-OES; extracts were prepared with 250 mg soil (<2 mm, milled), 6 ml HCl 37% and 2 ml HNO_3, and underwent microwave destruction (60 min;Tmax 220◦C; Pmax 75bar). Total elemental composition of the soil samples was also determined using XRF analysis, using the Thermo Scientific XRF Analyzer Niton; setting: mining Cu/Zn; Standard: NIST 2709a PP 180-649; 160 seconds.

Variance within each field and between fields with different management practices was determined using analysis of variance test. ANOVA was used in case of normal data distribution and Kruskal Wallis with non-normal data distribution

(Burt et al., 2009). The strength and direction of the relationship between different parameters was determined using a correlation coefficient, Pearson's R. All statistical analysis was done in Matlab, version R2014b. The measured results and calculated variances where corroborated with the results of the interviews and focus groups discussions..

Results

3.1 Interviews

While the interviews started with enquiring into the typical daily activities these turned out to vary too much from person to person and season to season to provide a meaningful clustering. Fertilizer use is mostly in the form of locally produced or homemade compost (4 of 8) or the use of unprocessed cow manure (2 of 8). The other two interviewees used either mineral fertilizer or cow manure with occasional application of mineral fertilizer. All interviewees named fertilizer as something the soil needs for growing crops, but none really knew what fertilizer does for the soil in technical terms. The knowledge regarding the effects of fertilizer is limited to visible effects only.

When it comes to other methods to increase soil fertility the results are more divided. 2 interviewees knew no other methods aside fertilization, 3 named mulching, 4 mentioned fallow periods, and 4 mentioned crop rotation. All interviewees that named other fertility increasing methods also apply these methods when needed and many noted that they see a visible difference in their crops when one or more of these methods is applied. The agricultural information sources named during the interviews were relatives, including parents, grandparent, or husband, trainings by NGO's or extension workers, elementary school, and observing others. Information from relatives was most common, being named by 5 of the interviewees, followed by trainings by NGO's or extension workers, named by 3 interviewees. As point of interest, one of the interviewees got her information from her grandmother, who was also interviewed, and who got her information from training by NGO's and extension workers.

"*Next to the information we got from our ancestors, we get information from the look of things, when you come and see somebody farming and you ask what they are doing and how it is going. So by observing is also how we get information"* (FGD 1, participant I5).

All interviewees noted that they meet either monthly or weekly with others and feel that they can speak freely and that their input is valued in general. Of the 8 women interviewed 5 responded that it is easier to share knowledge with women and 3 responded that they share equally easily with men. However all interviewees noted that women overall seem more open to input or that they listen and understand better. Many felt that the shared circumstances of women, meaning similar problems and the care for the household and children, spending more time at the house or on the field, is the leading cause of this. Two of the women said that men are less open to advise and can even become violent.

"*Women are easier to work with because they are the people who take responsibility in the houses and can solve this."* (FGD 2, Participant I5).

3.2 Focus group discussions

Much of the information from the interviews was confirmed in the focus group discussions (FGD). The exceptions were as follows. Although the types of fertilizers named during the FGD were mostly the same as those in the interviews, more of those responding appear to be using a form of mineral fertilizer. It also became apparent, in contrast to what came forward from the interviews, that the farmers do have knowledge of the way to work intercropping in a manner that can add N to the

soil, but that they have a different name for this method: green manuring. The management of the farms and decision regarding using one of the various methods to restore soil fertility is largely reactionary - actions are undertaken only when the crops seem to do less well than previously.
While mineral fertilizers seem to be used more than inferred from the interviews, the participants do show a preference for organic types of fertilizer. According to them vegetables grown with organic fertilizers taste better and keep longer and mineral fertilizer damages the soil.

During the women only FGD we learned that most of the women work in the urban gardens as a way of generating income, to provide for themselves and their children. At least half of the women participating in the FGD are widows and agriculture is their sole form or income. Their main issue in working with men is a lack of mutual understanding and the men's tendency to refuse to share resources with them. They believe it would help if there was at least 1 women on the groups' board and this would lead to more equal distribution of resources among the group members. There are some limitations on the women's activity due to cultural restriction, but not all of them are still actively followed. One that still is followed and limits the women is the prohibition for women to plant and own trees. Banana trees for example can bring higher profits than some other crops, yet women are forbidden from planting them.

When asked about the sources of agricultural information the participants of the FGD name 5 different sources. All rank family as the first and most important sources, followed by trainings and demonstrations. Observation and visiting others is ranked third. Media and exhibitions are ranked fourth and fifth respectively, and the farmers indicate that this is because of their lack of access to media and the expenses involved in visiting exhibitions.

3.3 Soil Analysis

The sampled soil was analyzed for its nutrient content, and by FAO standards generally fell within the ranking 'high' (FAO, 2006). Table 1 provides the average values of the main soil parameters for all 4 sampled fields. The pH of the soil in the sampled fields ranged from very slightly acid to very slightly alkaline, with an overall average of 7.25 (Table 1). The CEC was high overall with an average value of 33.5 $cmol_c\ kg^{-1}$, likely as a consequence of the high clay content of the soil (Table 1). Similarly, with an average of 36.6 $g\ kg^{-1}$ the total soil carbon was also high. The laboratory analyses showed relatively high amounts of water soluble and exchangeable cations, however there is a significant difference in nutrient content depending on the management practice.

The women of the Mesopotamia group possess limited technical knowledge and are aware of the effects of the management practices that they apply only in terms of the visible effects of these practices. From the interviews it is clear that there is a range of agricultural management practices known and practices within the Mesopotamia group, but it also became clear that while the farmers know that these methods work when aimed at improving soil quality – they do not why these methods work. They know that plants need nutrients from the soil and that they can add nutrients to the soil by applying fertilizers, mineral or organic, but how the fertilizers add these nutrients to the soil is unknown. The agricultural management practices that the women spoke of during the interviews were: crop rotation, fallow periods, fertilization with manure, compost and mineral fertilizer, intercropping, and mulching. Not all of the mentioned practices were familiar to all of the women, and some of the women found that they were limited in choice of management practice due to their socio-economic circumstances. For example, for many women fallow periods are not an option as their lands are simply too small. A certain yield is needed for sufficient income generation and leaving the land or a portion of it fallow would mean a significant reduction in income. A consequence of the lack of fallow periods is more pressure on the land, which can lead to increased erosion and may result in diminished soil nutrient content (*KNBS/AWSC, 2014)*.

	pH	C	N	Mg	Ca	K	Na	CEC	NO_x^-	NH_4^+	PO_4^-	SO_4^{2-}
	-	g kg^{-1}		mg kg^{-1}				$cmol_c$ kg^{-1}	mg kg^{-1}			
Mean	7.3	36.6	2.8	572.6	4842.1	1768.4	116.0	34.0	85.5	5.9	24.0	59.0
Std	0.2	11.0	0.4	89.2	761.2	879.2	30.3	5.4	62.7	3.7	15.6	44.5

Table 1. Average pH, total C and N (g/kg), exchangeable Mg, Ca, K and Na (mg/kg), CEC ($cmol_c$/kg) and water soluble ions NOx, NH^{4+}, PO_4^- and SO_4^{2-} (mg/kg) in the soil of Nyalanda field site (0-15 cm depth, 4 fields, with 12 samples per field; n=48).

Intercropping is done by 4 of the women in the Mesopotamia group, mainly with cowpeas, which should theoretically improve soil nutrient content. However, the intercropping technique is not always applied in a way that would accomplish this: the plants are harvested and not ploughed into the soil. Ploughing the cowpeas into the soil is needed for the nutrients accumulated to become available for other crops through the enrichment of the soil with organic matter (Okalebo, 2009). The women also use intercropping to prevent soil erosion while the main crops, often kale, is still growing. Intercropping also provides a source of income while the farmer waits for the kale to mature as cowpeas mature faster. Soil analysis shows that the application of intercropping has a significant effect on the soil nutrient content (Figures 1, 2, Table 1).

To support the soil analysis the two farmers whose fields were sampled were interviewed more extensively than the other interviewees. Both farmers have at least 5 years of experience and principally grow kales. The fields of the farmer that only uses compost have a slightly higher clay content and lower drainage capacity than those of the farmer that practices intercropping. The intercropped fields have a coverage of approximately 60-65%, less than those where only kale is grown, which have an approximate covering of 80-85%. The manure of both farmers is made of manure from cows and chicken mixed with organic waste. The farmer using only the manure applies this at time of planting and then again every 4-12 weeks as she feels is necessary. The application is ploughed into the soil. The farmer practicing intercropping applies manure as a topdressing at planting and approximately 8 weeks after planting. The cowpeas are broadcast on the field and a number of the plants is removed after 2 weeks to make room for the kales to grow. The farmer using manure weeds and ploughs her field every 10 days, whereas the intercropping farmer weeds every 14 days and ploughs her fields only every 26 weeks. In the fields of the farmer that uses only manure kales were grown in the fields in the previous growing season. The fields of the intercropping farmer were left fallow for 6 months before planting the current crops; in one of the fields maize was grown before the fallow period.

In case of manure application combined with intercropping the pH leaned towards being very slightly acid, whereas in case of only manure application the pH leaned towards very slightly alkaline (FAO, 2006). The CEC was nearly 10 $cmol_c$ kg^{-1} higher in fields under only manuring than in the fields where there is also intercropping. Similarly, total soil carbon is nearly 20 g kg^{-1} higher in the fields where only manure was applied in comparison with the fields where there was also intercropping (Table 1; Fig. 2a). While the soil organic carbon was slightly higher in the manured fields versus the intercropped fields the difference was not significant (Fig. 2c). The contents of the macronutrients N, P, K, Ca and Mg were almost all higher under the field management type manure application only, as compared to manuring combined with intercropping (Fig. 1; Fig. 2).

Figure 1a, 1b and 1c show the amounts of water soluble and exchangeable Mg, Ca and K as part of the total amount of the cation present in the soil, clearly demonstrating that the levels are higher under the practice of applying manure only. Figure

1d, 1e and 1f show the proportion of the total amount of Mg, Ca and K in the soil that is water soluble or exchangeable. Notable is that while the absolute amounts are higher under manuring only, under the practice of manure application combined with intercropping, often a larger proportion of the nutrients was water soluble or exchangeable (Fig. 1). Specifically, the average exchangeable fraction was higher for Mg and Ca under intercropping + manuring, and the average water soluble fraction was higher for Ca and K under intercropping + manuring. The Kruskal Wallis and ANOVAs tests showed that all the described difference between the fields and between the management practices were significant for these characteristics at a confidence interval of 95%.

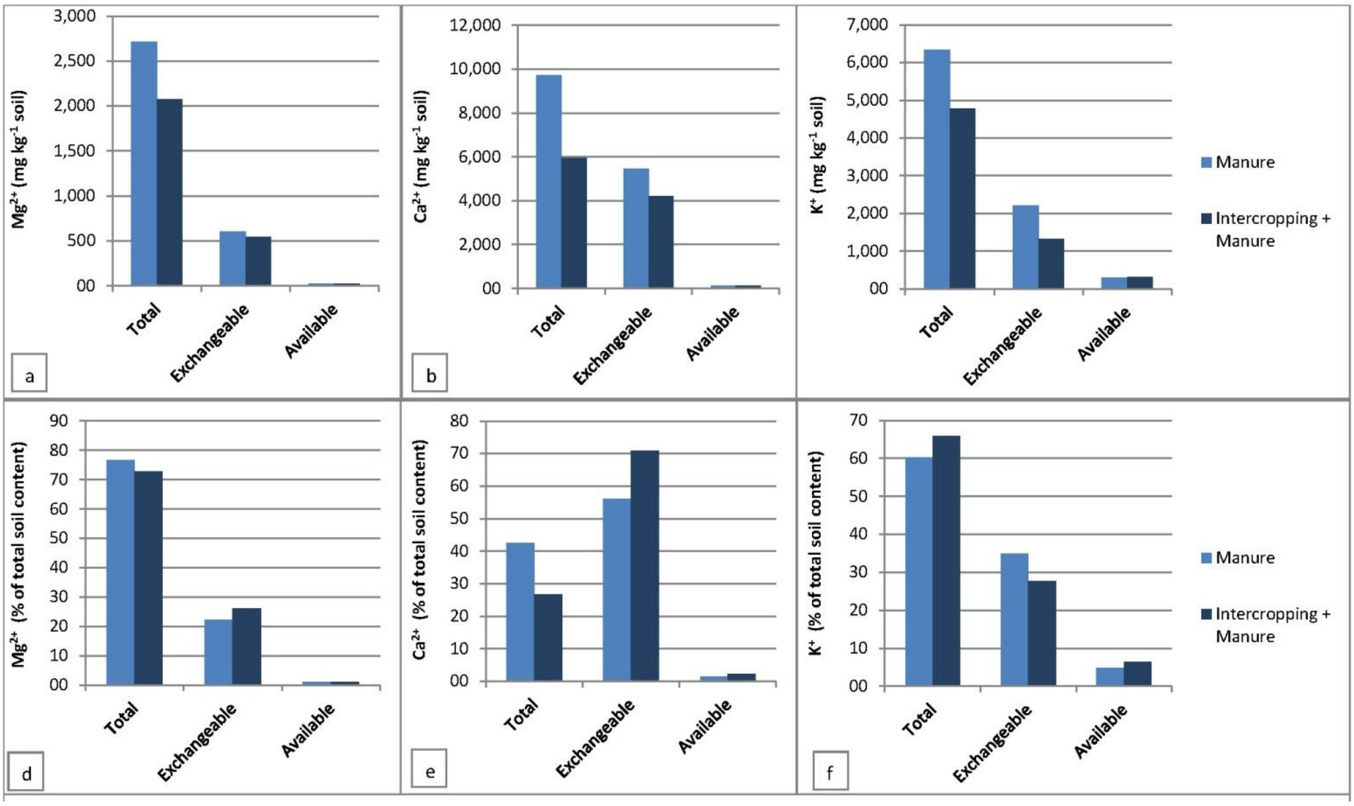

Figure 1. 1a, 1b and 1c: Bars length show the total, exchangeable, and plant available/water soluble amount of Mg, Ca and K in mg kg^{-1} soil under management 'manure' and 'intercropping and manure'. 1d, 1e and 1f: Total, exchangeable and plant available/water soluble Mg, Ca and K in the soil as percentage of the sum.

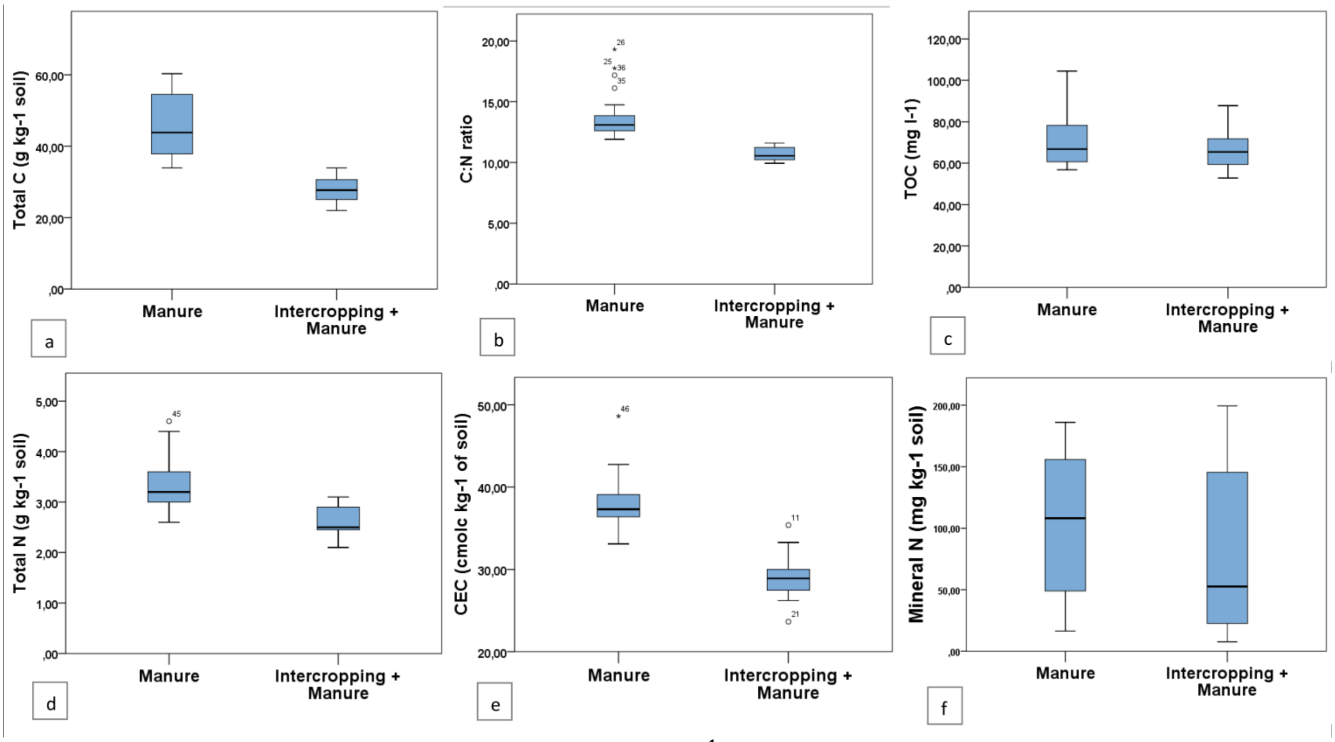

Figure 2. Boxplots showing the differences between 2a: total C (g kg^{-1} soil), 2b: C/N ratio, 2c: total organic C in the extracts (mg C l^{-1}), 2d: total N (g kg^{-1} soil), 2e: cation exchange capacity (CEC in cmol$_c$ kg^{-1}) 2f: Mineral N (mg kg^{-1} soil), for the agricultural management practices of 'manure' and 'intercropping and manure'.

Discussion

Results of the sample analysis of the soil of the urban gardens in Nyalenda showed a pattern consistent with the soil typology. The soils in the Nyalenda urban gardens can be classified as Vertisols, locally known as black cotton soils, which are soils characterized by a high clay content that shows shrink and swell patterns (FAO, 2006; FAO, 2014). Vertisols are generally fertile and productive soils, high in Ca, K and Mg, but often poor in N and P (FAO, 2006, FAO, 2014). Soil analysis has shown the rating for exchangeable Ca and K was very high and the rating for Mg was high according to FAO classification (Table 1; Fig. 1) (FAO, 2014). The high amounts of nutrients in the Nyalenda soils is most likely because of the parent material, which consists of river and lake sediments with inputs from the African rift valley, and the limited age of the soil material.

Earlier research on soil nutrients and possible solutions for soil fertility problems in rural western Kenya concluded that socio-economic factors determine how likely it is that scientific findings are taken up by farmers (Gicheru, 2012; Okalebo, 2005). The results from the interviews and the FGDs show that this is also the case in a more urban setting. This might be because the gardens were originally located in a more rural surrounding, but the urban centre of Kisumu has since spread to that area; effectively changing the gardens environs from rural to urban.

Gender-aware research has shown that women possess important knowledge regarding agricultural management, distinctly different from the knowledge of men in agriculture (Saito et al., 1994; KNBS/AWSC, 2014). When farmers do not use scientific findings it is often regarded as a sign of unwillingness, lack of understanding, or ignorance. This view is particularly damaging for the collaborative interactions between different institutions and farmers, and the success of any potential innovations in agriculture that are adaptive, affordable and applicable to the context.

When asked to name and rank their primary sources of information all farmers of the Mesopotamia group, male and female, indicated a preference for inherited knowledge, followed by trainings and demonstrations. There was some discussion on the differences between demonstrations and observations, and some of the farmers consider them equal in importance. Information from training and demonstrations is however often lost because techniques or elements thereof are forgotten over time and/or materials needed are unavailable or too expensive. Using and adapting techniques by observing other farmers is more common. Information from television or internet has less impact because these farmers lack access to these media. Exhibitions are considered good, but the expense to go and visit them is often considered to be too high.

Limited access to sources of information means that most of the Mesopotamia farmers possess limited technical knowledge regarding soil processes, however they are aware of soil processes and their consequences in practical terms from sensory knowledge and daily experience. For example, the women are aware of the need to rest the soil with fallow periods or crop rotation and that mulching improves soil structure. The majority of the women in the Mesopotamia group possess knowledge regarding agricultural management practices and the effects of these practices on soil in these basic terms. As this knowledge is mainly passed down from previous generations or disseminates through observation of other farmers in the group or community, this knowledge does not travel far (Alunga and William, 2004; Kabira, 2007).

The women farmers of Mesopotamia report that they prefer to share information with other women. Some of the women are occasionally wary of sharing information with men, as men might feel offended by ‘being taught’ by women. The women believe it is easier for other women to understand their knowledge because of their shared backgrounds and responsibilities and they indicate that they often continue beyond scheduled meetings to further discuss issues and solutions. On occasion they will choose not to share information with another, if for example they believe that the other woman does not have the resources to apply the technique.

In Nyalenda, a context where poverty is widespread, agricultural management and decisions are heavily influenced by social-economic constraints. These constraints can work against sustainable farming practices. For example, the farmers explained that some had taken to intercropping with cowpeas originally because they were told that they needed to increase N in the soil by government extension workers. Yet, the analysis of the soil samples shows that the soil nutrient content is significantly lower when the kales are intercropped with cowpeas (Table 1, Fig. 1, 2).

Soil samples from fields with intercropping show lower amounts of soil nutrients on average (Figs 1a, 1b, 1c, 2), however a comparison on the availability ratios of some of the nutrients showed that they have a higher availability or are more readily exchangeable under intercropping (Fig. 1d, 1e, 1f). The cause for this difference is not clear, but may be the influence of the presence of a legume species. The presence of the rhizobacteria on the root nodules of the legume can promote the availability or exchangeability of nutrients beyond nitrogen by immobilizing nutrients and preventing them from leaching from the soil (Lavakush et al., 2014; Vejan et al., 2016). Furthermore, the lower amount of nutrients in the intercropped fields may be due to the different approaches that the farmers have to applying manure. Farmer I2, who applies intercropping, applies the manure as a topdressing only. Farmer I7, who does not practice intercropping, ploughs the manure into the field. Ploughing the manure into the field preserves the N and promotes the biological breakdown of the manure, which increases the availability of the nutrients therein (Baligar, 2001). The decrease in soil nutrients in intercropped fields (Fig. 1) was most likely caused by the farmers not ploughing the cowpeas into the soil in combination with the different manuring practice (Okalebo, 2009).

During the interviews it became clear that instead of ploughing the cowpeas into the fields, the farmers are harvesting the cowpeas for sale. Harvesting the cowpeas means a greater uptake of nutrients from the soil and no additional organic material is added to the soil. Selling the cowpeas has become the primary motivation for intercropping as it gives the farmers a source of income in the period before the kales are mature and the advantage of doing so is more readily apparent to farmers than a potential increase of N in the soil. This shows that the lack of effect of intercropping on soil N contents in the examined soils is most likely not the cause of a lack of women vegetable farmers' knowledge of proper application or the technical knowledge of intercropping. Rather it appears to be a conscious choice related to a shift in the aim to be achieved by intercropping, i.e. gaining a secondary crop to be harvested and sold rather than increasing the yields or quality of the primary crop.

Conclusion

The results of the soil analysis showed that the soil in the Nyalanda urban gardens is rich in macronutrients. Further analysis indicated that, while seemingly small, the impact of different agricultural management practices on soil nutrients is significant. The growing of the cowpeas beside the kales causes a more rapid extraction of nutrients from the soil. Growing cowpeas and ploughing them into the soil should increase soil N content, however the farmer that applied intercropping sold the cowpeas on the market rather than ploughing them into the soil. This practice likely resulted in the observed decrease in nutrient contents, but provided the farmer with income at a time when the kales were still maturing.

The interviews and FGDs with the Mesopotamia group showed that there is knowledge of a wide range of agricultural management practices present. However, the interviews with the individual women members of the group showed that the knowledge on these practices is unequally distributed and that while they may be known to a technique they do not possess technical knowledge on the effects of their management practices. We conclude that the incomplete knowledge of these farmers is a consequence of the way they acquire and rank knowledge. During the FGDs a clear preference was given by all farmers to knowledge gained from family members. Observation of other farmers and trainings by outside groups were also appreciated, but considered less important. Knowledge from the trainings was often forgotten or materials needed were unavailable or unaffordable, making the training virtually ineffective.

The ineffectiveness of trainings showed that these should be adapted to take the socio-economic circumstances of the trainees into account. Furthermore, the gender differences in ability and access should similarly be taken into account in order to improve the effectiveness of a given training or agricultural recommendations. While this paper covers a case study of limited scale, meaning that this should be taken into consideration when viewing the results and drawing conclusions, the circumstances found within the Mesopotamia group are representative for many other groups in the urban gardens of cities in Kenya and subtropical Africa. The case study showed that women are influenced by their socio-economic and cultural status when making decisions in agricultural management and that these decisions may differ from those of men in the same or similar circumstances due to a lack of access to knowledge, contacts, or materials and capital. While the women of the Nyalenda group are willing to share their knowledge with other women, they are more wary of sharing with men. This wariness on the part of women contributes to the presence of gender differentiated knowledge and hampers the spread of knowledge in general.

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