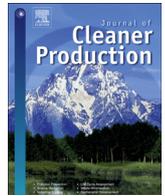


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Turning waste into value: using human urine to enrich soils for sustainable food production in Uganda[☆]

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ABSTRACT

This article builds on an action research process involving Ugandan smallholder farmers in collaborative experimentation on the use of human urine as a crop fertilizer. The aim is to explore farmers' perceptions and evaluation of the practice as a potential and partial solution to soil productivity problems. Findings show that urine fertilization is valued as a low-cost and low-risk practice contributing to significant yield increases, suggesting important contributions to food security and income, especially for those who have few options in soil nutrient management. Weaknesses identified by farmers relate mainly to limitations in collection and storage capacity rather than to inherent traits of the practice. In conclusion, urine fertilization should be acknowledged as a valuable strategy for supporting sustainable agricultural intensification. Furthermore, the importance of social norms and cultural perceptions should be recognized but not treated as absolute barriers to diffusion of the practice. Collective action, where groups of farmers jointly develop new procedures and adapt practices, serves as an important arena for social change and negotiation of norms and taboos, which can otherwise limit the acceptance and diffusion of alternative soil management practices. The research finally illustrates that transdisciplinary research can guide pathways towards sustainability through locally anchored and solutions-oriented knowledge generation.

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1. Introduction

Smallholder farmers in sub-Saharan Africa largely depend on, and continuously struggle to maintain, the productive capacity of their land (Sanchez, 2002). In order to improve land management, food security and rural livelihoods, it is important for agricultural research to collaborate with farmers – in all stages of development – in the search for affordable, locally anchored and sustainable practices. Only then is technology adoption expected to take root (Röling, 2009).

The promotion of inorganic fertilizer is a dominant strategy among governments and international development organizations to tackle low soil fertility. However, for the large majority of farmers in sub-Saharan Africa such initiatives have had limited effects due to high costs and limited access. At roughly 2 kg per hectare of farmland, the average fertilizer consumption¹ in Uganda is among

the lowest in the world (World Bank, 2013). Among women, who are likely to be more asset-poor and subsistence oriented compared to men, fertilizer use is even lower (Peterman et al., 2010). Soil fertility practices benefitting those who need it most are therefore called for.

Human urine is a valuable, yet underestimated and underutilized, resource for plant fertilization that has been used in agriculture since ancient times, not least in intensive farming systems in various parts of Asia (Goldstein, 2012; Netting, 1993). Nevertheless, in much of sub-Saharan Africa, including Uganda, its use in agricultural production is not a common practice (Winblad and Simpson-Hérbert, 2004). Until recently, the demand for additional fertilizer sources was low since agricultural land was generally fertile and farmers practiced shifting cultivation. Moreover, the handling of human waste is often surrounded by cultural norms and taboos, which restrict its use in agriculture (Dellström Rosenquist, 2005). Finally, the one-sided focus on conventional 'end-of-pipe' sanitation systems has not only created a techno-institutional lock-in (cf. Unruh, 2000), discouraging nutrient reuse in wealthier parts of the world, but this philosophy has also spread to the Global South (Bracken et al., 2007).

There is an increasing research interest in the fertilizer value of human waste. Studies have focused mainly on its yield enhancing potential (e.g., Mnkeni et al., 2008; Semalulu et al., 2011), possible

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¹ Refers to total consumption of nitrogenous, phosphate and potash fertilizers in kilograms per hectare of arable land.

health hazards (e.g., Höglund, 2001; Jönsson et al., 1997), and technical aspects of collection and storage systems (e.g., Maurer et al., 2006; Wohlsager et al., 2010). While most of these studies are based on off-farm research, participatory approaches that involve farmers remain marginal. Furthermore, although often identified as key barriers to the use of human waste in food production, related norms, attitudes and cultural perceptions have so far been insufficiently explored (Karak and Bhattacharyya, 2011).

In order to successfully promote nutrient reuse, we need to better understand not only if and how such systems can be introduced in specific contexts but also how farmers perceive the use of human waste in food production, and how they evaluate and adopt such practices. In this article, I draw on a collaborative process of experimenting with urine fertilizer in maize production in an Ugandan smallholder farmer community to explore these issues, and to evaluate urine fertilizer as a potential and partial solution to soil productivity problems, including both yield impact and farmers' perceptions.

The article is organized as follows. First I introduce the agrarian setting and outline the ideas of participatory action research. Then I discuss the process of identifying urine fertilizer as a partial and potential solution to soil productivity problems, followed by an account of the actual implementation of the experiments. After that, I discuss the evaluation of the practice, both from a yield perspective and by the expressed views of farmers. In the concluding section, I summarize the research findings and discuss them in the wider context of agricultural development and a solutions-oriented sustainability science agenda.

2. Setting the scene

My research with smallholder farmers of the Jopadhola ethnic group is set in the Tororo District in eastern Uganda (Fig. 1), which is a region suffering from particularly severe land degradation (Pender et al., 2006). Soils are varied but dominated by sandy clay



Fig. 1. Location of the Tororo district in Uganda. Source: Wikimedia Commons.

and loam soil types with low organic matter content and soil fertility (NEMA, 1997).

The situation in the region reflects the generally dire conditions experienced in many parts of rural sub-Saharan Africa where the majority of the population depends on rain-fed smallholder agriculture as a principal source of income. Poverty in the region is widespread and purchased inputs are few (c.f. Pender et al., 2006). Farmers operate in the unfavourable environment of poor infrastructure, weak social security systems, fluctuating food prices and few credit services. At roughly 1 ha per household, land holdings are generally small and intensively cultivated. As pressure on land is growing (Hundsbaek Pedersen et al., 2012), it is urgent to find strategies to sustainably produce more on existing farmland. Farmers grow mainly cassava, millet, maize and plantain. Due to land pressure and disease, livestock numbers have decreased considerably over time (Field data 2010–2012). Gender inequalities, in terms of access to land and other productive resources, are significant. While responsible for much of the agricultural labour, women are often discriminated against in land disputes (c.f. Pedersen et al., 2012).

Many farmers experience a dwindling capacity to sustain the household through agriculture; yields are typically well below potential yields, found at research stations, and have gradually declined over time (cf. Pender et al., 2006). Farmers identify low and declining soil fertility as one of the main reasons for the poor agricultural performance. A range of soil fertility management methods are practised, including crop rotation, intercropping with nitrogen-fixing crops, composting and crop residue management, in combination with various soil conservation measures. A key limitation is that organic resources are generally low in nutrient content and have numerous competing uses (Field data 2010–2012).

In response to these harsh livelihood conditions, farmers in the area have increasingly begun to organize themselves in local farmer groups. Compared to previous forms of collective action, which were short-term and centred around specific agricultural activities, these new groups can be described as continuous and well-organized 'communities of practice'. Women in particular engage in such groups for the purpose of making better use of their limited assets and supporting each other in daily livelihood provision (Andersson and Gabrielsson, 2012).

3. Doing participatory action research

This research is guided by a participatory action research approach, which distinguishes itself from conventional research approaches in two important ways: 1) it aims to contribute practical solutions to 'issues of pressing concern to people' (Reason and Bradbury, 2008), and 2) it directly involves people affected by such problems, not merely as 'research participants' but more as 'co-researchers'. Collaborative learning and action thereby become essential elements of the research process, implying a shift from the traditional divide between the 'researcher' and the 'researched' towards a greater sense of shared ownership of the research process and its results (Herr and Anderson, 2005).

In the context of agricultural development, action oriented research approaches represent an alternative to the conventional 'transfer-of-technology' model, which espouses the idea that knowledge be generated by research institutions and then diffused among farmers via extension services (Röling, 2009). Proponents of participatory approaches have emphasized that farmers are neither just passive victims of changing realities, nor merely recipients of agricultural innovations, but 'agents of change' (Chambers et al., 1989; Gabrielsson and Ramasar, 2013; Olsson and Jerneck, 2010). Close interaction with farmers is therefore seen as imperative for

in-depth understandings of their social, economic and biophysical circumstances, and for identifying opportunities for improvements based on their specific needs and capacities (Sanginga et al., 2009).

Collaborative experimentation is one way to strengthen farmers' ability to influence research and generate more relevant and usable knowledge by drawing on their own priorities and insights. It starts from the realization that their decision-making is highly complex; the scope of experimentation therefore goes beyond mere technology demonstration, with the process of inquiry in itself becoming equally as important as its specific outcomes (Misiko, 2009; Ramisch, 2012).

Knowledge generation in action research is thus practice-driven, but theoretically informed and potentially also theory generating; fundamental to action research is not only that social research can bring about social change, but also that such processes of change are important sources of knowledge generation (Brydon-Miller et al., 2003). By combining critical and problem solving research and by linking knowledge to action and social learning in transdisciplinary processes, action research can make important contributions to the field of sustainability science, which seeks to address sustainability challenges and develop solution options (Jerneck et al., 2011; Miller et al., 2013). This makes action research explicitly normative and socially engaged thereby challenging positivist notions of knowledge (Reason and Bradbury, 2008).

Action research is an iterative, cyclical process comprising one or several cycles of action and reflection. Susman (1983) identifies five phases within each research cycle: diagnosing, planning action, taking action, evaluating and specifying learning, as depicted in Fig. 2. These phases have guided this collaborative experimentation process on urine fertilizer. For each phase, the key activities are summarized in the boxes and discussed in the following sections.

4. Identifying the problem and imagining a solution

Building on these principles, I engaged with farmer group members to identify and develop potential solutions to the soil productivity problems that negatively affect their well-being. The initial problem identification builds on fieldwork conducted in 2010–2011 within the scope of a larger research project on farmers' land management strategies and responses to soil

productivity decline in the Tororo district (Andersson, 2014). The problem analysis, preceding our joint identification of potential solution options, is based on a mixed methods approach including a household survey, a series of individual interviews, focus group discussions and various participatory diagramming, ranking and mapping tools, in parallel to an extensive literature review.

Prior to the initiation of the urine fertilizer experiments, I arranged group discussions with farmers to identify potential solutions to their soil productivity problems. The discussions proceeded from the question: *what* can, within the given opportunities and constraints, be done to improve soil fertility practices in this particular place? By situating a seemingly individual issue within a larger social context we could envision alternative solutions and re-think current resource-use patterns (cf. Mills, 1959).

The decision to focus on urine fertilizer arose from an iterative process. Inspired by documented experiences of low-cost soil fertility measures elsewhere, I had previously asked farmers about their experiences from using urine as a crop fertilizer. Only a few had such experience, which gave rise to further discussions and gradually stimulated our mutual curiosity to learn more about and evaluate the practice in their particular setting.

The urine fertilizer experiments took place during the first cropping season of 2011, from March to August, in collaboration with seven community-based farmer groups, each including 20–25 members, both women and men. I approached a village chairperson who was familiar with the landscape of local farmer groups to assist in the selection of the groups according to the following sampling criteria: groups should receive no external funding, be self-initiated and involved in multiple activities for more than two years. Previous research has demonstrated that such groups serve as important arenas for knowledge exchange and generation (Andersson and Gabrielsson, 2012) and that collaboration with well-established groups may facilitate discussion, collective work and trust-building (de Haan, 2001). One farmer in the village took the role of an 'experiment facilitator' to assist in and support the process of implementing the urine fertilizer experiments. Each farmer group, with support from the facilitator, implemented and managed the experiment, including urine collection, application and documentation. In sum, all this created constructive initial



Fig. 2. Visualizing the action research cycle. Text boxes indicate key activities in each phase of my research. Source: adapted from Susman (1983).

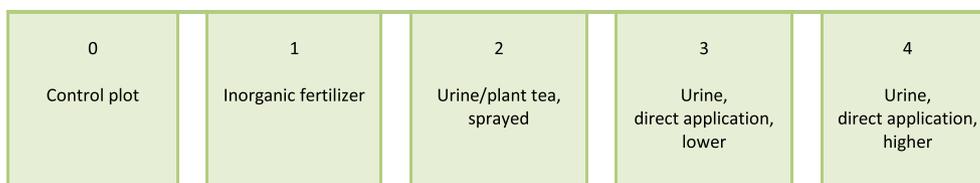


Fig. 3. Experimental design. Each plot was 8×10 m with a buffer zone of 1.5 m between plots.

conditions of readiness and strong motivation for co-production of knowledge through experimentation.

Together with the farmer groups, and proceeding from an integrated socio-ecological perspective on yield impact in relation to cultural aspects, I evaluated the use of urine fertilizer as a potential and partial solution to soil productivity problems. For that I conducted a modified SWOT analysis with each group (Narayanasamy, 2009) wherein Strengths and Weaknesses refer to positive and negative attributes of the practice itself, and Opportunities and Threats refer to factors that may influence its adoption in favourable or unfavourable ways. Drawing on the ideas of experimental learning, the purpose was to 'make meaning' of participants' experiences by reflecting on, analysing and synthesizing the new ideas and insights gained from the experiment. In each group, we also did an 'After Action Review' (Serrat, 2010) to share experiences in retrospect and summarize reflections on the experimentation process.

One year after the completion of the trials (2012), I followed up on farmers' adoption of and attitudes to urine fertilizer in one group discussion with each participating group plus individual interviews with thirty farmers, of which half were experiment participants and half were non-participants. The rationale of including the latter group was to compare views and capture some of the reactions to the urine fertilizer experiments and perceptions of the practice in the wider community. I identified volunteers for individual interviews during the group meetings, as well as through snowball sampling for non-participants. I analysed the empirical evidence iteratively using thematic analysis, in which recurring themes were identified, clustered and interpreted in relation to my overall understanding of the specific setting – and then continuously adjusted and refined to create a reasonable representation of reality (Ragin and Amoroso, 2010).

5. Implementing the solution

Together with the experiment facilitator, I arranged a meeting with each group where participants were informed about nutrient content in urine, recommended application methods, and proper handling procedures. We also discussed the choice of a test crop, treatments to compare, the division of responsibilities and urine collection options. The experimental design² is described in Fig. 3.

All groups selected maize as a multi-functional test crop that is both a staple food and a cash crop. The common practice of growing maize in rows also made it suitable since this facilitates both the application of urine and visual comparison of treatments. All groups deliberately selected test sites that were easily observable as showcases for other community members, for instance along roads. Each group provided a 100-L drum and set up a collection point by the test site to which participants brought urine from their households.

² In this process I consulted Dr O. Semalulu at the Kawanda agricultural research institute (NARO).

Based on participant priorities, all groups compared the following treatments: 0) unfertilized control plot, 1) micro-dosing of inorganic fertilizer 2) sprayed application of urine mixed with 'plant tea', and 3, 4) direct application of urine in two different amounts. A hybrid maize variety was used and the spacing of plants was 50×70 cm.

Plot 0 served as a control plot and reflected the reality of much of the farmland in the area. In plot 1, one bottle cap of Triple Super Phosphate (TSP) was applied to each seed hole at planting and urea was used as top-dressing at a rate corresponding to 45 kg N/ha. The 'plant tea' used in plot 2 is a locally used liquid fertilizer based on various green leaves, wood ash, soap and red chili that is left to ferment in water. It was mixed with equal parts of undiluted urine and sprayed on plants four times, ending one month before harvest to prevent pathogen spreading (cf. Richert et al., 2010). In plots 3 and 4, urine was applied undiluted in amounts corresponding to 60 and 75 kg N per hectare, respectively. The N content was estimated at 2.3 g per litre of urine, based on data from a different region in Uganda (Semalulu et al., 2011). The total amount of urine was applied in split doses in order to prevent nutrient leaching (Richert et al., 2010). A first dose was applied at planting, followed by five weekly doses after seed germination and then two bi-weekly doses, ending by the time the plants were setting ears. The urine was applied close to the ground in furrows along the plant rows, which were immediately covered with soil. Besides preventing ammonia losses, this practice helps to reduce the smell and avoid burning crop leaves (Kirchmann and Pettersson, 1995). Following the recommendations by Richert et al. (2010), the urine used in the trials was stored in closed containers and kept for at least two weeks in farmers' homes before application in order to reduce the risk of potential pathogens.

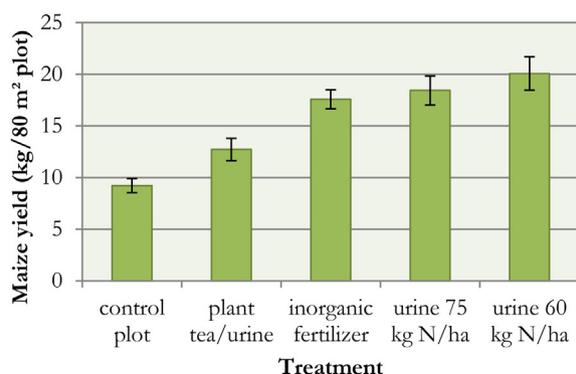
6. Evaluating the solution: impact on maize production

The conditions for the trials do not suffice to establish the yield-enhancing potential of urine fertilizer, which would require controlled experiments over a longer period of time. The comparison of treatments (Table 1), however, confirms the positive impact of urine fertilizer on crop growth reported in other studies (e.g. Andersson et al., 2011; Pradhan et al., 2010; Semalulu et al., 2011).

Compared to the control plot, all treatments show a statistically significant difference in yield. The lower rate of direct urine application (i.e., 60 kg N/ha) was the best performing treatment, with a mean yield more than double that of the control plot. It also produced a higher mean yield (12 percent) compared to the inorganic fertilizer treatment. Based on these results, using urine fertilizer is likely to increase smallholder yields significantly. However, plots receiving a higher rate of urine (i.e., 75 kg N/ha) produced slightly lower yields compared to that of the plot with the lower application rate. This shows that more application does not result in higher yields; more tests are needed however to establish the optimal level of urine application for various crops.

Furthermore, the results indicate that *spraying* of urine/plant tea is not recommended for the purpose of soil nutrient replenishment. Farmers repeatedly reported, however, that spraying efficiently

Table 1
Aggregated mean yield of maize by treatment. $N = 7$.



controls various crop pests, including banana weevil, maize stem borers, aphids as well as grasshopper infestations (cf. Wightman, 1999).

The post-harvest soil analysis³ revealed that plots receiving direct urine application had almost three times higher phosphorous content than the control plots. Nitrogen content was also higher, which might suggest a residual build-up of these nutrients in the soil following urine application (Semalulu, 2012, personal communication). However, further research would be needed to fully validate this.

7. Evaluating the solution: going beyond the biophysical

Smallholder agriculture entails a range of interrelated components and functions; although yield is a key determinant in the evaluation of agricultural practices, it is not the only one (IAASTD, 2009). Our joint assessment of urine fertilizer allowed for discussion among participants of their opinions and attitudes and generated in-depth understanding of the criteria and trade-offs according to the farmers' evaluation, including aspects such as labour demand, required investments and social acceptability. The outcomes of the SWOT analyses are aggregated and summarized in Table 2 and discussed in the following sections.

7.1. Strengths

Participants identified several strengths. Most importantly, urine was unanimously seen as an excellent crop fertilizer that may also act as a pest deterrent. Based on plant growth and leaf colour, the majority of groups also considered maize plants to be most healthy where urine was applied directly, while the occurrence of yellow and tender leaves was observed in the other treatment plots. One year after the experiment, almost all of the participants still used urine fertilizer, while many had spontaneously experimented on other crops such as sorghum, millet and various vegetables. One farmer summarized her views:

It increases the yield but it also makes plants look greener. I really saw a difference in the maize. I have now been using it on a small scale and my garden is doing very well compared to before. Like on pumpkin – it is really very good and the taste is even sweeter. I have used it on beans and on the eggplant nursery bed. It did so well! And at some point my sorghum

³ Dr O. Semalulu and B. Bosco at Kawanda agricultural research centre (NARO) assisted in soil collection and analysis.

Measured against control	Treatment			
	Inorganic fertilizer	Plant tea/urine	Urine direct 60 kg N/ha	Urine direct 75 kg N/ha
<i>P-value</i>	<0.0001*	0.0094*	<0.0001*	<0.0001*
<i>t, df</i>	t = 13 df = 6	t = 3.2, df = 6	t = 9.0 df = 6	t = 9.3 df = 6
<i>Difference between means</i>	-8.4	-3.5	-11	-9.2

* Difference is significant ($P < 0.05$)

garden was almost dying off but after I poured the urine it all recovered (...) I don't know any crop that does not like urine. It helps even with the banana weevil because when you use it you won't find those weevils (Amollo Margret).⁴

The above observations reflect the fact that urine contains most of the key nutrients, as well as a number of micronutrients, which are required in crop production (Kirchmann and Pettersson, 1995). Its use is particularly beneficial where soils are low in nitrogen, as is often the case in sub-Saharan Africa (Henao and Baanante, 2006). Farmers' appreciation of urine fertilizer demonstrates that the ability of farming practices to enhance soil fertility, particularly nitrogen, is a key factor influencing their acceptability in this setting, as argued by Snapp et al. (1998).

Even if used only on a small scale, such as vegetable production, farmers identified urine application as an important strategy to increase food security, both by increasing food production, and by contributing to more balanced diets by improving access to vegetables. The economic value associated with urine recycling, through increased incomes from crop sales, was also commonly seen as of great potential (cf. Semalulu et al., 2011).

Another important benefit of urine identified by farmers is its ubiquity. In contrast to inorganic fertilizers, it is a locally and constantly available resource, free of charge. This makes it a highly valuable source of soil nutrients. As explained by one farmer:

Urine is a very good fertilizer. I have been using it now and the crops look really very healthy. It is also cheap because we just get it from the family members so there is no problem – it is better than the [inorganic] fertilizers which at times are very difficult to get. You may need it in a season when it is not there because the stockist normally brings it during certain periods. But this one is there from Monday to Sunday, from January to December! [laughs] Whenever you want to use it, it is available! (Athieno Loliana)

Many farmers also pointed out that the use of urine does not involve the continuous or risky investments associated with inorganic fertilizer, since the equipment for collection, storage and application has to be procured only once. Even for farmers who can afford inorganic fertilizer, urine could be used as a strategy to optimize such investment by complementing the input of phosphate and potash fertilizers with nitrogen-rich urine.

⁴ All interviewees' names have been changed.

Table 2
Summary of farmers' evaluation of urine fertilizer.

Strengths	Weaknesses
<ul style="list-style-type: none"> • Excellent fertilizer: increases food security and income • Free and available resource • Reduces need for (expensive) inorganic fertilizer • Controls crop pests • Moderate labour requirements • Low-risk practice 	<ul style="list-style-type: none"> • Limited availability at household level • Lack of equipment for collection, storage, transportation and application • Requires knowledge for appropriate use and safe handling • Smelly – creates negative attitudes • May require complementary nutrient inputs
Opportunities	Threats
<ul style="list-style-type: none"> • High potential for wide adoption • Construction of urine separating toilets to facilitate home collection • Larger-scale collection, e.g. from schools, to increase availability • Potential for local fertilizer market and cottage industry development 	<ul style="list-style-type: none"> • Fear of disease and witchcraft • Social exclusion by challenging norms and taboos • Theft of equipment • Uncertainty about long-term effects on soils

Although direct application of urine via watering cans is labour intensive, farmers stressed that it is less demanding compared to the application of other organic resources, which are generally bulky and have a relatively low nutrient content (Ayuk, 2001). Limited access to watering cans and safety gloves was commonly identified as a factor contributing more to the labour burden than the application itself. Moreover, although urine application resulted in weed growth, farmers generally agreed that this was a minor problem given the increase in crop yield: “We value what we get from it so the weeding does not bother us much. The benefits are greater than the weaknesses” (Alowo Rosa).

Most participants reported that the collection of urine at the household level was easy and functioned well. It was carried out in various ways: some used small buckets and poured the urine into a bigger storage container; others made a hole in the ground into which a jerry-can with a funnel was placed. This system was appreciated because it facilitated handling of the urine and kept the storage container in an appropriate place. One farmer summarized her experience:

From just seeing what is happening it was not even difficult to convince my family. Each person now has their own bucket and then we have it out to a container where we all bring it. Each one knows where to take *the product*. [laughs] (Nyadoi Miriam)

7.2. Weaknesses

Participants indicated several weaknesses. The limited availability of urine is an obvious factor determining the use level of the practice, particularly for small households whose urine suffices only to fertilize parts of the farm. As the participants often argued, however, farm sizes in the area are generally very small with few alternatives for nutrient replenishment. Even small amounts of urine therefore represent a valuable soil nutrient source which otherwise would remain unutilized.

Inadequate access to suitable and sufficient containers for collection and storage, as well as equipment for application and safe handling of urine is another key limitation. For many households, procurement of drums implies a considerable investment, and the risk of theft was brought up as a major concern. Equipment such as watering cans and protective gloves also involves certain costs. The general lack of wheel-barrows and other means to transport heavy containers can, furthermore, impede application, particularly on fields far away from homesteads. Despite its potential to increase yields, limited collection, storage and

transportation capacity could therefore discourage wider adoption of the practice, at least on larger scales. One farmer explained:

What was difficult was not to *get* enough urine, but the containers to *keep* that urine. If you have a large plot, you need to collect a lot. We actually need drums both for fermentation [storage] and others that are ready to use. The problem is if you have the garden far away. You cannot leave it there to ferment because you might not find it when you get back. [theft] (Oburu Julius)

Furthermore, appropriate use and safe handling of urine fertilizer in food production requires awareness about appropriate dosing, application and hygiene procedures. Farmers identified poorly functioning agricultural extension services, both in terms of quality and access, as a key constraint on the wider diffusion of the practice. One farmer pointed to this:

Many people around here have seen that it is beneficial but still they have not put it into practice. That is because they do not have the skills – because the right knowledge is required to master it. Now only those who are in groups know about it (Owore Peter).

Cultural issues recurred in the discussions with farmers as did the paradoxes associated with the handling of human waste. It is typically a subject buried by avoidance, yet surrounded by numerous unwritten rules, norms and taboos (cf. Dellström Rosenquist, 2005). Participants were initially reluctant to talk about personal sanitation routines but gradually shared their thinking. The fact that the experiment involved only urine, which generally is perceived as less offensive compared to faeces, may have facilitated the dialogue.

Many participants identified the distinctive smell of urine as a sensitive issue and a key aspect that negatively influences attitudes towards its use in food production. Smelling other's urine in particular was associated with feelings of undesired intimacy and repulsion. Initially it was also generally perceived as embarrassing to be openly 'guilty' of such a smell, for instance when individual buckets were poured into the collective drum (c.f. Dellström Rosenquist, 2005). One farmer explained that it took some time before they got used to it:

At first most people did not collect as agreed. Most of them were shy about carrying the containers – because it somehow looks strange to carry your urine to another person's home (...) The first time it took three weeks to fill the tank, but then things got easier and later it was even filled too fast! [laughs] (Awori Jessica).

In the discussion of other weaknesses associated with urine fertilizer, some farmers brought up concerns about the long-term effects on soils. Previous research shows that drawbacks are low compared to the advantages, although complementary sources of phosphorous and potassium may be necessary to optimize production. More research is needed to fully examine potential risks, for instance in terms of salt accumulation in soils (Mnkeni et al., 2008). However, high salt content in urine is associated with consumption of processed foods (Mattes and Donnelly, 1991), which is not a concern among African smallholders. Risks of negative impacts of hormones and pharmaceutical substances in urine are also regarded as low (Richert et al., 2010).

7.3. Opportunities

Participants identified many factors that make the adoption of urine fertilizer favourable. By being a low-cost practice implying few major changes in existing farming systems, most considered

urine fertilizer to have high potential for wide uptake. One year after the experiments, each group reported that the practice had already spread to 15–50 additional farmers as a result of their observing and learning from the group members. Finding appropriate ways to spread knowledge and demonstrate its benefits was unanimously identified as fundamental for disseminating the practice further and de-mystifying the use of human waste in food production.

Farmers brought up various ideas about how urine collection and storage at the household level could be improved. Since the lack of containers was commonly identified as a major constraining factor, the collecting capacity of households could improve significantly through relatively small investments. An alternative use of urine, if storage containers are limited, is to pour it on compost heaps, which improves the nutrient content of organic manure by speeding up the decomposition process (Winblad and Simpson-Hérbert, 2004).

Pre-fabricated urine-separating toilets were considered an unaffordable investment for most households, but various ideas on locally constructed systems based on available material were expressed and debated. One idea was to improve already existing pit latrines by simply adding a device that segregates the urine and siphons it to a container. This would not only facilitate its collection, but would also reduce the smell and delay fill-up of the latrines. In addition, this would contribute to improved sanitation and could reduce hazardous leakage from latrines into the groundwater (Höglund, 2001). One farmer explained his idea:

For most people, it [urine] is now just a waste. But when we have seen how valuable it is, we have almost started to get stressed when we realize how much is wasted every day [laughs]. So what is needed now is to construct some kind of facilities to improve the pit latrines so we could, you know, pipe the urine to a jerry can (Okello Charles)

Numerous participants suggested that even human faeces could be used as manure in the future. This would, however, involve considerably higher risks in terms of pathogen spreading and would therefore require substantial training and sensitization in order to establish systems and routines for safe handling (Richert et al., 2010).

In order to meet the growing demand for urine fertilizer, various options for collecting urine from additional sources beyond the household level were discussed. In particular, schools and public gathering places such as markets and churches were identified as strategic sources. Even during the experiment, one group started collecting urine from a local bar in order to ensure that the quantities would be enough for both the trial and for household use. The owner eventually started to demand payment, which was interpreted by some of the group members as an indication of an increasing recognition of the (commodity) value of urine, and even as a sign of an emerging local market for the product. Examples of such development have been observed in other regions (Coulibaly, 2009).

Numerous farmers also suggested that the use of urine fertilizer could spur the creation of new income generating activities, both in terms of innovations for collection and application and investment in agricultural production. Similar 'cottage industry' developments, leading to income generation and entrepreneurship in rural areas, has been seen, for instance, in the production of rhizobia bio-fertilizers (Sethi and Adhikary, 2012) and biological pest-control (Ahmed and Grainge, 1986). Farmers brought up a range of ideas, as examples: the creation of urine storage systems, tools and machines to pump and spread urine to the fields; measures to reduce its smelliness; alternative constructions of low-cost separating toilets; investment in fruit and vegetable production for home consumption but also in high-value crops for income-generation.

7.4. Threats

Since the use of urine as a crop fertilizer is not a common practice in eastern Uganda, this was a new experience for most participants, and some initially expressed hesitation. Although gradually decreasing during the process, the 'fear of the unknown' was identified as a major barrier in further diffusion of the practice. One woman referred to urine as 'the kind of fertilizer which name we cannot mention' and explained: "The fear is there – because of the name itself. We decided to just call it 'our fertilizer' instead" (Apoya Felistar).

Uncertainties about health risks and fear of spreading disease through urine application were articulated as a main concern, especially for leafy plants and vegetables that are eaten raw or unpeeled. This fear was particularly associated with sexually transmitted diseases, including HIV/AIDS (cf. Drangert, 2004):

Some neighbours know that I use it and say that if you leave urine to ferment, it can bring disease. But they do not specify what type, just 'bad diseases' – like maybe HIV or syphilis and the rest (Oketch Wilbur)

Although the use of urine fertilizer entails no risk of spreading sexually transmitted diseases, it is true that it may contain certain pathogens (e.g. *Leptospira interrogans*, *Salmonella typhi/paratyphi*, *Schistosoma Haematobium*). However, their survival time is relatively short and health risks are therefore low, given that faecal cross-contamination is minimized through source separation (Höglund, 2001; Niwagaba, 2009; Richert et al., 2010).

Due to various cultural perceptions associated with human waste, the fear of exclusion and stigmatization is a key barrier identified by farmers to the use of urine fertilizer: "Urine– or let me say human waste– is seen as a dirty thing. If you want to use it, you are not seen as normal" (Aketch Frances). This evidently makes some farmers hesitant to (openly) fertilize their crops with urine. This could be particularly true for persons who already are vulnerable to stigmatization, such as widows and people living with HIV/AIDS. According to participants, women are generally more socially controlled and have stronger reasons to guard their social position in the community.

Importantly, there is another aspect that makes urine fertilizer a socially sensitive issue. In Jopadhola culture human waste is sometimes associated with evil and believed to be used for magic and witchcraft to create misfortune for others. Women in particular repeatedly reported that they fear being accused of using urine or crops fertilized with urine to bring bad luck upon others:

Some neighbours say that I am wasting time. Others even fear to come close to the vegetables. If I would collect from others, people may ask where the urine is going to be taken and for what reason, because they fear that they are going to be bewitched (Anyango Mary)

Yet another aspect of how urine fertilizer is closely tied to social relationships is related to certain norms and taboos around respect and intimacy between family members, especially in-laws, which are particularly strong in Jopadhola culture (cf. Prince and Geissler, 2001). The relationship between a married woman and her father-in-law is especially influenced by cultural norms, which prescribe avoidance and distance.⁵ Sharing the same toilet is not only perceived as implying undesirable intimacy but is also associated

⁵ As an illustration of this intimacy taboo, a particular type of plant (*Mimosa pudica*) is locally called *Or bino*, meaning 'the in-law is coming'. Just like the plant folds its leaves when touched, you are expected to 'close' yourself when your parent-in-law is approaching to avoid embarrassment and undesired intimacy.

with various fears (cf. Drangert, 2004). Some of the participants explained how this created some tensions in the collection of urine:

There are some issues, because – let's say – the in-laws cannot mix [their urine] directly. Imagine, your in-law carried this bucket of urine, and you have also contributed to that container! [group laughs] This is something we can call a challenging issue! (Apoya Yoanina)

Because of such taboos, the participants unanimously agreed that a fundamental requirement for the future diffusion of urine-separating toilets is that they consist of two separate sections. Interestingly, however, such taboos are seemingly negotiable to a certain degree; as long as toilets are kept separated, most participants could accept that the collected urine eventually ends up in one common tank. This is one example of the negotiation of norms that takes place in processes of reframing; what in one context is perceived as dirty waste requiring avoidance can in another be reframed as a productive resource (c.f. Douglas, 2002).

The fact that the urine trials were carried out collectively arguably facilitated the acceptance of the new practice socially and reduced individual risks of social exclusion. Members of such farmer groups, generally dominated by women, typically construct individual and collective narratives and identities of being open-minded and innovative farmers 'at the forefront', while questioning old tradition and attitudes (Andersson and Gabriellson, 2012). This inarguably empowered them to support each other and resist negative attitudes: "We just ignore and continue", as one member declared. In the Jopadhola social world, showing willingness to share knowledge and openness about your motives is an important strategy to counter gossiping and 'bad talk':

In the beginning we had some bad experiences – with witchcraft and what not. But when we explained to people what we were doing and when they later saw the result from what we had been doing, that thinking stopped – it is no longer there. (Ofamba Esther)

Women in particular explicitly said that they informed neighbours about their activities and openly shared their knowledge with others in order to "avoid jealousy" and social difficulties. The fact that all groups selected experimental sites that were easily observable and invited others to explain what they did, can be seen as another expression of this. This willingness to share knowledge and experiences with others may thereby not only prevent pioneers from exposure and stigmatization, but is also fundamental for successful farmer-to-farmer diffusion of new agricultural practices (Reij and Waters-Bayer, 2001).

8. Conclusion

In action research with farmers – designed to envision, implement and evaluate solution options for soil fertility problems – the use of urine as a fertilizer in food production is largely perceived as an efficient, low-cost and low-risk practice. Importantly, our experiments demonstrate that urine application has a positive impact on crop yields, suggesting important contributions to food security and income, even if used on a small scale. The practice can help increase production and reduce vulnerability, especially for women, who are often responsible for food production for the household but have limited options in soil nutrient management. It should be stressed that farmers' evaluations indicate that the strengths of urine fertilizer largely outweigh its weaknesses, which are mainly attributed to limitations in collection and storage capacity rather than to inherent attributes of the practice.

This highlights and supports the argument that urine fertilization is a viable strategy to enrich soils. Based on principles of resource use-efficiency, nutrient circulation and low-tech precision agriculture, it should be treated as an integral part of sustainable intensification efforts. Ongoing attempts to support agriculture in sub-Saharan Africa could therefore benefit greatly from broadened perspectives on what constitutes relevant agricultural technologies, particularly in the context of the generally one-sided focus on technology-packages of inorganic fertilizers and improved seeds. To realize the potential of urine fertilization, it must be integrated into existing agricultural extension programs and supported in everything from creation of locally adapted guidelines to facilitation of larger-scale urine collection while supporting farmers' innovations. Needless to say, such measures do not exclude other soil fertility improvement strategies, including promotion of inorganic fertilizer. The design of mechanisms and policies to support the use of urine fertilizer is an important area for further research.

While recognizing that the use of human waste in food production is a sensitive issue in most societies, I have also argued that the power of social norms and taboos should not be exaggerated. As demonstrated, norms are rather fluid and negotiable, meaning that negative perceptions are relatively open to change. Waste is a relative concept; what was once seen as an unwanted waste product can be turned into a valuable resource when benefits are discovered, recognized and demonstrated. Collective action, where groups of farmers jointly adapt and develop new procedures, appears to be key to such reframing. It opens up a space for negotiation of social norms and taboos that otherwise might have made individuals vulnerable to social exclusion and prevented wider acceptance and uptake of new practices. Groups can thereby act as a source of social change by strengthening both collective and individual agency.

The findings highlight that agricultural practices are fundamentally influenced by social and cultural dimensions in a way that clearly goes beyond seeing farming as solely an economic activity. Aspects that from an outsider's perspective may be seen as details of no importance, may evidently turn out to be fundamental to whether an initiative to promote a certain practice will be successful or not. Such promotion must therefore pay greater attention to the interplay between environmental, economic and social aspects influencing farmers' attitudes and choices. The action research process of joint experimentation and learning elucidates the proposition that farmers' close involvement in research not only generates practical solutions to local problems but may also strengthen their motivation and capacity to try new strategies and adapt to changing conditions. This illustrates the crucial role that sustainability science can play in engaging with communities to envision solution options, explore those options and jointly learn from such processes in order to develop strategies and direct action towards sustainability.

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