Contents

Response Reviewer 1:

We would like to thank the reviewer for taking the time to read and review our manuscript. Below we have given response to the different comments.

p.5 L. 40: introduce the abbreviation FGD in the paragraph above. To make understanding easier, use mixed FGD, women FGD, both FGDs. As it is now, it is still a bit confusing, which information is derived from where.

We received a similar comment from the other reviewer. We have introduced the abbreviation FGD in the methods in this revision (P4, L23) and have changed the relevant paragraphs to show more clearly which information came from which focus group discussion (mixed or women-only) (Paragraphs 1 and 2, Page 7). We hope that this alleviates the confusion created.

p. 9 L 37. To which information do the references point to? That knowledge passed down from previous generations does not travel far in general, or are the references specific for the Nyelenda group? Please specify: e.g. It was also shown by ..., that

We see how the term knowledge is too vague and have specified the type of knowledge. We have also specified that this concerns specifically the situation found in the urban gardens in SSA (P11, L10-11).

Three questions you could include for better understanding:
1. Why did government extension recommend intercropping for increasing soil N, although the soil is rich in nutrients?

Nutrient recommendations are soil and crop specific, so while a soil may not have enough nitrogen to support the growing of maize, it can support the growth of cabbages or other leafy vegetables. The government extension workers may have made their recommendation based on what was being grown at the time on some of the fields, or on the request of a farmer in the group that would like to grow maize, or based on the comparison of soil analysis results to a standard they are supplied with by the county agricultural office. This is unfortunately something we cannot determine with certainty and also, in our view, does not fall entirely within the scope of our manuscript. As such have not included it in the manuscript.

2. Can you make conclusions on the practice of intercropping cowpeas and selling the crop, also? Is this practice recommendable, or does it decrease soil nutrients too much? Or is there more research needed, especially also on the effect of not incorporating the manure thoroughly?

To have more certainty as to the long term effects of the current practice, especially in concurrence with the fertilization practice, more research is needed. We have included this in our conclusions (P13, L11-12). Due to the natural richness of the soils under study, the current practice is not depleting the soil much faster, and more importantly not impacting the yield or crop quality noticeably. We have included a section in the revised manuscript in which this is mentioned (P6, L30-34). Whether the practice can really be recommended would need a close consideration of both the environmental and financial aspects.

3. What is the main benefit of the soil analysis for the understanding of the interview and FGD results? How would you propose to use the combination of soil analysis and farmer interviews in future (bigger) studies?

The results of the soil analysis help to understand if changes in agricultural practice (i.e. the implementation of intercropping) have an actual influence on the soil nutrient content. The interviews and FGD alone would not have shown that intercropping as it is currently practiced removes more nutrients from the soil than growing only kales.

Also, during the initial field work it was assumed the farmers were practicing intercropping by ploughing the cowpeas into the soil. If only the soil analysis results would have been used without the interviews and the FGD, the conclusion might have been drawn that the technique is ineffective. In this study the two (types of) methods supported one another and led to a more holistic view of the situation.

In future studies similar methods can help scientists develop more suitable agricultural practices, which take into account the socio-economic circumstances of the farmers. As the same time, a larger study can also more easily involve the farmers; this would give the farmers more ownership of both the collected data and the developed agricultural practices. This increase in ownership is likely to increase the likelihood of uptake and implementation of newly developed agricultural practices.

We would again like to thank the reviewer reviewing our manuscript and giving thoughtful comments and questions based thereon.

Response Reviewer 2:

First of all we would like to thank the reviewer for again taking the time to go through the manuscript so thoroughly and highlighting the weaknesses. We hope that this time we are able to more fully address these issues raised to satisfaction.

The article improved considerably concerning structure, however, there are still some language issues; especially on the first two pages.

We are sorry to hear about the language issues, though happy to hear that the structure has improved. To prevent more language issues we had our manuscript checked by a native language speaker before submission this round.

More important, unfortunately concerning the content the article still remains limited in scope and some more input regarding the information gathered during the interviews would be necessary in order to show that the conclusions drawn are based on the field work. The main aims of the paper to understand "what knowledge women working in urban agriculture have on agricultural practices, and how their practices affect their soil" (p.3, L8-9), & "we aimed to determine how the agricultural knowledge and motivations of women farmers influences their soil' nutrients status" remain so far only sufficiently answered, as no detailed profiles of the two women concerned, their knowledge and their motivations and how they differ are given. Furthermore, the differences in management practices are described very superficial, which makes it almost impossible to say whether the differences in soil properties come from the management practices or rather from the long-term use history or the baseline conditions of the soil.

We have tried to limit the scope in the previous version as per the reviewer's suggestions. However, this was clearly not extensive enough. We did include more information on the interviews and focus group discussions in the previous version as requested, however these were added mostly in the supplements and therefore not immediately clear. We moved more of the information to the main text now and expanded it even further in an attempt to accommodate the reviewer's suggestions as much as possible. Below we have indicated where one may find the specific information connected to all specific comments of the reviewer. In some cases we were unable to fulfill the request as the data was not available. This is also indicated below, and has now been explicitly mentioned in the text as well.

1, Concerning the aim of the paper focusing on women knowledge and practices and how it differs from men's knowledge few new insights seem to have been generated through the research, the only reference found with regards to this is that the FGD including men mentioned some other information sources (not clear however whether this statement came for a men) and maybe have better access to mineral fertilizer (?). The study does not present in how far the practices of women really differ from that of men in the case study, here the results from FGDs should be presented in more details.

While it was our intent to focus on women's knowledge, it was not our intent to directly compare it with men's knowledge; this is outside the scope of this article and this research. As such, in the previous

resubmission we attempted to remove any sections that might have given the impression that a comparison between men and women was an aim of our study. It was in the mixed focus group discussions that mineral fertilizers were named more often as a tool and in interviews with the women they indicated that men often keep resources for themselves rather than sharing equally, this led to the conclusion that mineral fertilizers are used more often by men (P7, L14-L16). We have rewritten the section on the focus group discussions which will hopefully give a clearer picture of the information gained and from whom the information came. In addition, we have now indicated even more explicitly that a comparison between men and women was not an aim in itself (P3, L16-17).

2, Little effort can be seen to understand the reasons for the two women to decide for the different strategies. So it becomes difficult to understand the decision processes. I cannot see where "the study showed that women are influenced by their socio-economic and cultural statues when making decisions in agricultural management" /p11, L3&4, the detailed reasons are not presented; we do not get any information about why the two women use different approaches. The results of the interviews should present the differences (and or similarities) between the two women for which the soils were sampled.

E.g. How old are the two women, how many people do they have to take care of, what are their specific sources of information, for how long have the practiced the soil management practice, why do they do so. What does the women using intercropping say about the soil fertility on her field? Is she aware of the problem of removing the cowpeas? Or is she simply so far happy with the soil fertility = no need to leave the cowpeas on the field (this should also be discussed in relation to the soil analysis, e.g. would the soil analysis suggest that she would need to fertilize her field or are the values still high enough, making fertilizer use unnecessary) Other examples in this regard:

- p3, L31: here it would be interesting to understand who changed strategies, and why.

We agree in hindsight that in our attempt at conciseness we included too little information on the two women whose fields we sampled in the previous resubmission. We have corrected this by including a table with information that should allow for a clearer overview and easy comparison (P7, table 2) as well as a more in-depth exploration of their specific interviews including the women's view on their practices and its results (P6, L27-35). More specifically, the table includes information on the women's agricultural management, their experience and crop coverage in the fields sampled. Some of the requested information, such as family size, we could not provide.

We believe the influence of the socio-economic circumstances is demonstrated by the continued intercropping with cowpeas for financial reasons, but may not have linked this clear enough in the text. The cultural limitations for women were shown through the context (P2, L24-37) and the results of the focus group discussions (P7, L11-12), but also here we could have marked these results more clearly in the relevant section. We have corrected that in this new version of the manuscript.

3, The potential and the real impact of the two applied strategies is impossible to discuss, based on only rough qualitative description. The article does not give quantitative information concerning the amount of manure that is applied on the fields, the spacing of the cowpeas, the time that the practices have been different and so on. Or

e.g. on understanding the long-term history of the field. While it is mentioned that one of the fields was left fallow the year before, one was planted with maize and two with kales, the information from one year alone does not really help.

The study could furthermore discuss which kind of input is probably provided through the kind of manure applied and how this differs from the input that cowpeas could bring (even if they are harvested… at least in case the root are left in the soil.

The potential reasons for the differences in CEC should be discussed.

We agree that it is difficult to draw firm conclusions on some of the data provided. For the most part we were forced to rely on qualitative descriptions as these farmers do not keep track of their inputs and the study was too short a duration to track these ourselves. Wherever data was available, such as the coverage of the vegetables per field, it can now be found in the data table added on page 7 of the manuscript or in the text on page 6, L15-25. The limitations of the study are now more clearly discussed in the manuscript (P11, L29-34) and the conclusions have been amended to better reflect the limitations of the study as well (P13, L7-12). A potential reasons for the higher CEC is included in the discussion (P11, L21-28)

5, As the findings might be too limited in answering the research question, the focus could move to a closer description on the findings that could be achieved (the FGD in more depth, the interview analysis in more depth (e.g. the daily strategies at least of the two women….).

We hope that with the revision of the manuscript and the inclusion of the additional data as described in the comments above we have provided this shift of focus.

Some other specific points:

P.2, Paragraph 3: it is not clear which of the information given (sources cited) refer to Kisumu specifically and which ones talk about women (in which countries?) in general.

We expanded the text of this paragraph and moved several references to make it more clear which sources cover which location/area.

P3, L1: Reference SAITO is missing, Is SAITO referring to Kenya, Kisumu, the World?

We are grateful the reviewer pointed this oversight out. We have added the reference to the list and specified in text what area was covered by the research.

P.3, L 10-13: should rather be moved to the methods part.

We have moved all information in this paragraph that is related to the description of the field sites to the methods (P3, L19-24).

P3, L 20 “of” is missing “one OF the” (there are more language mistakes in the text, this is just one example)

Thank you for pointing out this error. As mentioned above, we arranged to have a native speaker check the manuscript before re-submission to ensure these errors are removed.

P.5, L11: Why do you talk about “Some” Women. Given the sentence just before it would make sense to give the concrete number here. IN general, the information about the constraints reported could best be presented in table form (constraint and number of times mentioned)

We understand and appreciate the need for numbers that are as exact as possible. At the named instance we have now included a specific number (P5, L32-33). We attempted to construct a table as requested, but had to conclude that the data was too limited for this. Therefore, we did include it in the body text and more clearly and explicitly addressed this issue there. In line with this, we also more clearly expressed the limitations of the study in the discussion and conclusion (see our response to the previous comments of the reviewer).

Like on P5 the information sources and the differences between men and women e.g. Sources of information Number of times mentioned by women Number of times mentioned by men Radio

As we indicated previously, the focus of our manuscript explicitly does not lie on a gender comparison. We have altered the text to explain this more clearly (see our response to the previous comments of the reviewer).

P5 L 15-16: Sentence a bit strange and not really useful here.

The sentence was amended in its present form based on a request of the other reviewer in the previous round. We have attempted to rephrase it.

P5, L21: Bring examples on how you concluded that the knowledge is limited to visible effects?

This was directly indicated by 6 of the 8 women during the interviews. During 7 of the 8 interviews it was indicated that they did not know how fertilizers work or what they do in the soil and that they just know that it helps their crops to grow. The one interviewee that did have some knowledge only had a rudimentary understanding of the working of fertilizers. We have altered the indicated section to reflect this more closely (P6, L1-3).

P5, L34: which resources? Where do they come from?

We have added an example that was named during the focus group discussion to clarify (P7, L7-8).

P5, L35f: mention all the cultural restrictions that were mentioned and which ones are still followed and how they impact on soil management practices.

All examples mentioned in the focus group discussions are already present in the text. We have now explicitly mentioned this fact in the text (P7, L9-11).

P5, L 38: consider deleting the last half sentence.

We deleted it as requested.

P6, L1: discrepancy: a pity you can't say more

We agree that this is unfortunate, however the limitations of the study, which we now more explicitly delineate, indeed prevent further elaboration.

P6, L25-34: why do they use different practices? (+ this part does not really belong to the soil analysis, but rather to the interviews)

We have moved this section and amended it as requested. Some more information on where the practices come from may be found on page 6 (L27-35)

P9, L19-23: this paragraph should rather be moved to the introduction

Moved to introduction, incorporated into paragraph 4, page 2 (continues on page 3)

P9, L24-29: here it should rather be discussed whether differences between men and women could be found or not and to which extent and what can be learned out of that. E.g. are there really important differences in knowledge between men and women? Yes or no, this should be discussed here.

As mentioned before, it was not within the scope of this study or article to make a comparison between men and women.

P9, L38-43 Reasoning in this paragraph is wrong, as the example given doesn't provide evidence for the claim that decisions are heavily influenced by socio-economic constraints. Here it would be better to enter the information given p10, L14-22 which gives at least one socio-economic reason. Again it would be interesting to know whether famers are aware of the fact that harvesting reduces the positive effect of the intercropping.

Upon re-reading we agree that the current example is suboptimal. We replaced it with a better one (P11, L16-21).

P. 10 L 1-10, might in parts better be moved to chapter 3.3

We understand that some parts of this paragraph could be interpreted as a result and have attempted to correct this by removing some of these statements. Any remaining statements were kept in the paragraph to preserve the flow of the argument (P11, Paragraph 2).

P10: L8 and 9 Numbering of farmers (I2,I7) has not been introduced before. No need to introduce it at the end. See comments above, here it would be interesting to get some information about why one of the farmers is ploughing the manure into the soil and the other doesn't. It would further be interesting to know, what "ploughing" means (3cm, 10cm, 20cm?). .

Numbering has been introduced earlier and with better context (Table 1 on page 4, and paragraph 2, page 6). Ploughing is done by handheld tools that reach an approximate depth of 20 cm; we have included this in the manuscript (P6, L19).

P10, L24-26: Am not convinced that the study could show this. Yes, there are differences, but do they come from this one year of doing either only manure or manure and intercropping? Maybe in the past the management practices have been much more different? Maybe one of the soil samples contained more sand than the other? (Did you measure the clay, loam, soil content?)

We have changed the text to reflect the uncertainty better (P12, L13-18). We do not have multiple year observations and now more clearly indicate that for full quantification it would be necessary to focus on land-use history over longer time-scales. That said, the lack of a positive effect coinciding with the improper use of intercropping (i.e. crops were not ploughed into the soil) do make our observation of a lack of a clear positive effect plausible. In addition, from the interview results we know that the farmer started intercropping in 2013 and has been applying this practice ever since. The fields were sampled in 2016, which means the practice had been going on for 3 years. At the same time the other farmer decided not to adopt te practice, which means the field's treatments started to deviate 3 years ago. The results are the net effect of those three years of different management. This is now more clearly indicated in the text (P6, L23-25).

L26: Is it really the growing of cowpeas that causes a more rapid extraction from the soil? (What is the plantation density?). It could also be that farmer that is only applying manure is simplying applying more manure. I would be careful with such statements.

Due to the inclusion of the cowpeas the fields that are intercropped have a greater plantation density. This information can now also be found in the data table on page 7. However, it is indeed possible that manure amounts and methods may have had a significant effect; we have included this in our discussion (P11, L16-27).

L29-31: Given the scope of the study, it would really make sense here to talk to the farmer again and ask her, why and when she decided to intercrop and what she thinks about the strategy.

The answer is already available in the interview data, but clearly was not made explicit well enough by us in the previous versions. The farmer adopted intercropping with the others that did in 2013 after a visit by local extension workers that advised them to do so. She has kept up the strategy as she has noticed that it gives her financial benefits, in the manner that she currently practices it (P6, L28-33).

P11, L4-6: "The case study showed that women are influenced by their socio-economic and cultural status when making decisions in agricultural management and these decisions may differ from those of men in the same or similar circumstances due to a lack of access to knowledge, contacts, or material and capital." I think it would help a lot, if the authors think about this conclusion and bring together all specific statements (in the interviews and the FGD) that support their conclusion. As said before: what are the specificities of the socio-economic and cultural status of women in Nyalenda that were found during the study and that influence management decisions and how do they differ from that of men and why; which kind of different contacts, access to material and capital

of men could be found on the ground compared with that of women? Please provide us with the kinds of questions you asked during interviews and FGDs

We did include this information in the previous resubmission. However, we had placed it in the supplement for the sake of conciseness. It is clear that we failed to clearly indicate the availability of this information in the main text. We have corrected this and now more clearly and explicitly refer to the additional information in the supplementary material where appropriate in the format that is laid out in the authors guide of SOIL.

We would like to thank the reviewer again for their thorough and clear review of our manuscript. Their contribution has helped us increase the quality of the article.

List of major changes:

- Abstract: revised
- Introduction: moved section from last paragraph to methods chapter
- Methods: inserted table 1: list of interview participants
- Results: inserted table 2: Details on sampled fields and related management practices
- Results: moved paragraph on agricultural practices sampled fields from soil section to interview section
- Results: inserted paragraph elaborating on management practices farmers whose fields were sampled
- Discussion: inserted elaboration on effects of soil management on soil characteristics
- Conclusion: revised first paragraph

Track changes version of the manuscript:

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

Nicolette Tamara R.J.M. Jonkman[1], Esmee D. Kooijman[1], Karsten Kalbitz[2], Nicky R.M. Pouw[3], Boris Jansen[1]

[1] Ecosystem and Landscape Dynamics group, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam, 1090 GE, the Netherlands

[2] Soil Resources and Land Use, Institute of Soil Science and Site Ecology, Technische Universität of Dresden, Tharandt, 01737, Germany

[3] Governance and Inclusive Development Programme Group, Amsterdam Institute for Social Science Research, University of Amsterdam, Amsterdam, 1018 WS, The Netherlands

Correspondence to: Nicolette Tamara Jonkman (N.t.Jonkman@uva.nl)

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Abstract. In Kisumu up to 60% of the inhabitants practices 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,~~ Therefore women's knowledge is pivotal for~~to~~ effective agricultural management. To enhance and better use women's knowledge, gender related social cultural obstacles linked to land ownership, investment, and farm inputs have to be taken into account.~~This means taking into account that women face greater obstacles in land ownership, investment, and farm inputs due to social and cultural constraints as consequence of their gender.~~ We aimed to determine how the agricultural knowledge and motivations of women 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. ~~This case study aimed to better understand the position of women farmers in the urban gardens by determining what agricultural knowledge the women farmers 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. Interviews and focus group discussions were organized in Nyalenda, one of Kisumu's informal settlements where urban gardening is practiced, to determine what knowledge the women farmers possess, and where they acquired their knowledge. Soils were sampled at the site 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 to determine how the agricultural management practice influences soil nutrient content: applying 1) ~~applying~~ manure only, and: 2) ~~applying~~ manure while intercropping with cowpeas~~ to determine how the agricultural management practice influences soil nutrient content~~. 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~~ing led to~~ fields contained significantly lower total soil nutrients ~~contents~~ than~~-~~ fields where~~n~~ only manure was applied. While theoretically intercropping with a legume such as cowpeas should increase soil N content, due to socio-economic factors, such as poverty, intercropping was applied in a way that did

not increase soil nutrient contents; rather it diversified revenue ~~for the women farmers~~. The knowledge of the women farmers ~~female vegetable growers~~ 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, ~~in addition to~~ socio-economic conditions and cultural context, as well as gendered knowledge differentiation has to be acknowledged ~~and used in agricultural training, when aiming to improve soil nutrient status and agricultural yields.~~

Keywords: Agricultural management, ~~women in agriculture~~gender and knowledge, urban agriculture, urban horticulture, soil nutrient content

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 activities 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 have faded. The agricultural areas were~~have~~ fragmented and now fall within the municipal boundary.~~,~~ A~~a~~s 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 is female, and that on average ~~the~~ 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~~watching any~~ children and elderly people. As urban agriculture sites in most sub-Saharan cities 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 in Kenya (Kabira, 2007; Kameri-Mbote, 2006; Kiriti-Ng'anga, 2015a; Kiriti-Ng'anga, 2015b) and in Kisumu in particular (Likoko et al., 2019; Mireri, 2013) work on a subsistence basis ~~(Kabira, 2007; Kameri Mbote, 2006; Kiriti Ng'anga, 2015a; Kiriti Ng'anga, 2015b; Likoko et al., 2019; Mireri, 2013)~~ and any excess produce is sold to pay for expenses such as their children's ~~school fees~~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, 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; Likoko et al., 2019). As a consequence of these obstacles, few modern techniques are applied in the urban gardens of sub-Saharan Africa. Lack of access to capital, and 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*).* There is further rResearch by Saito et al., 1994 that 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(Saito et al., 1994). However, there is also research that showsing that due to a lack of education and training, women farmers use practices that are less environmentally friendly due to a lack of education and training, which 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 beare more knowledgeable on agricultural management practices than their rural counterparts. 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). However, wWhen 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.

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. 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, as well as the prevalent soil type and water accessibility at the site itself. The farming group is characteristic for the urban gardening situation that can be found throughout other cities of Kenya and (sub-)tropical Africa in general as well. 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,Therefore, we aimed to determine how the agricultural knowledge and motivations of women farmers working in urban gardens in Kisumu (Kenya) 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 their urban agricultural plots.in the Nyalanda urban gardens. 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 women farmers as an important group in their own right rather than making a comparison with men as farmers.

Materials and Methods

The decision to work with the Mesopotamia group was made after various meetings with partners from a local scientific institution and NGO[1] in conference with the Mesopotamia group itself in January 2016. The Mesopotamia group was 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. ~~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.~~ 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, as well as the prevalent soil type and water accessibility at the site itself. ~~The farming group is characteristic for the urban gardening situation that can be found throughout other cities of Kenya and (sub-)tropical Africa in general as well. 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~~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 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 farming group is characteristic for the urban gardening situation that can be found throughout other cities of Kenya and (sub-) tropical Africa in general.

~~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*) in 2013 (Likoko and Jonkman, 2016).

The research approach 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. 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 70^0C, 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. The two women that own the sampled fields and~~, along with the~~ 6 other female members of Mesopotamia~~,~~ were

[1] Victoria Institute for Research on Environment and Development (VIRED), Centre for African Bio-Entrepreneurship (CABE),

interviewed to determine ~~what~~ their agricultural knowledge ~~they have, where they get their information, and how this influences their~~ 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 women farmers had about the effects of fertilizers on crops and soil, where they ~~received~~ obtained this information, and to what degree and with whom they shared this knowledge. A ~~set list of questions~~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 ~~complete list of questions~~questionnaire can ~~used may~~ be found in the supplement of this article, section 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).

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

Interviewees:				
ID	Gender	Age (approximate)	#/size of fields	Farming experience
I1	female	early 40's	3	5-6 years
I2	female	late 40's	3	8 years
I3	female	late 20's	3	5 years
I4	female	early 30's	6	5 years
I5	female	late 30's	3	8 years
I6	female	late 20's	4	6 years
I7	female	late 30's	4	13 years
I8	female	early 50's	8	15 years

In addition to the interviews, two focus group discussions (FGD) 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, given the aim of our study to focus on women farmers as a group in its own right. 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), ~~which may be found in the supplements of this article.~~ 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 which may be found in the supplements of this article (S2). The discussion was closed with a short summary by the discussion leader. Due to the open platform and the presence of multiple participants, the focus groups discussions provided more in-depth answers and clarifications, which~~to~~ supports and complement the information from the interviews.

2.2 Laboratory analyses and data processing

The ~~analysis of the~~ soil samples were analysed~~is~~ to determine how soil nutrient contents was~~ere~~ 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 electrical conductivity (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_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 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 sieved and 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 an 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. The interviews did show that a range of agricultural management practices is known and practiced within the Mesopotamia group. Specifically, t~~T~~he 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 2 knew no other methods aside fertilization for improving the soil, 3 named mulching, 4 mentioned fallow periods, and 4 mentioned crop rotation. ~~Some 3~~Three of the women found that they were limited in choice of management practice due to their socio-economic circumstances. For example, for ~~many~~ 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 ~~consequence of the~~ lack of fallow periods combined with intense agriculture puts ~~is~~ more 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 (4 of 8) or the use of unprocessed cow manure (2 of 8). The other ~~two~~ 2 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 women indicated that their knowledge regarding the effects of fertilizer is limited to visible effects only. One told that she fertilizes when the plants will wilt slightly and the leaves start to yellow specifically.~~,~~ 6 of the interviewees~~but most~~ told~~l~~ that they add extra fertilizer when their yields go down or when the plants grow less vigorously than usually, but 2 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, 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. The agricultural knowledge women accumulate over their lifetime thus travels in small ~~social and~~ 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~~5~~ years of experience and principally grow kales. Both farmers use manure from cows and chicken mixed with organic waste. The farmer using only ~~the~~ manure, I7, applies manure~~this~~ by ploughing it into the soil at time of planting and then applies manure again every 4-12 weeks as she feels is necessary. ~~The application is ploughed into the soil. Ploughing is done with handheld tool by both farmers reaching a depth of approximately 20 cm.~~ 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 ~~is~~are removed after 2 weeks to make room for the kales to grow.~~-~~ Both farmers plough using a handheld tool, reaching a depth of approximately 20 cm. F~~The f~~armer ~~using manure~~I7 weeds and ploughs her field every 10 days, whereas ~~the intercropping~~ farmer I2 weeds every 14 days and ploughs her fields only every 26 weeks. In the fields of ~~the~~ farmer I7~~that uses only manure~~ kales were grown in ~~the~~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 to 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 five years.

Both farmers have had training by different NGO's and extens~~t~~ion officers and incorporated this in their agricultural management, which has led them to decided to use different practices.~~-~~ F~~The f~~armer I2~~that does intercropping~~ indicates 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 NGO's/extension officers. This is reflected by her own adaptation of the intercropping technique. She indicates that she relies on observation ~~and~~ of her crops and experience to determine if fertilizer is required. As her crops continue to grow well she does not feel the need to change her practice by ploughing the cowpeas into the soil, what 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~~s~~. She indicate~~ds~~ 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.

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

	Field type 1: Manure		Field type 2: Intercropping + Manure	
Farmer	I7, late 30's, 13 years' farming experience. Management practice established since 2011.		I2, late 40's, 8 years' farming experience. Practiced intercropping since 2013.	
	Field 1	Field 2	Field 1	Field 2
Crops	Kales: Coverage 80% Average height 45cm	Kales: Coverage 85% Average height 90cm	Kales, intercropped with cowpeas: Coverage 60% Average height 50 cm	Kales, intercropped with cowpeas: Coverage 65% Average height 60 cm
Agricultural Management Practice				
Planting	Kales (6 weeks)	Kales (28 weeks), Some of them were removed and new kales (1 week) were planted in between.	- Kales (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
Ploughing	Every 10 days		Every 26 weeks
Weeding	Every 10 days		Every 14 days

~~Table 1. Details on the 2 farmers whose fields were sampled with a description of their crops and agricultural management practice.~~

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 do 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 it would help if there would be at least 1 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 ~~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 limitation explicitly named during the women-only FGD ~~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~~.

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, 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~~e~~ FGD. It also became apparent during the mixed FGD ~~, 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, in contrast to what came forward from the interviews~~,~~, but that they have a different name for this method: green manuring. During both FGDs and the interviews it came forward that t~~T~~he management of the farms is largely reactionary. ~~and d~~Decisions 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 previous crops.

While mineral fertilizers seems to be used more than inferred from the interviews, the participants of the FGDs do show a preference for organic types of fertilizer. According to ~~them~~ 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 5 different sources. All ranked family as the first and most important source~~s~~, followed by trainings and demonstrations. Observation and visiting others was~~is~~ ranked third. Media and exhibitions were~~are~~ 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~~while~~ there are more and closer sources of information on agricultural management in the urban environment. ~~, accessibility remains a problem for these farmers.~~

3.3 Soil Analysis

Intercropping is done by 4 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 ploughed into the soil. Ploughing the cowpeas into the soil is needed for the nutrients accumulated to become available for other crops (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.

~~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. Both farmers use 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.~~

The sampled soil was analyzed for its nutrient content, and overall~~, by FAO standards,~~ fell within the ranking 'high', by FAO standards (FAO, 2006). Table 3~~1~~ provides the average values of the main soil parameters for all 4 sampled fields, as well as those parameters 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~~1~~). The CEC was high overall with an average value of 34.0 $cmol_c\ kg^{-1}$, likely as a consequence of the high clay content of the soil (Table 3~~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.

Table 3. Average pH, total C and N (g/kg), exchangeable Mg, Ca, K and Na (mg/kg), CEC ($cmol_c$/kg) and water soluble ions NO_3^-, NH^{4+}, PO_4^- and SO_4^{2-} (mg/kg) 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, 4 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}			$cmol_c$ 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 + 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)

~~**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 NO_3^-, NH^{4+}, PO_4^- and SO_4^{2-} (mg/kg) 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, 4 fields, with 12 samples per field; n=48).**~~

In case of manure application combined with intercropping the pH was neutral, 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. ~~This is difference may be caused by the way intercropping is applied, but may also be caused by the difference in fertilizing the fields, incorporating the fertilizer versus applying it as a topdressing. While theoretically a texture difference is possible the sampled fields did not differ much in texture or structure according to field observations and were in close proximity to one another.~~

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~~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 (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, the average exchangeable fraction ~~was higher~~ for Mg and Ca ~~under intercropping + manuring,~~ and the average water soluble fraction ~~was higher~~ for Ca was higher, ~~under intercropping + manuring~~ even though the absolute amounts are higher under manuring only (Fig. 1). 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%.

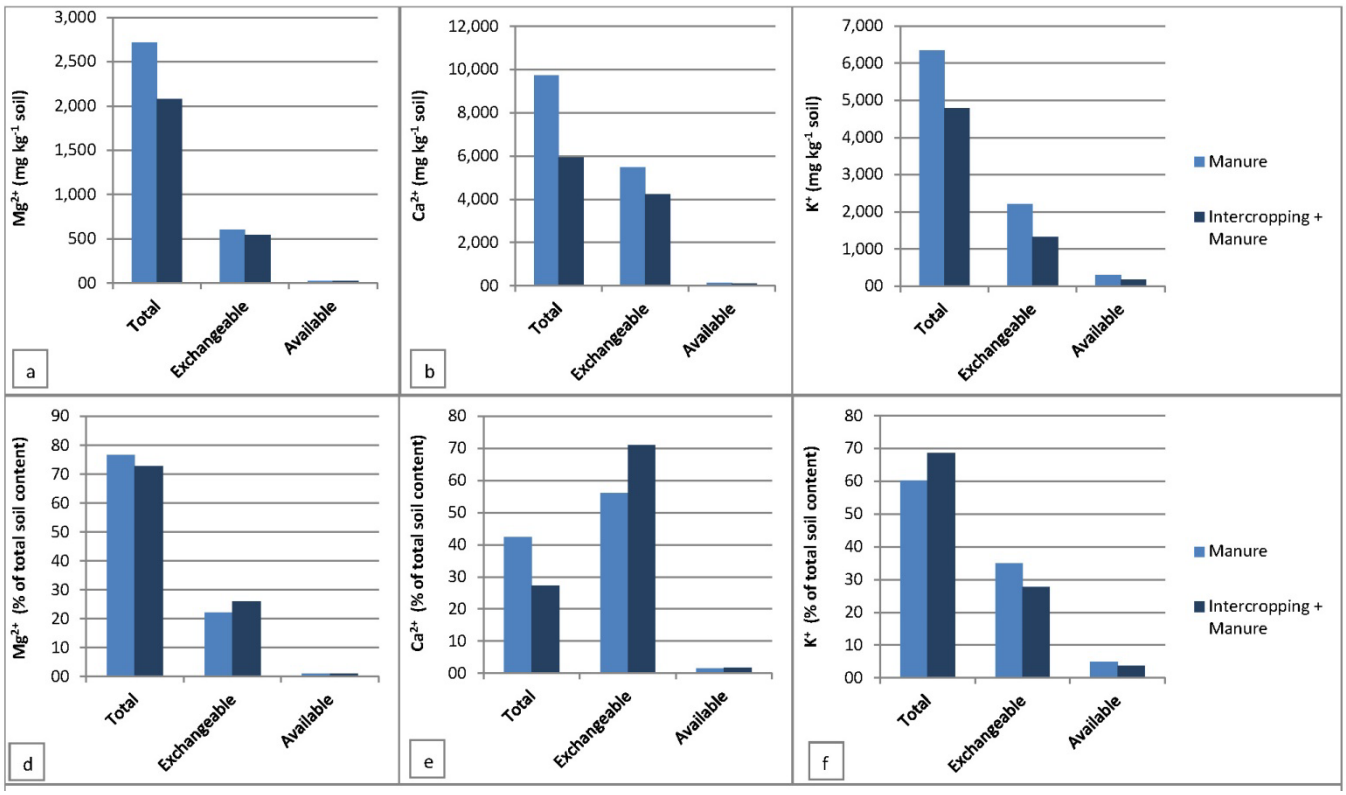

Figure 1. 1a, 1b and 1c: Bars length show the total, exchangeable, and plant available/water soluble amount of Mg, Ca and K in mg kg^{-1} soil under management 'manure' and 'intercropping and manure'. 1d, 1e and 1f: Total, exchangeable and plant available/water soluble Mg, Ca and K in the soil as percentage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

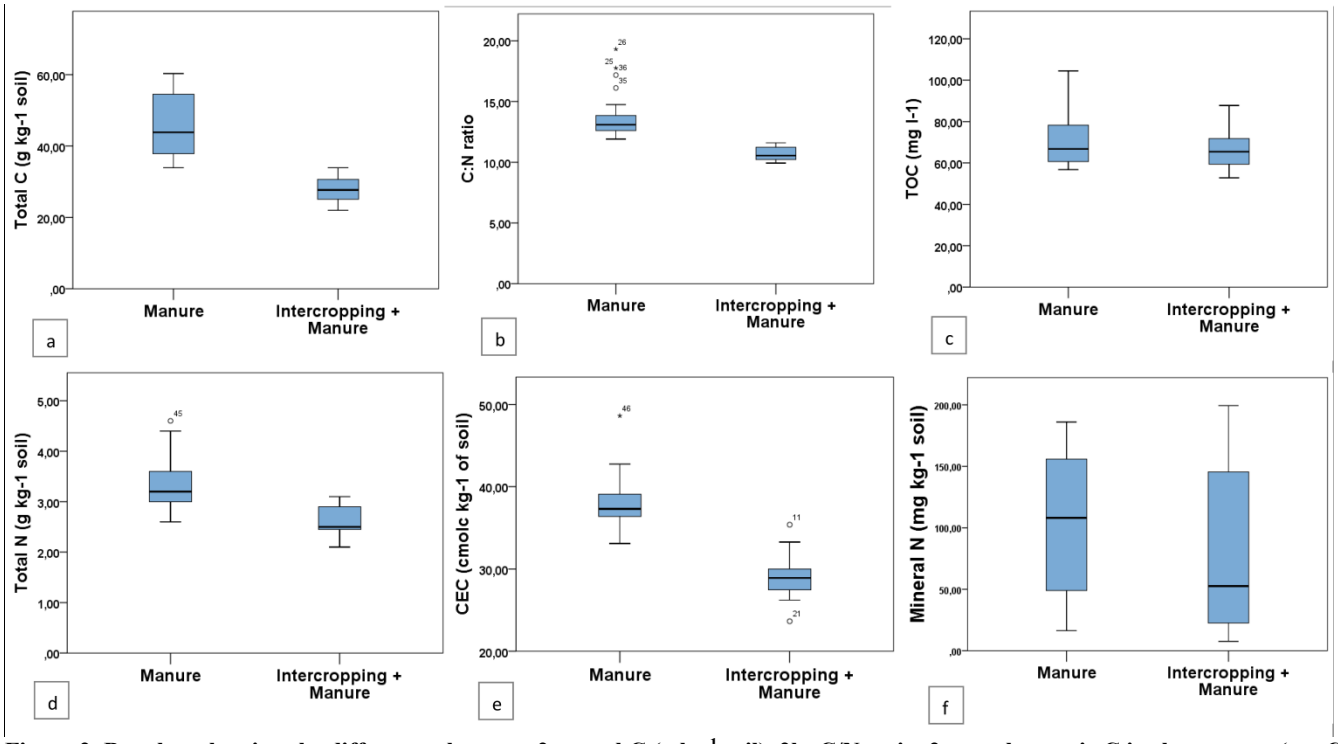

Figure 2. Boxplots showing the differences between 2a: total C (g kg^{-1} soil), 2b: C/N ratio, 2c: total organic C in the extracts (mg C l^{-1}), 2d: total N (g kg^{-1} soil), 2e: cation exchange capacity (CEC in cmol$_c$ kg^{-1}) 2f: Mineral N (mg kg^{-1} soil), for the agricultural management practices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

Discussion

Results of the sample analysis of the soil of the urban gardens in Nyalenda show 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 3~~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 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 centre of Kisumu has since spread to that area; effectively changing the gardens environs from rural to urban. The extension of the urban environment has ~~however~~ not led to a greater accessibility to information ~~sources~~ for the farmers that now live in the informal settlements of the city. Information from media and exhibition were indicated to be too costly for the farmers in this study.

~~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. 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. So even though the number of information sources is higher in the urban environment, the access to these sources remains a challenge for the women 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 do 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 k~~Knowledge is mainly passed down from previous generations or disseminates through observation of other farmers in the group or community.~~,~~ As such, ~~this~~agricultural knowledge ~~does not travel far~~generally stays within the confines of family and community groups within the urban gardens in SSA does not travel far (Alunga and William, 2004; Kabira, 2007).

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 they took up~~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. A~~Yet, the a~~nalysis of the soil samples showed~~s~~ that the soil nutrient content is significantly lower when the kales are intercropped with cowpeas~~–~~, while Mg and Ca showed a higher availability or are more readily exchangeable (Table 3~~1~~, Fig. 1, 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 to applying manure. The farmer who applies intercropping, I2, applies the manure as a topdressing only. The farmer who does not practice intercropping, I7, ploughs the manure into the field. Ploughing the manure into the field preserves N and promotes the biological breakdown of the manure, which increases the availability of the nutrients therein. Ploughing 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 ploughing 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 we can conclude that three years of intercropping did not increase nutrient contents as was the original purpose of adopting the practice.~~,~~

T~~but t~~he 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 ~~indicated that~~ there is a sufficiently large financial incentive for the

farmers to not change their current practice~~. It also showed~~ and that the farmers rely heavily on visible ques 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~~be incentivesed~~ to shift to another form of agricultural management ~~more sustainable practice unless there are other advantages~~. As the soil in the Nyalenda urban gardens is particularly rich (table 3), ~~this~~it is not likely that there will be a need for a large scale adaptation. ~~.~~

~~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 magnesium and calcium 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. The fFarmer I2, who applies intercropping, applies the manure as a topdressing only. The fFarmer 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 furthermore became clear that the farmers are harvesting the cowpeas for sale, 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 caused by a of 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~~ there is a statistically significant difference between soil nutrients ~~i~~contents and availability between similar plots after 5 years of manuring only and 3 years of manuring plus intercropping with cowpeas. While nutrient contents is slightly lower in the intercropped plots, exchangeable nutrients Ca and Mg are slightly higher~~s statistically significant~~. The growing of the cowpeas beside the kales might be causinge~~s~~ 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 ploughed 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 would need to be done to determine which of the two practices has the greater impact on soil nutrients:~~,~~ intercropping or fertilization method.~~ is has the greater impact on soil nutrients.~~

Nevertheless, even allowing for such other factors, the absence of any sign of increased nutrient content in the intercropped fields is remarkable, given that gGrowing cowpeas and ploughing them into the soil should drastically increase soil N content.~~,~~ An explanation for this absence of an observed effect is that ~~however~~ the intercropping farmer ~~that applied intercropping~~ sold the cowpeas on the market rather than ploughing them into the soil. ~~While i~~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 ~~instead of ploughing them into the soil~~ 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 as a consequence.

~~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 ploughed 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 would need to be done to determine which of the two practices, intercropping or fertilization method is has the greater impact on soil nutrients.~~

The interviews and FGDs with the Mesopotamia group showed that there is knowledge present 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, as well as their lack of access to alternative sources such as the internet. Further research would be 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 socio-economic and cultural status. ~~when making decisions in agricultural management and 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.~~ Trainings 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.

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