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Women's agricultural practices and their 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. Therefore women's knowledge is pivotal for effective agricultural management. To enhance and better use women's knowledge, gender-related sociocultural obstacles linked to land ownership, investment, and farm inputs have to be taken into account. We aimed to determine how the agricultural knowledge and motivations of female farmers working in the Nyalenda urban gardens in Kisumu (Kenya) influence the soil nutrient status as reflected by the total soil C and N; available soil N and P; and exchangeable soil Na, K, Mg, and Ca. Two prevailing practices were compared to determine how the agricultural management practice influences soil nutrient content: (1) applying manure only and (2) applying manure while intercropping with cowpeas. Interviews and focus group discussions were held to explore the agricultural knowledge and motivations of the women working in Nyalenda. Soil analysis showed that the soil in Nyalenda was rich in nutrients overall but that the intercropped fields contained significantly lower total soil nutrients than fields where only manure was applied. While theoretically intercropping with a legume such as cowpeas should increase soil N content, due to socioeconomic factors, such as poverty, intercropping was applied in a way that did not increase soil nutrient contents; rather it diversified revenue. The knowledge of the female farmers was found to be limited to practical and sensory knowledge. This shows that when aiming to improve soil nutrient status and agricultural yields through agricultural training, socioeconomic conditions, cultural context, and gendered knowledge differentiation have to be acknowledged.

1 Introduction

This paper builds on a case study conducted in the urban gardens of Kisumu, Kenya. The study seeks to link women's knowledge on agricultural practices and their motivations in choosing specific practices with the nutrient content of their soils at this site. Urban gardening is part of the practice of urban agriculture, which encompasses all agricultural activi-

ties practiced within municipal borders (FAO, 2012). Urban gardening is found in most cities in the developing nations, such as Kenya, and ranges in scale from sack gardening to several acres being used for food production. For the urban poor the urban gardens provide employment and affordable vegetables. These vegetables are less expensive than those imported from the rural areas due to the lack of transporting costs. Moreover, limited infrastructure makes it difficult for

fresh vegetables 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 a possible way to increase local food and nutrition security and provide employment. However, there are concerns surrounding urban gardening, including some concerning health risks and environmental degradation (Cofie et al., 2003; FAO, 2012).

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 40 % (Mireri, 2013). Over 60 % of Kisumu's inhabitants live in informal settlements (Mireri, 2013; Obade, 2014; UN-Habitat, 2005). An estimated 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 faded. The agricultural areas were fragmented and now fall within the municipal boundary. As such, these areas have been reclassified as urban gardens (Anyumba, 1995). 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 are female and that on average women spend more hours a day on the farms than men. Women in Kenya and many other countries in sub-Saharan Africa are culturally expected to take responsibility for household duties like family food provisioning, cleaning the house, and caring for children and elderly people. As urban agriculture sites in most sub-Saharan cities are relatively near to 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 female farmers in Kenya (Kabira, 2007; Kameri-Mbote, 2006; Kiriti-Ng'ang'a, 2015, b) and in Kisumu in particular (Likoko et al., 2019; Mireri, 2013) work on a subsistence basis, and any excess produce is sold to pay for expenses such as their children's education (Mireri, 2013; World Bank, 2009). Gender inequality makes it difficult for these women to move beyond subsistence agriculture. Women in Kenya and in most of sub-Saharan Africa face greater obstacles than men in regards to land ownership, investment, and farm inputs due to historical, sociocultural, and financial constraints as a consequence of their gender (Alunga and William, 2013; Dolan, 2015; Kabira, 2015; Kameri-Mbote, 2006; Kiriti-Ng'ang'a, 2015a, b; Likoko et al., 2019). As a consequence, few modern techniques are applied in the urban gardens of sub-Saharan Africa. Lack of access to capital, knowledge, and security limits these women to traditional techniques and sensory knowledge passed down within families and small social circles (FAO, 2012).

Overall, women consistently have agricultural yields that are on average 20 %–30 % less than men in developing countries due to a lack of equal access to technologies such as fertilizers (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 in several counties in Kenya 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). Research by Saito et al. (1994) suggests that women could potentially produce up to 20 % more on the same surface area than men if given equal access to resources in sub-Saharan Africa. However, there is also research showing that due to a lack of education and training, female farmers use practices that are less environmentally friendly and can lead to a more rapid degradation of the soil (Doss et al., 2018). It could be expected that sources of information and knowledge are present and accessible more readily in an urban environment and that because of this, the women in urban agriculture could be more knowledgeable of agricultural management practices than their rural counterparts. However, when farmers do not use scientific findings, it is often regarded as a sign of unwillingness, a 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.

Therefore, we aimed to determine how the agricultural knowledge and motivations of female farmers working in urban gardens in Kisumu (Kenya) influence 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 their urban agricultural plots. The methods used combine analyses from the natural and social sciences and were designed to triangulate and provide complementary information. We specifically aimed to study female farmers as an important group in their own right rather than making a comparison with men as farmers.

2 Materials and methods

This study was done with the help of the Mesopotamia farming group from the Nyalenda urban gardens of Kisumu. The decision to work with the Mesopotamia group was made after various meetings with partners from a local scientific institution and NGO (Victoria Institute for Research on Environment and Development – VIREED; Centre for African Bio-Entrepreneurship – CAFE) in a conference with the Mesopotamia group itself in January 2016. The Mesopotamia group was seen by the scientists gathered

at the conference as being representative of many of the urban gardening groups in Kisumu, especially those working on the border of the Nyalenda informal settlement. The site is considered to be representative of the area and farmers' groups in the urban gardens of the city in terms of size and composition and the prevalent soil type and water accessibility at the site itself. Nyalenda is one of six informal settlements in Kisumu and is one of the largest 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 km². 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 to 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 farming group is characteristic for the urban gardening situation that can be found throughout other cities of Kenya and tropical or sub-tropical Africa in general.

The Mesopotamia group had previously been informed by government extension services that their soil might be lacking in nitrogen (N). In response to this apparent lack of N, at least five 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 fixing root nodules, cowpeas (*Vigna unguiculata* L. Walp), in 2013 (Likoko and Jonkman, 2016).

The research approach combines semi-structured interviews and focus group discussions with female food entrepreneurs (WFEs) working in Nyalenda and soil analysis of their urban garden plots. The four fields selected for soil sampling were all used to grow kale; in two of the fields the kale was intercropped with cowpeas. All four sampled fields are centrally located in the urban gardens, limiting the differential influence that the nearby river might have on fields lying closer or farther away from it. The soils of these fields were classified as Vertisols (FAO, 2014), characterized by the presence of heavy clay which shows shrinking and swelling behavior. 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, with 48 samples total. All samples were subsequently dried at 70 °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, with each member owning two of the fields. The two women that own the sampled fields and six other female members of Mesopotamia were interviewed

Table 1. List of interview participants, including approximate age, number of fields (size between 0.1 and 1.5 acre – 0.04 and 0.6 ha), and farming experience in years.

Interviewees				
ID	Gender	Age (approximate)	No. of fields	Farming experience
I1	Female	Early 40s	3	5–6 years
I2	Female	Late 40s	3	8 years
I3	Female	Late 20s	3	5 years
I4	Female	Early 30s	6	5 years
I5	Female	Late 30s	3	8 years
I6	Female	Late 20s	4	6 years
I7	Female	Late 30s	4	13 years
I8	Female	Early 50s	8	15 years

to determine their agricultural knowledge and management choices. The eight women varied in age and experience (Table 1), capturing a broad spectrum of views and knowledge. The semi-structured interviews used open questions to determine what knowledge female farmers had about the effects of fertilizers on crops and soil, where they obtained this information, and the degree to which and with whom they shared this knowledge. A structured questionnaire was used for the interviews to gather complementary and comparable information on the women's knowledge and views. There were two themes incorporated in the interviews: fertilizer use and information gathering and use. The questionnaire can be found in the Supplement of this article, Supplement S1. The interviews were conducted with the assistance of an interview guide, including an introduction, opening questions, key questions, and a summary (adapted from Woodhouse, 1998; Curry, 2015a).

In addition to the interviews, two focus group discussions (FGDs) were held with members of the Mesopotamia group. One focus group discussion was held with six female participants and another with 11 participants, 6 women and 5 men. A women's only discussion was held with the six women participating to go more in depth into the knowledge of women, given that the aim of our study is to focus on female farmers as a group in its own right. The focus group discussions were based on questions used in the interviews and the methodology proposed by Curry (2015b), Krueger and Casey (2002), and Johnson and Mayoux (1998), which may be found in the Supplement of this article (Supplement S2). 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 ended with a short sum-

mary by the discussion leader. Due to the open platform and the presence of multiple participants, the focus group discussions provided more in-depth answers and clarification to support and complement the information from the interviews.

2.2 Laboratory analyses and data processing

The soil samples were analyzed to determine how soil nutrient contents were influenced by the management choices of the female farmers. Water extracts of the soil samples were created (ratio of 1 : 2.5) and used to determine pH and electrical conductivity (EC). These water extracts were then filtered, and available P, K, S, Ca, and Mg were measured using a Perkin Elmer Optima 8000 ICP-OES Spectrometer. Available NH_4^+ , NO_3^- , 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 was 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 of BaCl_2 , 0.125 M, and 4 g of a sieved and milled soil sample (<2 mm). The cation exchange capacity (CEC) was calculated as the sum of the values for exchangeable Ca, Mg, K, and Na (in $\text{cmol}_c \text{ kg}^{-1}$).

Total C and N were determined with 50 mg of soil (<2 mm, 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 of soil (<2 mm, milled), 6 mL of HCl 37%, and 2 mL of HNO_3 and underwent microwave destruction (60 min; T_{max} of 220 °C; P_{max} of 75 bar). 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 s).

Variance within each field and between fields with different management practices was determined using an analysis of variance (ANOVA) test. ANOVA was used in the case of normal data distribution, and the Kruskal–Wallis test was used 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 were supported by the results of the interviews and focus group discussions.

3 Results

3.1 Interviews

While the interviews started with investigating the typical daily activities, these turned out to vary too much from

person to person and season to season to provide a meaningful clustering. The interviews did show that a range of agricultural management practices are known and practiced within the Mesopotamia group. Specifically, 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. Of the interviewees, two knew no other methods aside fertilization for improving the soil, three named mulching, four mentioned fallow periods, and four mentioned crop rotation. Three of the women found that they were limited in choice of management practice due to their socioeconomic circumstances. For example, for these 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 lack of fallow periods combined with intense agriculture puts pressure on the land, which can lead to increased erosion and may result in diminished soil nutrient content and yield (KNBS/AWSC, 2014).

Fertilizer use is mostly in the form of locally produced or homemade compost (four of eight interviewees) or the use of unprocessed cow manure (two of eight interviewees). The other two interviewees used either mineral fertilizer or cow manure with occasional application of mineral fertilizer. All interviewees named fertilizer as something that the soil needs for growing crops, but none really knew what fertilizer does for the soil in technical terms. The women indicated that their knowledge regarding the effects of fertilizer is limited to visible effects only. One explained that she fertilizes when the plants wilt slightly and the leaves start to yellow specifically. Six of the interviewees explained that they add extra fertilizer when their yields go down or when the plants grow less vigorously than usual, but two of these also mentioned other possible ways to increase production, like crop rotation or fallow periods. The agricultural information sources named during the interviews were relatives, including parents, grandparents, or husbands; training by NGOs or extension workers; elementary school; and observing others. Information from relatives was most common, being named by five of the interviewees, followed by training by NGOs or extension workers, named by three interviewees. As a 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 NGOs and extension workers. The agricultural knowledge women accumulate over their lifetime thus travels in small family and social circles.

To support the soil analysis, the two farmers, I2 and I7 (Table 1), whose fields were sampled, were interviewed more extensively than the other interviewees. Both farmers have at least 8 years of experience and principally grow kale. Both farmers use manure from cows and chicken mixed with organic waste. The farmer using only manure, I7, applies manure by plowing it into the soil at time of planting and then

applies manure again every 4–12 weeks as she feels necessary. The farmer practicing intercropping, I2, 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 are removed after 2 weeks to make room for the kale to grow. Both farmers plow using a hand-held tool, reaching a depth of approximately 20 cm. Farmer I7 weeds and plows her field every 10 d, whereas farmer I2 weeds every 14 d and plows her fields only every 26 weeks. In the fields of farmer I7, kale was grown in both 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. Both farmers I2 and I7 use occasional fallow periods lasting between 3 and 6 months. Farmer I2 using intercropping started this practice in 2013 and has been using it ever since. Farmer I7, using manure application only, has been applying this practice for at least 5 years.

Both farmers had training by different NGOs and extension officers and incorporated this into their agricultural management, which led them to decide to use different practices. Farmer I2 indicated, however, that knowledge is often quickly forgotten due to a combined lack of use by the farmers and a lack of follow-up visits from the NGOs and extension officers. This was reflected by her own adaptation of the intercropping technique. She indicated that she relies on observation of her crops and experience to determine if fertilizer is required. As her crops continue to grow well, she did not feel the need to change her practices by plowing the cowpeas into the soil, which they call green manuring, or changing her fertilization practices. The farmer only using manure, I7, learned about the use of manure and creating compost from an NGO. She indicated that using manure is better than leaving the land fallow, as her crops continue to do well. The details of the sampled fields in terms of crops and management practices are provided in Table 2.

3.2 Focus group discussions

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 of income. They feel that their gender puts them at a disadvantage, as they feel that there is a lack of mutual understanding between the men and women of the group and that the men have a tendency to refuse to share resources with them. They believe that it would help if there would be at least one woman on the groups' board and that this would lead to more equal distribution of resources among the group members, such as fertilizers received from a local NGO. There are some limitations on the women's activity due to cultural restrictions, but not all of them are still actively followed. One limitation explicitly named during the women-only FGD still followed is the prohibition for women

to plant and own trees. Banana trees, for example, can bring in higher profits than some other crops.

Much of the information from the interviews was confirmed in the focus group discussions. The exceptions were as follows. Although the types of fertilizers named during the FGD were mostly the same as those in the interviews, during the mixed FGD more of those responding appear to be using a form of mineral fertilizer. This discrepancy may be due to the inclusion of men in this FGD. It also became apparent during the mixed FGD that the farmers have knowledge of the way to work intercropping in a manner that can add N to the soil, in contrast to what was revealed from the interviews, but that they have a different name for this method: green manuring. During both FGDs and the interviews it was revealed that the management of the farms is largely reactionary. Decisions regarding using one of the various methods to restore soil fertility are undertaken only when the crops seem to do less well than previous crops.

While mineral fertilizers seem to be used more than inferred from the interviews, the participants of the FGDs show a preference for organic types of fertilizer. According to the Mesopotamia farmers, vegetables grown with organic fertilizers taste better and keep longer, whereas mineral fertilizer is reported to damage the soil.

When asked about the sources of agricultural information the participants of the mixed FGD named five different sources. All ranked family as the first and most important source, followed by training and demonstrations. Observation and visiting others was ranked third. Media and exhibitions were ranked fourth and fifth, respectively, and the farmers indicated that this is because of their lack of access to media and the expenses involved in visiting exhibitions. This may indicate that accessibility remains a problem for these farmers, even though there are more and closer sources of information on agricultural management in the urban environment.

3.3 Soil analysis

Intercropping is done by four of the women in the Mesopotamia group, mainly with cowpeas. Theoretically intercropping should improve soil nutrient content, specifically soil N content. However, the intercropping technique is not always applied in a way that would accomplish this: the cowpeas are harvested and not plowed into the soil. Plowing the cowpeas into the soil is needed for the nutrients accumulated to become available to other crops (Okalebo, 2009). The women also use intercropping to prevent soil erosion, while the main crop, 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.

The sampled soil was analyzed for its nutrient content and overall fell within the ranking "high" by FAO standards (FAO, 2006). Table 3 provides the average values of the main soil parameters for all four sampled fields as well as those pa-

Table 2. Details on the two farmers whose fields were sampled, with a description of their crops and agricultural management practice.

	Field type 1: manure		Field type 2: intercropping and manure	
Farmer	17, late 30s, 13 years of farming experience. Management practice established in 2011.		12, late 40s, 8 years of farming experience. Has practiced intercropping since 2013.	
	Field 1	Field 2	Field 1	Field 2
Crops	Kale: coverage 80 %, average height 45 cm	Kale: coverage 85 %, average height 90 cm	Kale, intercropped with cowpeas: coverage 60 %, average height 50 cm	Kale, intercropped with cowpeas: coverage 65 %, average height 60 cm
Agricultural management practice				
Planting	Kale (6 weeks)	Kale (28 weeks): some of it was removed and new kale (1 week) was planted in between.	– Kale (11 weeks) – Cowpeas (4 weeks)	
Fertilization	Compost from manure (cow, goat, sheep) and organic waste; applied with planting (6 weeks)	Compost from manure (cow, goat, sheep) and organic waste; applied with planting (28 weeks) and twice after (16 and 4 weeks)	– Compost from manure (cow, chicken) and organic waste; applied as topdressing after planting (9 weeks). – Intercropping: cowpea seeds were spread randomly (broadcasting), and most cowpea plants were removed from the fields 2 weeks after planting	
Plowing	Every 10d		Every 26 weeks	
Weeding	Every 10d		Every 14d	

rameters separated per management practice. The pH of the soil in the sampled fields ranged from neutral to very slightly alkaline, with an overall average of 7.3 (Table 3). The CEC was high overall, with an average value of $34.0 \text{ cmol}_c \text{ kg}^{-1}$, likely as a consequence of the high clay content of the soil (Table 3). 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.

In the case of manure application combined with intercropping, the pH was neutral, whereas in the case of only manure application, the pH leaned towards being very slightly alkaline (FAO, 2006). The CEC was nearly $10 \text{ cmol}_c \text{ kg}^{-1}$ 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). There was no significant difference in soil organic carbon content between the intercropped and the manured fields (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 (Figs. 1 and 2).

Figure 1a, b, and c 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, e, and f show the proportion of the total amount of Mg, Ca, and K in the soil that is water-soluble or exchangeable. It is notable that under the practice of manure application combined with intercropping, the average exchangeable fraction for Mg and Ca and the average water-soluble fraction for Ca were higher even though the absolute amounts are higher under manuring only (Fig. 1). The Kruskal–Wallis and ANOVA tests showed that all the described differences between the fields and between the management practices were significant for these characteristics at a confidence interval of 95 %.

4 Discussion

Results of the sample analysis of the soil of the urban gardens in Nyalenda show a pattern consistent with the soil typology. The soils in the Nyalenda urban gardens can be classified as Vertisols (FAO, 2006, 2014). Vertisols are generally fertile and productive soils, high in Ca, K, and Mg but often poor in N and P (FAO, 2006, 2014). Soil analysis has shown that the rating for exchangeable Ca and K was very high and that the rating for Mg was high according to the FAO classification (Table 3; Fig. 1; FAO, 2014). The high amount 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 Great 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 socioeconomic factors determine how likely it is that scientific findings and developments 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 center of Kisumu has since spread to that area, effectively changing the gardens environs from rural to urban. However, the extension of the urban environment has not led to greater accessibility to information for the farmers that now live in the informal settlements of the city. Information from media and exhibitions was considered to be too costly for the farmers in this study.

When asked to name and rank their primary sources of information, all farmers of the Mesopotamia group indicated a preference for inherited knowledge, followed by training and demonstrations. Information from television or the internet has less of an 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. So even though the number of information sources is higher in the urban environment, the access to these sources remains a challenge for the female farmers in Nyalenda that were part of the present study.

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 to rotate crops 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. Knowledge is mainly passed down from previous generations or disseminates through observation of other farmers in the group or community. As such, agricultural knowledge generally stays within the confines of family and community groups within the urban gardens in sub-Saharan Africa (SSA) and does not travel far from its point of origin (Alunga and William, 2004; Kabira, 2007).

In Nyalenda, a context where poverty is widespread, agricultural management and decisions are heavily influenced by socioeconomic constraints. These constraints can work against sustainable farming practices. For example, the farmers explained that they took up intercropping with cowpeas originally because they were told that they needed to increase N in the soil by government extension workers. Analysis of the soil samples showed that the soil nutrient content is significantly lower when the kale is intercropped with cowpeas, while Mg and Ca showed a higher availability or are more

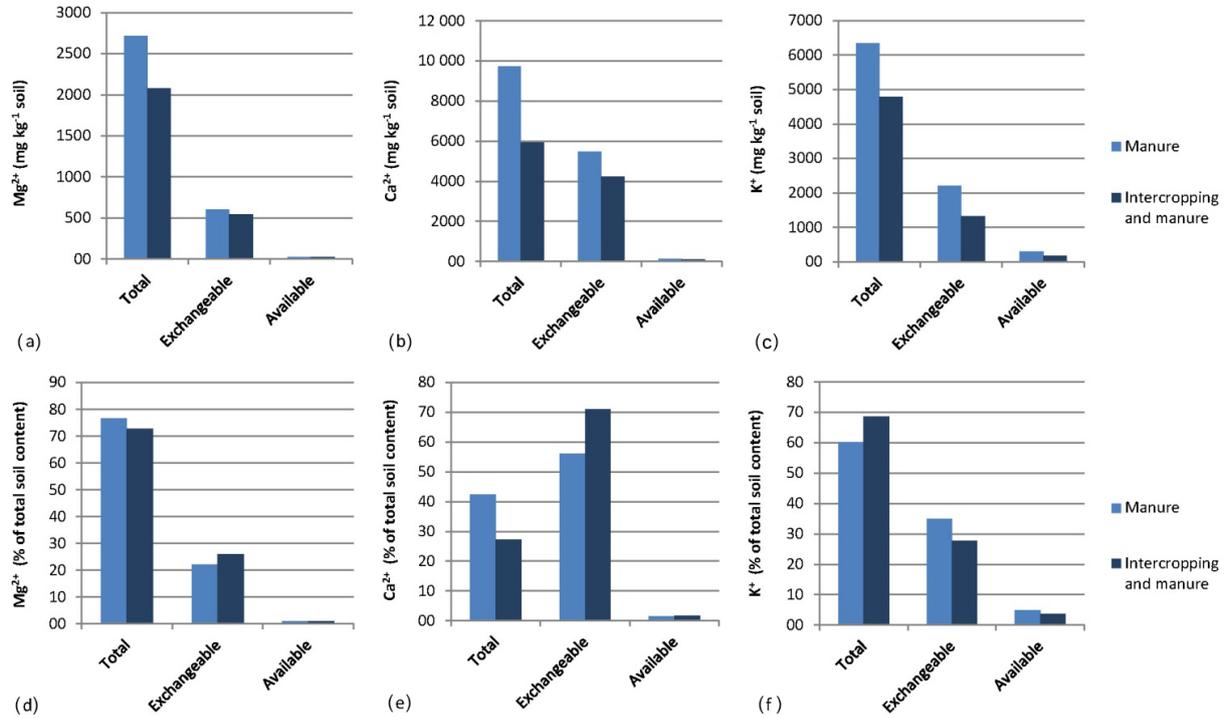


Figure 1. (a, b, c) Bars length show the total, exchangeable, and plant available / water-soluble amount of Mg, Ca, and K (in mg kg⁻¹ soil) under management practices of manure and intercropping and manure. (d, e, f) Total, exchangeable, and plant available / water-soluble Mg, Ca, and K in the soil as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

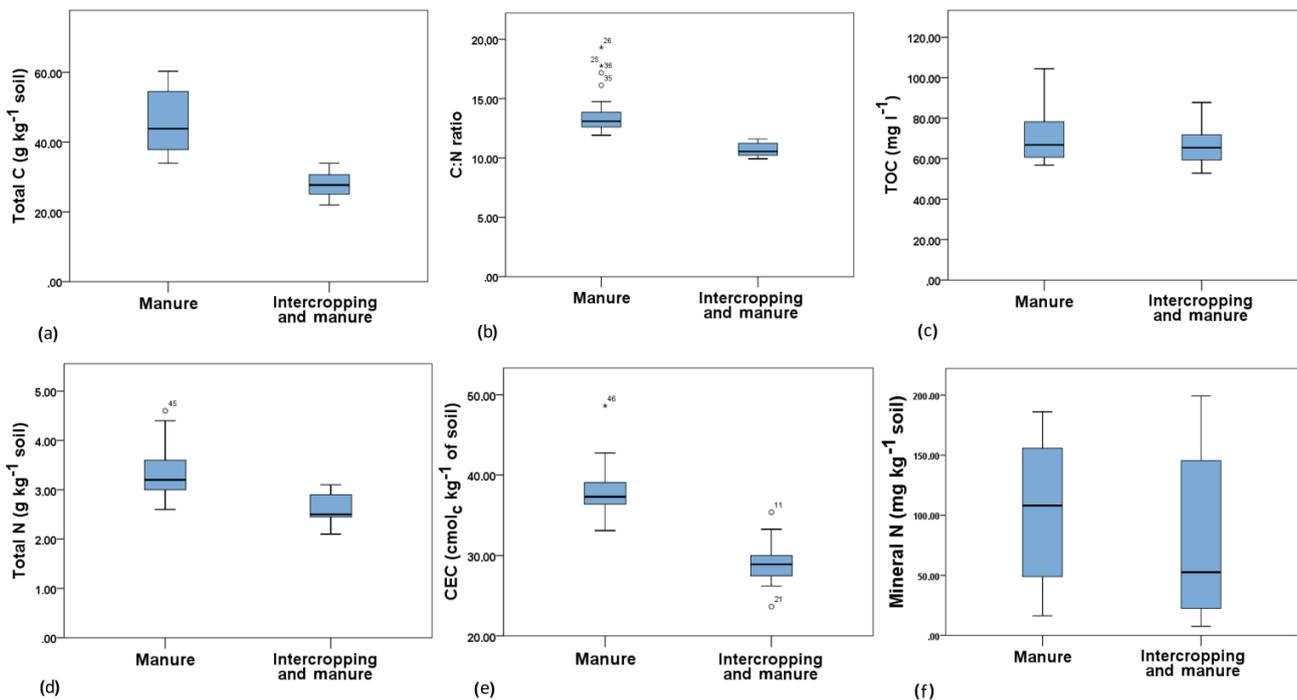


Figure 2. Boxplots showing the differences between (a) total C (g kg⁻¹ soil), (b) C/N ratio, (c) total organic C in the extracts (mg L⁻¹), (d) total N (g kg⁻¹ soil), (e) cation exchange capacity (CEC in cmol_c kg⁻¹), and (f) mineral N (mg kg⁻¹ soil) for the agricultural management practices of manure and intercropping and manure.

Table 3. Average pH; total C and N (g kg^{-1}); exchangeable Mg, Ca, K, and Na (mg kg^{-1}); CEC ($\text{cmol}_c \text{kg}^{-1}$); and water-soluble ions NO_3^- , NH_4^+ , PO_4^- , and SO_4^{2-} (mg kg^{-1}) in the soil of Nyalanda field site overall for fields with manure application only and for fields with intercropping and manure application. Standard deviations in parenthesis (0–15 cm depth and four fields, with 12 samples per field; $n = 48$).

	pH	C	N	Mg	Ca	K	CEC	NO_3^-	NH_4^+	PO_4^-	SO_4^{2-}
	–	g kg^{-1}		mg kg^{-1}			$\text{cmol}_c \text{kg}^{-1}$	mg kg^{-1}			
Overall average	7.3 (0.2)	36.6 (11.0)	2.8 (0.4)	572.6 (89.2)	4842.1 (761.2)	1768.4 (879.2)	34.0 (5.4)	85.5 (62.7)	5.9 (3.7)	24.0 (15.6)	59.0 (44.5)
Manure only	7.3 (0.16)	45.3 (8.9)	3.13 (0.3)	603.6 (102)	5467.8 (467.9)	2210.5 (1056)	38.6 (3.2)	96.7 (56.9)	6.7 (4.9)	31.2 (18.3)	84.1 (56.9)
Intercropping and manure	7.1 (0.2)	27.9 (3.4)	2.6 (0.3)	541.7 (60)	4216.3 (395.9)	1326.3 (200)	29.5 (2.4)	74.3 (66.3)	5.0 (1.4)	16.9 (6.9)	33.9 (10.3)

readily exchangeable (Table 3; Figs. 1 and 2). 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 for applying manure. The farmer who uses intercropping, I2, applies the manure as a topdressing only. The farmer who does not practice intercropping, I7, plows the manure into the field. Plowing the manure into the field preserves N and promotes the biological breakdown of the manure, which increases the availability of the nutrients therein. Plowing also results in greater contact between the soil mineral matrix and the organic matter; this promotes the stabilization of organic matter through binding to soil minerals and/or occlusion in soil aggregates (Baligar, 2001). The increased stabilization of organic matter in the soil could in turn have caused the significantly higher CEC in the fields of farmer I7. The decrease in soil nutrients in intercropped fields (Fig. 1) was most likely caused by not plowing the cowpeas into the soil in combination with the different manuring practice (Okalebo, 2009). However, factors such as a difference in initial soil composition between the intercropped and non-intercropped fields prior to the adoption of intercropping may also have influenced the observed difference. Therefore, the observed differences must be interpreted with caution. Nevertheless, we feel that we can conclude that 3 years of intercropping did not increase nutrient contents, as was the original purpose of adopting the practice.

The interviews shed light on why the practice of intercropping is still continued if it does not lead to increased nutrient contents. Specifically, the interviews revealed that there is a sufficiently large financial incentive for the farmers to not change their current practice and that the farmers rely heavily on visible cues when deciding to apply a different practice or more fertilizer. So as long as the practice does not visibly

influence the crops, farmers will not feel an urge to shift to another form of agricultural management. As the soil in the Nyalanda urban gardens is particularly rich (Table 3), it is not likely that there will be a need for a large-scale adaptation.

During the interviews it furthermore became clear that the farmers are harvesting the cowpeas for sale instead of plowing the cowpeas into the fields. Harvesting the cowpeas means a greater uptake in 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 kale is mature, and the advantage of doing so is more readily apparent to farmers than a potential increase in N in the soil. This shows that the lack of an effect of intercropping on soil N contents in the examined soils is most likely not caused by a lack of female 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.

5 Conclusions

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, there is a statistically significant difference between soil nutrient contents and availability between similar plots after 5 years of manuring only and 3 years of manuring and intercropping with cowpeas. While nutrient contents are slightly lower in the intercropped plots, exchangeable nutrients Ca and Mg are slightly higher. The growing of the cowpeas beside the kale might be causing a more rapid extraction of nutrients from the soil. However, other factors may also play a role, such as a different initial soil composition. Another difference between the practices of the two farmers whose fields were sampled was the fertilization scheme. The farmer that intercropped applied her manure as a topdressing, while the other

farmer plowed the manure into the soil. This too could have led to a difference in the total amount and availability of nutrients in the soil. Further research needs to be done to determine which of the two practices has the greater impact on soil nutrients: intercropping or the fertilization method.

Nevertheless, even allowing for such other factors, the absence of any sign of increased nutrient content in the intercropped fields is remarkable, given that growing cowpeas and plowing them into the soil should drastically increase soil N content. An explanation for this absence of an observed effect is that the intercropping farmer sold the cowpeas on the market rather than plowing them into the soil. It is likely that the farmer originally took up intercropping to increase soil N after the advice from the visiting extension workers. However, she, at some point, changed her practice to make use of the opportunity that harvesting the cowpeas offered her in terms of additional income. It is unclear when or why exactly she changed her practice, but it is likely that this was financially motivated. Due to the originally rich soil in the Nyalenda urban gardens, the farmer also saw no noticeable reduction in yield while intercropping.

The interviews and FGDs with the Mesopotamia group showed that there is knowledge present on a wide range of agricultural management practices. However, the interviews with the individual female members of the group showed that the knowledge on these practices is unequally distributed and that, while they may know of 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 as well as their lack of access to alternative sources such as the internet. Further research is needed to confirm this conclusion.

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's decisions in agricultural management are influenced by their socioeconomic and cultural status. Training should be adapted to take the socioeconomic 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 given training or agricultural recommendations.

Data availability. Additional soil chemical data are available and can be found in the Supplement of this article. Any additional data from the interviews or focus group discussions can be requested through the corresponding author.

Supplement. The supplement related to this article is available online at: <https://doi.org/10.5194/soil-5-303-2019-supplement>.

Author contributions. NTJ suggested the study and contributed to the data analysis. EK contributed the soil data and the interview and focus group discussion data. KK, BJ, and NP contributed to the data analysis and background data on soil and social sciences.

Competing interests. The authors declare that they have no conflict of interest.

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