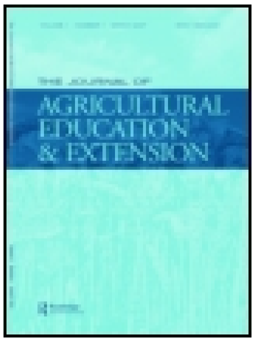

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The status of perception, information exposure and knowledge of soil fertility among small-scale farmers in Ghana, Kenya, Mali and Zambia

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ABSTRACT

Purpose: Soil fertility is decreasing in many parts of Sub-Saharan Africa. To mitigate this trend, various agricultural technologies are available, but their uptake by farmers has been low. Perception of the problem, information exposure, and knowledge play a major role in adoption of technologies. This study assessed empirically the levels of perception, knowledge and information exposure among African farmers as an indicator for potential adoption of soil fertility technologies.

Design/Methodology/approach: The study used survey data of more than 2,400 small-scale farmers selected through random sampling from Ghana, Kenya, Mali and Zambia. The survey investigated socio-economic factors, exposure to media, perception and knowledge of soil fertility and other information.

Findings: Many farmers did not perceive soil fertility as a major challenge, except in Mali; farmers were hardly receiving information on soil fertility from professional agricultural sources, and they often lacked accurate knowledge about soil fertility technologies. Radio was by far the most used information source for farmers.

Practical implications: The study has exposed the need for interventions to increase awareness, information exposure, and knowledge about soil fertility among farmers to strengthen the adoption of soil fertility technologies. It also calls for innovative ways of strengthening extension services through links with radio.

Theoretical implications: The role of communication in the uptake of agricultural innovations is still under-researched, and hence this study exposes the need to investigate in-depth knowledge, perception levels, and quality and frequency of information exposure on various channels of soil fertility management.

Originality: This is one of the few studies empirically measuring perception, information frequency on various channels, and knowledge of soil fertility among small-scale farmers in African countries.

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Introduction

Soil fertility decline is a major threat to sustainable agricultural production by smallholder farmers in sub-Saharan Africa (Mowo et al. 2006, 47; Vanlauwe and Giller 2006, 34). This situation is mainly attributed to soil nutrient depletion caused by intensification of land use without adequate replenishment of lost nutrients (Mugwe et al. 2009), leading to low productivity and reduced profitability of farming (Douthwaite et al. 2002; Henao and Baanante 1999; Wheeler and von Braun 2013).

Various technologies have been suggested to address the problem of declining soil fertility in the region (Vanlauwe, Tittonell, and Mukalama 2006), but the achieved rates of adoption are insufficient. Several studies have attempted to explain the reasons for the low uptake of many soil fertility management technologies. However, there is still no conclusive or consistent explanation for this occurrence (Meijer et al. 2015).

Nevertheless, perception of information, and knowledge play an important role in the adoption of technologies, both in the innovation-diffusion-adoption paradigm (Rogers 2003) as well as in the adopter-perception paradigm (Prager and Posthumus 2010), among other factors. Some researchers have suggested that for example proper communication with farmers plays a prominent role in the successful adoption of any agricultural innovation (Babu et al. 2012; Ahmad et al. 2015).

Presumably, the role of communication is even more vital in explaining the benefits of investing in soil fertility management because these are not only delayed, but also difficult to observe or distinguish from the effects of season-specific factors such as rainfall. This situation is distinct from, for example, planting a new maize variety where farmers are more likely to experience yield and income increases within one season.

It is obvious that communication with farmers has to be built on pre-existing information and knowledge of the target farmers. Since 2015, a multi-disciplinary research project called 'Farmer-driven Organic Resource Management to build Soil Fertility' (ORM4Soil),[1] is conducted in Ghana, Kenya, Mali, and Zambia. The project investigates technologies that are able to improve soil fertility, test adapted versions of them plus different combinations of inorganic and organic inputs, and then run a promotion campaign to increase the uptake of the best technologies. Eventually, the project aims at finding out what factors supported or hindered the uptake.

The ORM4Soil research project investigated the following soil fertility management (SFM) technologies (see Place et al. 2003 for details):

Use of inorganic fertilisers. Mineral fertilisers provide directly available nutrients for the plants, and might increase soil fertility due to higher yields, higher root mass and crop residues that serve as organic matter for the soil.

Animal manure. It provides organic matter to the soils, but less nutrients for the plants. It has challenges due to its bulkiness and thus laboriousness.

Intercropping. Main crops are grown jointly with other crops, mostly of the leguminous family, to provide nitrogen to the main crop, and add organic material.

Compost. Organic residues from all kinds of sources are collected and allowed to decompose in a specific manner.

Agroforestry. This approach integrates trees, plants, and animals. Trees provide organic matter and nitrogen for the soils, as well as fodder for animals.

Crop residues. Leaving crop residues on the field after harvest provides organic matter to the soil. Its use is contested as crop residues also serve as animal fodder or replace firewood.

To be able to measure the uptake and its contributing factors, a baseline study was conducted to determine – among other items – the status of farmers' perception of soil fertility as an agricultural challenge, exposure to information on soil fertility, and knowledge about existing soil fertility management (SFM) technologies. The baseline captures the actual situation; no intervention in terms of widely informing farmers has been made at this point of research. Only after the intervention an endline study will be conducted, which among others will assess the impact of the inputs given by the communication campaign.

This paper reports the specific findings of the baseline survey conducted in 2016 and 2017 to answer the following three research questions:

RQ1: What is the level of farmers' **perceptions** of poor soil fertility as a problem on the lands they are farming on?

RQ2: What is the status of farmers' exposure to **information** about soil fertility?

RQ3: What is the status of farmers' **knowledge** about soil fertility and soil fertility management technologies?

The paper is mainly descriptive, i.e. stating the current level of perception, information exposure and knowledge. Assessing the impact of various communication inputs and other factors on the uptake of technologies will be done later with data from the endline study.

Literature review on perception, information, and knowledge as factors for adoption

The ORM4Soil project assumes that learning about an agricultural innovation will boost its adoption. Being aware of the existence of a problem and having access to information about it, including knowledge of solutions, are important elements that enable and reinforce the learning process (Pannell et al. 2006).

The role of perception of a problem in gaining knowledge and motivating action

Media effects theory tells us that perception (e.g. of a challenge) is a pre-condition for gaining knowledge. It postulates that information disseminated via mass media plays an important role in increasing knowledge (e.g. about an innovation). However, social factors act as intermediates in determining knowledge gain such that high levels of education and high socio-economic status are correlated with higher media use and efficient information uptake (Bonfadelli 1999, 236). On the other hand, persons with low education level or socio-economic status – like most small-scale farmers in sub-Saharan Africa – take up information only when it is relevant to them and has an explicit link to their daily lives (Bonfadelli 1999, 237). Therefore, contextualised information, which considers the relevant challenges and provides solutions, has a higher chance of attracting attention and leading to gain in knowledge. In sum, knowledge gain through information is contingent upon previous perception of an issue as a particular problem.

In the context of the uptake of SFM technologies, models from communication and persuasion theory, especially those developed for health behaviour education are worth considering. The Theory of Reasoned Action and Theory of Planned Behaviour (Fishbein and Ajzen 1975; Ajzen 1991) claim that the most important determinant of behaviour is behavioural *intention*. Two determinants of intention are the attitude towards performing a given behaviour and the subjective norm associated with it (Glanz, Rimer, and Viswanath 2008, 70–72). These determinants require a certain level of awareness within individuals or groups about the problem that requires behavioural change in order to generate attitudes and norms. Therefore, with regard to soil fertility, perceiving the declining status of soil fertility as a problem would be a pre-requisite for the development of attitudes and norms that may lead to uptake of soil fertility management technologies. In addition, the adopter-perception paradigm argues that the adoption process starts with the perception that there is a 'need to innovate' (Prager and Posthumus 2010, 3). Therefore, the baseline study investigated specifically on the perception of soil fertility as a problem among farmers.

Exposure to information, knowledge gain, and adoption

The models used to explain the adoption of innovations consider information and knowledge as important pillars in this process. In the innovation-decision process described by Rogers (2003), farmers go through the stages of knowledge acquisition about an innovation, formation of positive or negative attitudes towards the innovation, and decision making to adopt and implement or reject accordingly. Rogers (2003) suggests that in most instances, mass communication channels are efficient ways of sharing knowledge about the innovations while interpersonal channels are deemed as more efficient in terms of creating attitudes that will foster rejection or adoption of an innovation.

Many other factors also influence adoption, the main ones being the characteristics of the innovation, characteristics of the decision maker, and the wider social system. To the best of our knowledge, there exists no consistent empirical evidence of the actual factors that drive adoption because different studies point at different factors with the same factor playing a role in one case but not in another, or having a negative or positive influence (Meijer et al. 2015).

Moreover, as the 'uptake [of these technologies] by smallholder farmers in Sub-Saharan Africa seems to be slow' (Meijer et al. 2015, 40), the ORM4Soil project assumes that the manner in which knowledge is communicated to farmers may be inappropriate, and therefore choose to investigate whether and how farmers receive information. Empirical studies in sub-Saharan Africa have examined mainly the kind of information channels farmers use to learn about agricultural innovations (Amudavi et al. 2009; Zossou et al. 2009; Fischler 2010; Adolwa et al. 2012; Murage et al. 2012; Kimaru-Muchai et al. 2013; Nyambo and Ligate 2013). However, the studies did not examine the quality of information or the frequency of exposure to information although other studies suggest that a strong information stimulus could be important. Perkins and Leclair (2011), for example, demonstrated that radio campaigns conducted in five African countries (Ghana, Mali, Malawi, Tanzania and Uganda) were successful in reaching farmers, improving their knowledge, and bringing about a significant increase in uptake of the technologies promoted. It is noteworthy that these campaigns had a strong information stimulus: they focused on one single improvement featured in a weekly programme for a period of four to six months and were broadcast in farmers' language when they had time to listen. Although the authors do not provide evidence of the effects of programmes with a lower stimulus, we argue that a single message transmitted once without repetition will probably not have as much effect on knowledge gain. These studies point to the need to explore the frequency with which farmers receive information from different sources.

In some cases, communication has also been considered as inappropriate for lacking farmers' local knowledge or an appreciation of their contexts (Kolawole 2013; Giller et al. 2011). Such information is characterised as 'top-down' because it is disseminated from 'experts' (researchers, extension staff) to farmers. This kind of top-down information flow breeds farmer apathy towards the recommended practice (Yahaya 2003) due to failure to incorporate their views about the new technology and message development (Brown, Nuberg, and Llewellyn 2018; Onasanya, Adedoyin, and Onasanya 2007).

'Participatory' or 'bottom-up' approaches have been recommended to solve these problems because they are considered more effective in enabling farmers to adopt recommended technologies (Elly and Silayo 2013; Dawoe et al. 2012). Participatory approaches make room for the inclusion of farmers' perspectives and local knowledge in the programmes of researchers, extension agents, and policy makers (Apata, Samuel, and Adeola 2009). Nevertheless, this dichotomy between top-down and bottom-up has to be seen as critical, as it implies that the local perspective, though often untapped, is an important source of knowledge among farmers (Nederlof and Dangbégnon 2007; Adjei-Nsiah et al. 2004). These assumptions, however, need to be examined further as some studies suggest that farmers' knowledge does not match with scientific insights (Adjei-Nsiah et al. 2004, 332, 341; Mowo et al. 2006, 56–57; Kolawole 2013).

For this paper, it was therefore pertinent to examine the existing knowledge of farmers with regard to soil fertility and soil fertility management.

Our research interest is shared by other recent empirical studies on the use of both modern and traditional communication channels by farmers and extension workers (Kacharo, Zebedayo, and Sife 2019; Birke, Lemma, and Knierim 2019; Bentley et al. 2019), the factors determining it (Yaseen, Ahmad, and Soni 2018), and on the influence of different dissemination strategies (classical extension, farmer-to-farmer extension, and reality television) towards adoption of agricultural technologies (see for example Shikuku 2019; Clarkson et al. 2018). However, the knowledge level of farmers, their perception of problems and information frequency did so far not play a role in those studies.

Methodology

The baseline survey was conducted in the eight sites of the ORM4Soil project.

Selection of sites by ORM4Soil project

The ORM4Soil project's selection of the countries and its two sites in each country was based on differences in rainfall, cropping patterns, soil type, availability of organic inputs, and socio-economic context Table 1.

Table 1. Sites of the ORM4Soil project.

	Ghana	Kenya	Mali	Zambia
First site	**Kade:** located at 6° 08′31.9"N 0°45′43.5"W; forest region; bimodal rainfall, 1200–1400 mm. Mean temperature 23°C. Soils are mostly clayey and loamy. Main crops: cocoa, oil palm, and maize; hardly any livestock kept	**Chuka:** located at 0° 19′16.7"S 37°39′20.5"E; Eastern slopes of Mount Kenya; bimodal rainfall, 1200–1400 mm; clay Nitisol; mean temperature 20°C; mixed crops; livestock present	**Mafèya:** located at 12° 57′59.8″ N and 7° 36′ 20.1″ W; Sahelian zone, annual rainfall of 700 mm; soils of low fertility; main crop is sorghum; few livestock, mainly cattle	**Kasama:** located at 10° 12′48.2"S 31°11′05.8"E; rainfall 1200 mm; fine loamy to clayey soils, highly weathered; main crops are maize, cassava, coffee and groundnuts, few livestock mainly small animals
Second site	**Sege:** located at 5° 52′42.8"N 0°21′33.9"E; coastal savannah; bimodal rainfall, 750 mm. Mean temperature 28°C. Soils are sandy. Main crops are tomato, pepper, sorghum and watermelon; livestock present	**Thika:** located at 1° 02′15.5"S 37°04′52.7"E; bimodal rainfall, 900–1400 mm; clay Nitisol; mean temperature of 26°C; main crops are coffee, tea; livestock present	**Zoumana Diassa:** located at 11° 33′14.5"N and 5° 38′29.7"W; annual rainfall 1000 mm; large diversity of soils; main crop is cotton, livestock present, mainly goats	**Chipata:** located at 13° 38′10.8"S 32°38′41.0"E; annual rainfall 800–1000 mm; loamy and clayey soils; main crops are maize, livestock, incl. cattle

Data collection

The areas for the baseline study were selected within a radius of 25–30 km around the location where the ORM4Soil project was conducting on-station and on-farm trials of adapted soil fertility management technologies. In each area, 300 farming households were targeted, not considering those who did on-farm trials.

The study used the random walk approach to systematically select farming households. The interviewers identified various reference locations as the starting points from where they proceeded to select the households from which the respondents were drawn. The respondents were household heads available at the time of the interview. The household heads were identified as male or female individuals, responsible for making key agricultural decisions on the farm. Only household heads aged 18 years and above took part in the study.

Research instrument

The research instrument was an interviewer-administered questionnaire developed by a team of researchers from all four countries to allow for country-specific adaptations where necessary and comparability of the data across countries. The study collected data on farm characteristics, farming context and socio-economic characteristics of the respondents such as age, education, and media use. Data on decision-making mechanism in the household, perception of soil fertility problems, frequency of receiving information about soil fertility, and knowledge about soil fertility and management practices was also collected.

I On perception, the study asked the respondents to indicate if they had a soil fertility challenge on their farms by selecting from three options as follows: 'Soil fertility is (a) not a problem at all, (b) a minor problem, and (c) a major problem'. The respondents were also asked to indicate whether they had observed any changes in soil fertility in the last five to ten years using the following five-item scale: 'Soil fertility has

(a) declined tremendously, (b) declined, (c) remained stable, (d) somewhat improved, and (e) improved tremendously'.

II Information exposure was assessed through enquiring about farmers' sources of information with regard to soil fertility and the frequency of exposure to such information. The questionnaire listed 23 information sources (from neighbours, over radio to agro-dealers) for which the respondents were asked to indicate the frequency of using 'never', 'rarely' (once in 3 months), 'often' (1–2 times a month) or 'very frequently' (once a week or more frequent). In the analysis those four categories were condensed into two to distinguish between rare users (= 'never' plus 'rarely') and frequent users (= 'often' plus 'very frequently').

III Moreover, the study used open-ended questions to determine farmers' knowledge on soil fertility by asking them to explain the reasons for observed soil fertility change. The respondents were also required to explain aspects of common practices of SFM technologies such as handling animal manure, intercropping, and leaving crop residues in the field. These three SFM technologies (out of those mentioned in the introduction) were the most jointly practiced by farmers in all four countries. Using qualitative content analysis (Mayring 2015), agronomists and social scientists recoded the responses jointly to identify accurate, incomplete, or inaccurate knowledge relating to soil fertility management.

As for knowledge on animal manure, it was tested by asking respondents to describe its management until the time of application to the fields. Qualitative coding identified three categories of knowledge as being 'correct knowledge' (that is, resting time of 3–4 weeks and leaving it for some time plus mentioning 'decay' and 'decompose'). The criteria for identifying 'incomplete knowledge' was mentioning only one factor from 'letting it dry'; 'putting under the shade'; or simply resting 'for some time'. 'Inaccurate knowledge' was indicated by any of these items: apply 'directly from the cowshed', or apply 'fresh', 'put in sacks or bags', or 'no idea'. This question applied only to those farmers who stated previously that they knew about the practice.

The questions on intercropping and leaving crop residues were related to perception rather than precise knowledge. Farmers were asked to describe the reasons for practicing intercropping. The identified 'soil fertility perceptions' in such responses were 'intercropping provides nitrogen', or 'it increased soil fertility'. Responses that focused on intercropping as a method to mitigate limited land size, or source of higher profits due to sale of two crop proceeds, were considered as not related to soil fertility.

Lastly, farmers were further asked about the benefits of leaving crop residues on the field after harvest. The responses were classified into benefits related to soil fertility (adds nutrients, increases soil fertility, conserves water, and organic input), and benefits not related to soil fertility (weed control, supports plant growth, cools the soil, and increases yield).

Analysing the data, we first conducted a descriptive data analysis for all variables, in order to get an impression how the situation is and how distinct the results are. Second, we looked at the correlation of the demographic variables with (I) perception of soil fertility, with (II) information exposure and (III) knowledge on soil fertility, and at the correlation between variables on (I) perception and (II) information exposure. However, the main goal of the analysis was to describe the actual situation.

Results

In this section, we present the results starting with a general overview on the socio-demographic profile of respondents.

Socio-demographic profile

The sample represents a small-scale farmer setting. Most farms were both subsistence- and market-oriented, but with rather limited land size (Table 2).

Our sample was almost evenly distributed with regard to the gender of household heads (males in Ghana, 59%; Kenya, 43%; Zambia, 52%) with the exception of Mali (96% male respondents) where hardly any females were heading farm households. This shows an important role of women in farming, as they often lead the farming enterprise. Even if men lead, women are integrated in decision-making, but with remarkable country differences. Zambia and Kenya showed a large proportion of joint decision making of spouses (56% and 46%) whereas Ghana had less (26%) and Mali almost none (1%).

Nevertheless, we did not discover significant gender differences with regard to our main criteria perception, knowledge and information exposure.

Farmers in all the countries were much older than the average of the economically active population, which is a typical set-up in rural areas of Africa. In Ghana, Kenya, and Mali, the proportion of farmers aged 51 years and above represented more than 40% of those interviewed. A low share of the elderly characterises the current age structure in sub-Saharan Africa. For example, the region has 9.7% people above 50 years, and only 19% of the economically active are elderly individuals (51–75 years, own computations using UN 2017).

In contrast, young farmers between 18 and 30 years took up only about 10% of the sample in Ghana and Kenya and less than 4% in Mali. In Zambia, almost one-quarter of the sample consisted of young farmers.

Generally, the level of formal education was quite similar in Ghana, Kenya, and Zambia, where at least 40% of the farmers either had no formal education or had not completed primary level education. The exception was Mali, with even more than 80% of the

Table 2. Socio-economic and demographic characteristics of respondents.

	Ghana ($N = 627$)	Kenya ($N = 592$)	Mali ($N = 600$)	Zambia ($N = 622$)
Farm size per household member (acres)				
Mean	1.7	0.44	1.51	1.16
Median	1.16	0.25	1.16	0.79
Age structure of farmers (%)				
18–30 years	12.1	10.1	3.7	23.7
31–50 years	44.7	43.4	37.2	47.6
51 years and above	43.1	46.5	59.1	28.7
Total	100.0	100.0	100.0	100.0
Level of education[a] *(%)*				
Very low	**52.2**	44.0	**86.0**	**53.3**
Low	40.4	35.5	6.8	39.2
Medium	5.4	14.6	2.3	6.0
High	1.9	5.9	4.8	1.5
Total	100.0	100.0	100.0	100.0

[a]*Definitions*: Very low = never went to school or attended primary school; Low = primary school completed or secondary attended; Medium = secondary completed or tertiary college attended; High = Tertiary college or university completed.

farmers belonging to this group. In Ghana, Kenya, and Zambia, about 40 percent of the farmers had completed primary education or attended secondary school. Kenya had a relatively higher proportion of farmers who had completed or gone beyond secondary level education (6%).

Perception, information, and knowledge

RQ1: status of perception of soil fertility as a problem

In all the four countries, at least 60 percent of the respondents reported some level of soil fertility problem. However, the perception of soil fertility as a severe challenge was highest in Mali (92.3%), but relatively low in Kenya (16%), Zambia (22%), and Ghana (28.4%) as shown in Table 3. In the three countries, about one-third of the respondents even reported that they did not have a soil fertility problem.

About half of the farmers in Ghana (58.2%) and Zambia (55.2%) reported that they were experiencing declining soil fertility, but almost all the farmers in Mali (94.5%) faced that situation (Table 4). These findings imply that soil fertility might become a severe problem in the future, if the declining trend is not addressed. In Kenya, slightly more respondents (41%) reported improvement in soil fertility compared with those who thought that there was a decrease (38.9%).

RQ2: farmers' exposure to information on soil fertility

Table 5 shows the proportion of farmers who frequently used one or more sources to access information on soil fertility. In order to identify specific patterns, the information channels were clustered[2] into five categories for ease of analysis as follows:

- Professional (extension services, research, agricultural shows, field days)
- Mass media (radio, television, newspapers, Internet, mobile phones, SMS)
- Interpersonal (family members, fellow farmers, neighbours and friends, and leading farmers)
- Commercial (agro-dealers, traders and buyers)
- Other (church, public meetings, and market days)

Table 3. Farmers' perception of soil fertility as a problem.

	Ghana (*N* = 627) %	Kenya (*N* = 592) %	Mali (*N* = 600) %	Zambia (*N* = 622) %
Not a problem	37.0	31.4	2.5	36.7
Minor problem	34.0	52.4	5.2	41.2
Major problem	28.4	16.0	92.3	22.0

Note: The figures do not completely add up to 100% due to rounding differences or single missing answers.

Table 4. Change in soil fertility.

	Ghana (*N* = 627) %	Kenya (*N* = 592) %	Mali (*N* = 600) %	Zambia (*N* = 622) %
Tremendous decline	17.4	4.1	75.8	7.1
Decline	40.8	34.8	18.7	48.1
No change	35.2	19.8	2.5	34.9
Improvement	4.9	33.8	1.5	5.1
Tremendous improvement	.6	7.3	.5	3.7

Note: The figures do not completely add up to 100% due to rounding differences or single missing answers.

Table 5. Exposure to soil fertility information from different sources.

Sources of information		Ghana	Kenya	Mali	Zambia
Professional sources[a]	**Frequent Users**	**17.4%**	**14.9%**	**58.3%**	**48.4%**
	Rare Users	82.6%	85.1%	41.7%	51.6%
Mass media[a]	**Frequent Users**	**22.8%**	**49.5%**	**83.2%**	**60.8%**
	Rare Users	77.2%	50.5%	16.8%	39.2%
Interpersonal[a]	**Frequent Users**	**17.7%**	**51.2%**	**87.0%**	**51.4%**
	Rare Users	82.3%	48.8%	13.0%	48.6%
Commercial sources[a]	**Frequent Users**	2.9%	7.6%	3.8%	**13.0%**
	Rare Users	97.1%	92.4%	96.2%	87.0%
Others (church, market, baraza)[a]	**Frequent Users**	0.8%	**11.5%**	8.7%	10.5%
	Rare Users	99.2%	88.5%	91.3%	89.5%

[a]A "frequent" user of the clustered sources is defined as someone who uses at least one element of the clustered elements often or more frequently.

Mass media and interpersonal contacts were the most utilised sources of soil fertility information with the level of frequent use varying from country to country. Farmers in Ghana used those two sources the least, but almost three-quarters of the respondents in Mali reported using them frequently.

Professional sources were used much less. In Ghana and Kenya, 83% and 85% of farmers respectively indicated that they did not frequently use any of the four professional sources to obtain information about soil fertility. In contrast, a substantially higher proportion of farmers in Mali and Zambia obtained information from those sources, 59% and 48% respectively.

Commercial sources were utilised frequently by less than 10 percent of the respondents in all the countries except Zambia (13%).

Table 6 contains information on the proportion of farmers using specific sources of information. The farmers in Mali showed the highest level and most diversified use of the different information sources. The level of frequent use of the various sources of information was generally low in Ghana. In all the four countries, radio was the most utilised source followed by various interpersonal contacts in Kenya, Mali, and Zambia. Agricultural extension was the second most important source in Ghana but this source came after interpersonal sources in Mali and Zambia and after interpersonal sources and television in Kenya. In Zambia, field days, agricultural shows and church meetings played a major role as sources of information; in Kenya, the traditional community meeting (Baraza) was also relevant. It is worth mentioning that the use of print media, mobile phones, social media or the internet hardly played a role as sources of soil fertility information in all countries.

This study also sought to shed light on the status of availability of information about agricultural innovations by asking respondents to give reasons for not implementing any kind of agricultural innovation during the last few years. In all countries, more than 50% of farmers had not implemented any innovation in the three years leading up to the study. In Kenya and Zambia, 47% and 45% of the farmers respectively, who stated that they had not implemented an agricultural innovation gave the reason of lack of information or knowledge about innovations. In Ghana and Mali, this reason was given by 26% and 10% of the respondents respectively.

Table 6. Use of information channels for soil fertility.

	Percentages of frequent users (multiple answers)			
	Ghana *N* = 627 %	Kenya *N* = 592 %	Mali *N* = 600 %	Zambia *N* = 622 %
Family	4.0	30.1	**46.3**	24.6
Neighbours	6.9	25.5	**67.3**	26.2
Other farmers	9.7	27.4	**70.0**	28.5
Leading farmers	1.4	3.4	12.3	8.7
Extension	**15.5**	**8.8**	**51.8**	**37.9**
Research	2.2	2.0	11.0	6.8
Agro-dealers	2.7	3.5	2.3	6.6
Traders	0.3	5.4	1.8	8.8
Community groups	0.5	7.3	5.0	15.4
National Radio	3.5	4.6	**72.3**	**30.4**
Local Radio	**22.2**	**42.6**	**57.8**	**56.9**
Television	4.1	**16.7**	**37.7**	5.6
Internet	0.2	1.9	0.3	0.6
Social Media	0.0	1.0	0.0	0.8
Magazines	1.0	2.0	0.3	1.6
Mobile phones	0.0	1.0	0.7	1.0
Agricultural shows	0.5	3.0	6.0	**14.3**
Church/Mosque	0.0	4.7	0.5	**8.4**
Field days	0.3	2.4	3.8	**11.6**
Market	0.2	1.2	8.5	3.7
Baraza	0.6	7.8	0.7	2.6
Training	0.3	1.9	1.7	2.1

Surprisingly, there were no significant differences on the frequent use of information sources, with regard to gender. Only in Ghana, did men use all information sources a bit more often by a margin of 5% points higher than women.

There is an obvious correlation between the frequency of information and perception of soil fertility: farmers from Mali showed the highest perception of soil fertility as a problem, and frequently use various information channels on soil fertility. In Ghana and Kenya, we observed the opposite phenomenon: poor exposure to information about soil fertility was correlated with low perception. But we need to be cautious in interpreting that as a causality.

RQ3: knowledge of farmers on soil fertility and SFM technologies

Farmers' reasons for observed change in soil fertility was used as an indicator for knowledge.

Generally, the reasons given to explain the observed changes in soil fertility revealed important differences between the countries. For instance, farmers in Ghana (41%) and Mali (58%) attributed the declining soil fertility to continuous cultivation but this was not recognised as an important factor in Kenya (5%) and Zambia (10%). Deforestation was mentioned only in Mali (8%), while mono-cropping (10%) and burning field residues were mentioned only in Zambia (9%).

Also, the farmers in Kenya attributed the increasing levels of soil fertility to the use of animal manure (47%) and to a smaller extent (10%) to the combination of fertiliser and animal manure; only the farmers in Zambia mentioned crop rotation to a large extent (10%) as a source of soil fertility improvement, which stands out against the rest of SFM technologies in focus of ORM4Soil (intercropping, mulching with crop residues, and composting). These were hardly mentioned by farmers as a reason for improvement, except the use of animal manure in Kenya.

In all countries, the contribution of inorganic fertilisers to soil fertility was inconsistent: some farmers mentioned a negative impact (between 4% and 10%), while others stated a positive contribution (between 3% and 8%).

With regard to knowledge, it is remarkable that many explanations given by farmers were not clearly related to soil fertility in general, not related to decline or increase, or not related at all to the question. For example, farmers mentioned climate change and lack of rain as a negative influence for soil fertility (between 6 and 10%). This seems difficult to argue for, as rainfall influences yields, and only indirectly soil fertility. Other farmers mentioned factors like diseases or specific soil types although those cannot be regarded as factors of change. Other explanations pointed to yields (' … because I have good yields', or 'My yields have been declining for many years.') which are not reasons, but indicators of soil fertility status. A number of farmers admitted that they did not know the reasons. The share of all those answers was quite large (between 13% in Mali to 35% in Ghana, see 'other explanations', lower part of Table 7). In sum, it can be seen that a considerable proportion of farmers is not knowledgeable about the factors that influence soil fertility.

Table 8 provides information on farmers' knowledge about animal manure.[3] These results are based only on the number of farmers who indicated that they knew about the practice. The majority of these farmers did not possess accurate knowledge about the management of manure. The highest proportion of farmers having the correct knowledge about animal manure was found in Kenya (about 40%, plus 33% with some knowledge in the right direction). In Zambia, the proportion of farmers with accurate knowledge

Table 7. Reasons for change in soil fertility.

Explanations for decline in soil fertility	Ghana $N = 502^a$ Percent	Kenya $N = 538^a$ Percent	Mali $N = 600$ Percent	Zambia $N = 617^a$ Percent
Continuous cultivation	41.2	5.0	58.5	10.2
Mono-cropping		0.7		10.0
Soil erosion /Leaching		6.7	6.3	4.2
Deforestation			7.5	
Burning crop residues /cutting trees in				9.6
Negative contribution of inorganic fertiliser	3.2	7.2	3.8	9.7
Sub-Total in % of N	***44.4%***	***19.6%***	***76.1%***	***43.7%***
Explanation for increase in soil fertility				
Positive contribution of animal manure or other organic inputs	5.6	46.7	8.8	2.7
Use of animal manure plus fertiliser		10.4		0.8
Positive contribution of inorganic fertiliser	8.0	2.6	2.3	4.4
Use of crop rotation		0.7		10.4
Use of other SFM technologies (intercropping, compost, crop residues, fallowing, agroforestry, mulching)	7.6	2.9		11.6
Sub-Total in % of N	***21.2%***	***63.3%***	***11.1%***	***29.9%***
Other explanations				
Lack of rain and climate change	6.6	6.1	9.5	3.4
Increase in pests and diseases	1.4	0.6	0.3	1.8
Soil type (both for increase of decrease)	10.0			1.6
Unclear answers (like too many trees, or land shortage, population growth, answers not related to question, Don't know)	16.6	10.5	2.8	19.8
Sub-Total in % of N	***34.6%***	***17.2%***	***12.6%***	***26.6%***
Total in %	*100%*	*100%*	*100%*	*100%*

[a]in Ghana 20%, in Kenya 10.2% and in Zambia 0.8% of respondents did not answer this question.

Table 8. Awareness and knowledge of preparation of animal manure.

	Ghana (*N* = 627) %	No.	Kenya (*N* = 592) %	No.	Zambia (*N* = 622) %	No.
Awareness of Animal Manure						
Do not know **about** the practice	**44.2**	277	**5.4**	32	**51.4**	320
Know about the practice	**55.8**	**350**	**94.6**	**560**	**48.6**	**302**
Knowledge of handling animal manure[a]						
	(*N* = 350) %	**No.**	**(*N* = 560) %**	**No.**	**(*N* = 302) %**	**No.**
Accurate **knowledge**	**8.0**	28	**41.1**	230	**21.9**	66
Incomplete **knowledge**		0	**32.7**	183	**17.5**	53
Inaccurate **knowledge**	**74.8**	262	**26.3**	147	**34.4**	104
No response	**17.1**	60			**26.2**	79

[a]Based on the number of respondents who said that they knew about the practice.

on the management of animal manure was 22%, and in Ghana, it was 8%. Although we did not establish thresholds for knowledge levels being high or low, we would characterise the knowledge levels in Zambia and Ghana as low.

Regarding intercropping, in Ghana (63.5%), Mali (66%) and Zambia (48%), many farmers did not know the practice. On the other hand, in Kenya, the practice was known to 85 percent of the farmers. The results reported are based on the number of farmers who knew the practice. A distinction was made between soil fertility related knowledge or perception and other perceptions not related to soil fertility Table 9.

Zambia had the highest share (66.3%) of farmers with soil fertility related perception of the importance of intercropping, followed by Ghana. In Kenya and Mali about 70% of the farmers who stated that they knew about intercropping, related its importance to other characteristics. Only 17% in Kenya and 24% in Mali mentioned its soil fertility enhancing properties.

More than two thirds of the farmers in all countries knew the practice of using crop residues. Majority of farmers in Ghana, Mali and Zambia (86–87%) possessed knowledge about the benefits of crop residues in relation to soil fertility. While many farmers in Kenya (45%) admitted that they knew the practice but were not familiar with the benefits Table 10.

Interestingly, it was noted that none of the knowledge questions above differed significantly when disaggregating for gender.

Table 9. Awareness and perception of intercropping as a soil fertility improving technology.

	Ghana (*N* = 627) %	No.	Kenya (*N* = 592) %	No.	Mali (*N* = 600) %	No.	Zambia (*N* = 622) %	No.
Intercropping awareness								
Do not know about the practice	**63.5**	398	**14.7**	87	**66.3**	398	**47.6**	296
Know about the practice	**36.5**	**229**	**85.3**	**505**	**33.6**	**202**	**52.4**	**326**
Perception of those who know about intercropping[a]								
	(*N* = 229) %	**No.**	**(*N* = 505) %**	**No.**	**(*N* = 202) %**	**No.**	**(*N* = 326) %**	**No.**
Perception related to soil fertility	**42.8**	98	**17.0**	86	**24.3**	49	**66.3**	216
Perception not related to soil fertility	15.7	36	**71.9**	363	**67.3**	136	26.4	86
No knowledge about Intercropping		0	9.7	49	5.4	11	7.4	24
No response	41.5	95	1.4	7	3.0	6		

[a]Based on the number of respondents who said that they knew about the practice.

Table 10. Awareness and knowledge of benefits of crop residues.

	Ghana (*N* = 627) %	No.	Kenya (*N* = 592) %	No.	Mali (*N* = 600) %	No.	Zambia (*N* = 622) %	No.
Crop residue awareness								
Do not know about the practice	30.1%	189	10.8%	64	6.9%	41	1.4%	9
Know about the practice	**69.9%**	**438**	**89.2%**	**528**	**92.1%**	**559**	**98.6%**	**613**
Knowledge of the benefits of crop residues[a]								
	(*N* = 438) %	**No.**	**(*N* = 528) %**	**No.**	**(*N* = 559) %**	**No.**	**(*N* = 613) %**	**No.**
Benefits related to soil fertility	**86.3%**	378	55.5%	293	**86.8%**	485	**86.0%**	527
Benefits not related to soil fertility or don't know	13.7%	60	**44.5%**	235	13.2%	74	14.0%	86

[a]Based on the number of respondents who said that they knew about the practice.

Discussion

Age and education

The farmers in our sample were older than the average age level of the economically active population groups suggesting that farming was not an attractive occupation amongst young people, with the exception of Zambia.[4] Additionally, the farmers had limited formal education (except in Kenya). Both factors are important in communication with farmers, as they limit the spectrum of options in developing and disseminating messages to farmers about innovations. Usually, elder people are less reachable via modern ICTs, and less educated people have challenges in understanding complex messages.

Status of perception of soil fertility as a major problem

In Kenya, Ghana and Zambia, there is an indication of the existence of a perception among farmers that soil fertility levels are declining but this perception is limited because less than a third of farmers see soil fertility as a major problem. The exception is Mali, where this perception is ubiquitous. Apparently, many farmers consider soil fertility as a challenge, but currently it does not seem to be their most important problem. This insight is corroborated by other inquiries within ORM4Soil (Participatory Rural Appraisals (PRAs) which were conducted in 2015, and Innovation Platforms (IPs) which have been held since 2016), where farmers were highly concerned about profitability, market access, access to inorganic fertilisers or seed quality, but not soil fertility.

The limited perception of problems with soil fertility contrasts to the scientific evidence of accelerated soil degradation in Sub Saharan Africa due to non-sustainable farming practices causing a significant decline in soil organic matter and nutrient content (Chivenge, Vanlauwe, and Six 2011; Konaté 2008; Jones et al. 2013).

However, farmers' perception seems to be in line with the assessment on policy level. In all four countries, policy documents mention the soil fertility challenge in the first place (GoK 2010; NAIP 2013), but not as a priority one. The policies for increased agricultural production and strategies for achieving this goal seem to place more emphasis on promoting access and use of inorganic fertiliser. Emphasis on action for sustainable soil fertility improvement is missing. These policies ignore basic insights from agronomy that fertilisers mainly increase yields whereas organic inputs build up soil fertility (Vanlauwe and Giller 2006, 40).

Frequency of information exposure

Our results show different levels of farmers' exposure to information on soil fertility among the countries as would be expected. The farmers in Ghana appear to be receiving little externally generated information, which also hints to limited availability of information to farmers.

For Ghana and Kenya it is especially worrying that farmers have very limited exposure to soil fertility information from professional sources (around 15% of farmers use them frequently), because (a) information provided by professional sources is deemed accurate and adequate, because experts provide it; and (b) various studies have identified professional sources as major ways in which information about agricultural innovation finds its way to farmers (Amudavi et al. 2009; Fischler 2010; Murage et al. 2012; Kimaru-Muchai et al. 2013). If farmers do not often use these professional channels, they may lose trust in any information, which will eventually hinder adoption. By contrast, information from neighbours or mass media may not be sound, especially when the information is not provided by professional experts and mass media lack adequate knowledge themselves. For example, in Benin, the radio stations responsible for producing an agricultural programme indicated that they lacked adequate knowledge to satisfy farmers' information needs (Zossou et al. 2012). Another study in Nigeria recommended that agricultural programmes should be presented by individuals who were competent in the field of agriculture (Ariyo et al. 2013). While in Kenya, private vernacular radio stations were not providing the agricultural information that farmers needed the most (Mithamo, Onyango, and Mwangi 2015) or did not provide the farmers with several options (Spurk et al. 2014). This therefore, indicates that mass media need to develop capacity in agricultural knowledge to be able to serve farmers better, and to include extension staff into their programming. This may result in dissemination of accurate information and compensate for the inadequate direct contact between farmers and extension services.

In Zambia and Mali, farmers receive more often information from professional services. This may be due to the confidence of farmers in extension officers and better access to them in the project but the national figures of farmer to extension staff ratios are generally very high and quite similar.[5]

With regard to the correlation between the frequency of information and perception of soil fertility as a problem, the causality is not clear. We may argue that exposure to information leads to perception, or we may say that the existing perception of soil fertility as a problem leads to more consumption of information. Maybe both processes work in parallel. It would also be possible that soil fertility in the Malian sites is objectively on a lower level than in the Kenyan sites for example, so the correlation would be spurious.

In conclusion, there is limited access by farmers to information on soil fertility, especially from professional sources, which is supported by some farmers saying they do not receive information on any innovation at all. This may contradict a common belief in the agricultural research community about an abundance of information for farmers. We have not analysed this supply side of information, but without doubt, there is an abundance of recommendations to enhance soil fertility from the research community (Adolwa, Schwarze, and Buerkert 2018, 436), especially considering the availability of information on the internet. This shortage might be partly compensated by the use of mass media and other channels, as some might voice professional sources in their transmissions, but we do not have data on that.

Knowledge and perception of soil fertility and SFM technologies

The results on knowledge point to differences between countries and with regard to the various technologies. It looks natural that farmers in Kenya, who experienced an increase in soil fertility, mention first the factors leading to an increase, and the farmers in Mali, facing soil fertility as a threat, talk more about the elements leading to decline (see Table 7). The farmers in Zambia and Ghana also reflect mostly their country-specific context. However, in all countries, the specific organic soil fertility technologies (except animal manure in Kenya) seem not to be known as essential elements of soil fertility change.

Additionally it is worrying, that some explanations of farmers with regard to soil fertility change contradict scientific evidence or indicate that farmers had no knowledge at all about the reasons for soil fertility change. It is worth noting that depending on the country between 13% and 35% of farmers showed this limited or inadequate knowledge.

This insight is confirmed when we look at specific technologies. Amongst farmer who indicated to know the technique of use of animal manure, only less than 50% were answering correctly to the related control questions (and far below that level in Zambia and Ghana). With respect to intercropping more than 50% of farmers in Ghana and Zambia had the correct soil fertility perception, in contrast to farmers in Kenya and Mali who related intercropping mostly to different features, but not to soil fertility. Only, the benefits of leaving crop residues were related to soil fertility by about 80% of farmers in all countries, with the exception of Kenya.

There were not many studies to compare our findings with. Few studies try to measure farmers' knowledge, and the few (Adjei-Nsiah et al. 2004; Mowo et al. 2006) did not confront it with the status of scientific evidence, by crosschecking farmers' understanding of the mechanisms leading to soil fertility enhancement.

Conclusions and recommendations

Soil fertility was not considered as a major challenge by farmers in this study, which seems to be in agreement with government policies that tend to give priority to the need to increase agricultural productivity and yields, but not the need to build up soil fertility. As perception of a challenge is an important element in addressing problems, this study recommends that (a) declining soil fertility and its long-term consequences is included in the agenda for both agricultural policy and communication with farmers, and (b) technologies that build up soil fertility and solve other urgent challenges of farmers at the same time are explored and recommended.

The results of this study confront the common perception within the research community that agronomic research outputs are widely disseminated and are available to farmers (see also Adolwa, Schwarze, and Buerkert 2018, 436). However, this is not the case. For many farmers, direct information from professional sources on soil fertility is scarce and hardly available, and thus used rarely.

In contrast to previous beliefs, recent studies show that radio is the main and best channel to reach mass audiences in farming communities and rural areas; digital channels are not yet relevant (Adolwa, Schwarze, and Buerkert 2018; Spurk et al. 2014). This is largely confirmed by our study. Radio transmissions can be complemented with services on mobile phones to become interactive, but mobile phones alone or other online devices are far from being suitable to reach mass audiences. TV only becomes important in areas where electricity is readily available. Therefore, we recommend undertaking special efforts in research to inquire more about the appropriate dissemination of information to and with farmers.

Concerning the limited knowledge about soil fertility, the recommendation is to provide basic knowledge on soil fertility mechanism in any communication campaign before talking about specific technologies, as a first step to improve uptake of the technologies.

We also recommend that extension services are strengthened: and for mass media to be transformed into a reliable provider of information about soil fertility. One option could be linking up extension services with local radio stations. This would greatly enhance the impact of extension services. However, this would also require well-trained reporters with specialised knowledge in agriculture.

Notes

1. ORM4Soil is jointly funded by the Swiss National Science Foundation and Swiss Development Cooperation, under the 'Swiss Programme for Research on Global Issues for Development' (R4D).
2. A 'frequent' user of the clustered sources is defined as someone who uses at least *one* element of the clusters often or more frequently.
3. Mali is left out for this analysis as the question was not well understood by farmers and their answers focussed on the mode of transportation.
4. The age distribution of farmers was confirmed by extension officers working with ORM4Soil in the countries as typical in their regions.
5. In Kenya, Mali, Ghana and Zambia the ratio of public extension officers to farmers is between 1:1000 and 1:1200 for crops.

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