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Why Agricultural Tools Work in Theory But Aren't Adopted in Practice: A Grounded Theory Approach to ICT in Ghana and Kenya

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ABSTRACT: Organic fertilisers could contribute to addressing the issues of declining soil fertility, food security and waste management by recycling human waste for use in sub-Saharan Africa. The variable nutrient content of such products can make targetted application more difficult than in chemical fertilisers. One solution to this could be the use of in-field soil testing and information, particularly with the expansion of mobile technology. This research investigated the role of information and soil testing in 43 farmers using human waste derived fertilisers in Kenya and Ghana. Interviews were conducted to understand the use and sources of information in farming and the perception of soil testing technologies. It was found that mobile based testing was unlikely to be adopted for reasons of low priority, the type of knowledge being shared and trust after failures of different projects. Farmers did not see soil testing as the major issue that they needed to solve. Mobile technology was mostly used for visual and oral communication whereas soil testing often provided information in an unsuitable way. Farmers also had limited trust in new projects as they had previously had project failures that did not help them. In order to achieve sustainable adoption of technology there needs to be improved methods of disseminating and learning from project failures to prevent repeated attempts at inappropriate technology in the future.

KEYWORDS: Africa, agriculture, failures, international development, organic agriculture, soil testing, sanitation, farmer perception

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Introduction

The circular economy for sanitation is cited to address both SDG 2 (zero hunger) and SDG 6 (clean water and sanitation) through innovative systems which collect human waste from households, treat it, turn it into fertiliser which is then applied to land and improves crop productivity (McNicol et al., 2020). However, the demand for and revenue from this kind of fertiliser is not yet sufficient to drive improvements for sanitation further up the chain (Mallory et al., 2020). One potential barrier to the adoption of human-waste derived fertiliser (HWDF) by farmers is its nutrient variability, which may make targetted application more difficult than with current chemical fertilisers of set ratios of nutrients (Golicz et al., 2019; Mallory et al., 2022). To avoid over application of nutrients that can lead to both wasted resources in a farm context and nitrogen run off that leads to pollution of water bodies, one potential solution is the use of in-field soil testing which can yield quick soil assessments (Golicz et al., 2021; Nyi et al., 2017). Such kits have already been established in countries in the Global North and in South-East Asia (Jemison & Fox, 1988; Nyi et al., 2017; Wetselaar et al., 1998). These in-field test kits are now combined with apps or software that can provide information for farm management.

At a simple level, ICT tools for agriculture can support easier and cheaper communication between farmers and buyers reducing costs of journeys for sales and purchases (Hanson & Heeks, 2020). This has been shown in fishing markets where mobile communication lowers the cost of getting price information from different markets enabling sellers to get the best price, eventually stabilising the differences between markets (Jensen, 2007). This is comparable to horticulture as products are also quickly perishable so fast decisions need to be made in terms of finding markets.

At a more technical level, ICT tools can also provide inputs to support the agronomic management of the farm (Yonazi et al., 2012). For example, providing information that can inform decisions about the application of fertilisers based on assessment of soil, climate or market conditions. Such information is especially important with animal or human-waste derived fertilisers whereby nutrient content is variable, as compared to industrially produced fertilisers that have standard application approaches (Moya et al., 2019).

Despite the focus and hopes for ICT to improve agricultural productivity, particularly in Sub Saharan Africa, a review of the 'app' landscape in mobile technology for farmers found that there is an over-supply of apps that provide singular functions such as soil testing or market prices and hence there is low adoption (Eichler Inwood & Dale, 2019). This echoes findings from an earlier review into technology adoption within agriculture, that highlighted a problem with technologies addressing the 'wrong problem' in the eyes of farmers (Graves et al., 2004). For example, subsistent farmers often did not prioritise soil fertility when adopting technologies but focussed on technologies that impacted on the farmers perception of the 'workability' of soil (Graves et al., 2004). This indicates a broader issue in the mismatch between scientific and

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expert communities, often responsible for tool development, and local farming communities in terms of how they conceptualise farming as a system and identify priority problems (Halbrendt et al., 2014; Lalani et al., 2021).

Kenya and Ghana have been selected as cases for this study. Kenya is a hub of development for technology and information services and is largest investment market for the mobile economy in Sub-Saharan Africa except South Africa (GSMA, 2018). It is a champion country for many developments in ICT in agriculture (Verdier-chouchane & Karagueuzian, 2016). The expansion of mobile-phone based technology into sectors that were previously difficult to reach is of particular significance in Kenya where in 96% of households at least one member now uses M-Pesa, a mobile-based banking system (Suri & Jack, 2016). Ghana was also selected as a contrasting case as usage of mobile and ICT information in farming is less developed here (GSMA, 2018; Verdier-chouchane & Karagueuzian, 2016).

This paper presents findings from a project investigating the use of nitrate-sensitive paper strips alongside Akvo Caddisfly (an app that temporarily turns a smartphone into a portable reflectometer), to understand farmers perceptions and willingness to adopt such technologies in Kenya and Ghana (Mallory et al., 2022). The paper uses a grounded theory approach to examine these issues and to locate the process of app adoption within an understanding of how farmers currently use and share information within agronomic decision-making. This leads to a discussion about why the app and soil testing kits are unlikely to be adopted in these types of context, and the implications for the circular economy for sanitation. Broader reflections are given on the implications for development research and its focus on technological innovations that are often inappropriate.

Methods

Study context

Data collection and analysis. The farmers interviewed were purposively selected to reach the regular customers of Human Waste Derived Fertiliser (HWDF) producing companies. These were targetted as the original aim of the study was to inform the increased use of HWDF, but the final results had much wider relevance. Snowball sampling was used to find other HWDF users until saturation was reached. In both countries, the farmers using HWDF were horticultural farmers growing cash crops, as this is the market segment targetted by HWDF-producing companies.

Semi-structured interviews were conducted with the twenty farmers in Kenya who were currently using HWDF supplied from a sales hub in the town of Embu and 23 farmers in Ghana who were identified by the extension worker and research assistant in two irrigation projects where the HWDF Company were selling their fertiliser. In terms of understanding how they interacted with mobile technology for information in farming, they were asked the following key questions and probed further depending on the answers:

- Do you own/use a smart phone?
- How much and what type of fertiliser do you use?
- What are the main challenges in horticulture?
- What are the main sources of information you use for farming?
- Why do you use these?
- Have you ever used mobile phone/internet resources for decision making in farming? Why?
- What are the main areas of information gaps that would be useful to know in farming?
- Have you ever carried out soil testing in your farm?

The interviews were conducted before any soil tests were conducted and the questions were not specifically about any technology, rather were about any soil tests that farmers had experienced or were familiar with. Interviews were conducted in the preferred language of the interviewee with the assistance of a translator. In Kenya a research assistant was hired to translate and arrange interviews. One focus group was conducted with an existing association of farmers in Kenya, this group contained 12 members who used HWDF in horticulture around Embu; no similar group meetings existed in Ghana so focus groups were not arranged.

In Kenya the farmers were mainly in horticulture growing tomatoes or watermelons. The farms were in three counties, Machakos, Tharaka and Embu, as shown in Figure 1. Seventeen out of twenty farmers were using smartphones capable of running android apps that could assist in agriculture. Their farms ranged from 5 to 50 acres (2–20.2 ha) in total size. Farmers often moved from one short term rental farm to another. Twelve of the farmers were in a collective group that worked together, whilst the remaining eight were in informal networks of support.

The two projects visited in Ghana were Tuba and Klagon, both within 50 km of Accra as shown in Figure 1. Each project contained around 200 hectares of land with 200 farmers each, so most farmers had around 1 hectare of land on which they grew different vegetables depending on season and demand, okra and tomatoes being most common. For each project there is a government extension officer responsible for providing information and training to farmers and a management team responsible for maintaining the distribution of water.

Interview transcripts and focus group notes were coded thematically using Nvivo 12 according to guidelines set out by Robson and McCartan (2016). The research had ethical approval from Cranfield University CURES/5687/2018.

Soil testing methods. A short overview of the soil testing method is given here to inform the results section and the reflections on the practicality of the tool. More details can be found in (Mallory et al., 2022). The intended research method was to take

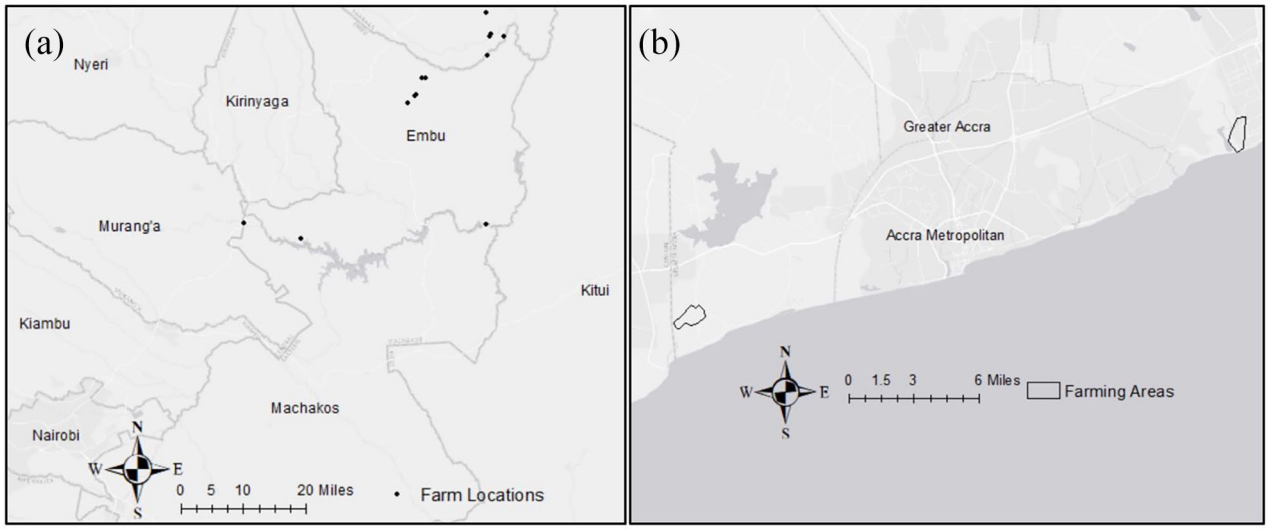


Figure 1. Area of Interviewees in Kenya (a) and Ghana (b).

10 g of soil from a farm area that was about to have fertiliser applied and seeds planted. This was mixed with water and shaken for 5 minutes. It was then filtered through a course filter paper, then a Quantofix paper strip (manufacturer: Machery-Negel, product reference: 913 51) was dipped into the sample. The paper strip had a reactive agent that would react based on the strength of Nitrogen in the sample. A phone with Akvo-caddisfly app was then used as a portable reflectometer to take a photo and convert the strength of red on the reagent into a numerical nitrogen concentration for the soil.

Results

The soil is red

After 2 months of preparing and adjusting the methodology to use the paper strips so that the researcher would have a set method to apply in Kenya and Ghana, it was time to travel for fieldwork. As the flight brought the researcher over the slopes of Mount Kenya and Embu, a key first challenge emerged: The soil is red. The paper strip is supposed to turn red to indicate nitrogen strength in the *red* soil. The soil throughout the entire research area had a heavy enrichment of iron and aluminium giving a strong red hue to the entire landscape. When using the coarse filter papers that allowed for a quick filter and fast result, this left an entirely red filtrate that simply dyed the soil testing kits bright red and prevented any app or adjusted reading to be taken by the phone camera. Using a fine filter paper did remove the reddish hue from the filtrate, but added hours to a technology whose entire premise was speed. Other options that could advance its ability would have included using syringe filters where pressure could be applied instead of waiting for gravity settling, or using soil extractants (Golicz et al., 2021; Mallory et al., 2022). Both of these options would have also added to the cost and time per sample which stood at £0.90 per sample for a strip and filter paper already. Any soil fertility analysis tool would need to analyse more than simply nitrogen, so the cost for sampling one nutrient could prove to be prohibitive.

Solving the wrong problem

In both case studies, farmers were asked what the major challenges they faced were, to identify what the major gaps or areas of demand for information in farming would be. Here a key theme emerged that soil fertility and soil testing was not a major priority amongst the farmers either in Kenya or Ghana.

In Kenya, volatile market prices were cited as the major challenge (Figure 2). The prices of watermelons and tomatoes were very volatile with people often citing eight-fold variation in gate prices from season to season. This market volatility was one of the key challenges that the farmers felt a lack of an agency in being able to manage. They had limited management strategies to deal with or predict price volatility as they knew it was dependent on supply from other farmers who could also respond to price volatility. Instead the most common approach was to split the farm into smaller areas and plant at different times to get a constant supply of harvest to be able to sell crops throughout the year and balance out the fluctuating prices:

> *'Prices differ very much. Even in weeks. So tomatoes have had a good price recently but now its changing. Good price is around KSH30/kilo ($0.29/kilo) so if maintained can get KSH1,300,000 ($12,770) per acre but at bad times maybe KSH100,000 ($982) per acre'* (Interviewee 5, Kenya)

Other major issues that the farmers cited were pests, the climate which affects the survival of crops (particularly in heavy rains which there had been in May 2018), access to water for horticulture and the banning of logging which made accessing and using support stakes for tomatoes more difficult. Farmers were then asked about the most important gaps in information about farming and how they perceived the potential use of soil testing. Besides price information, further information about chemicals and rates of fertiliser applications were the main information gaps identified:

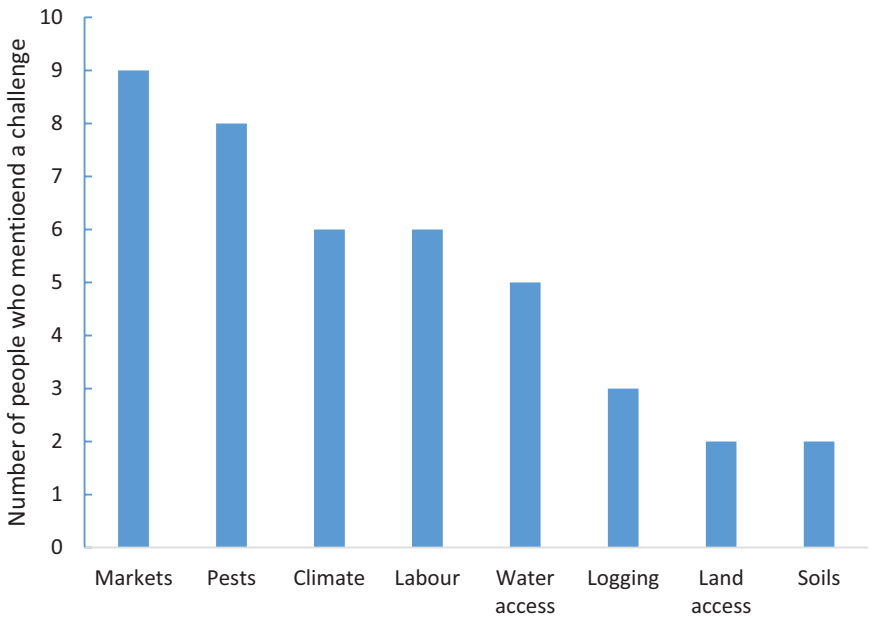


Figure 2. Challenges in agriculture in Kenya.

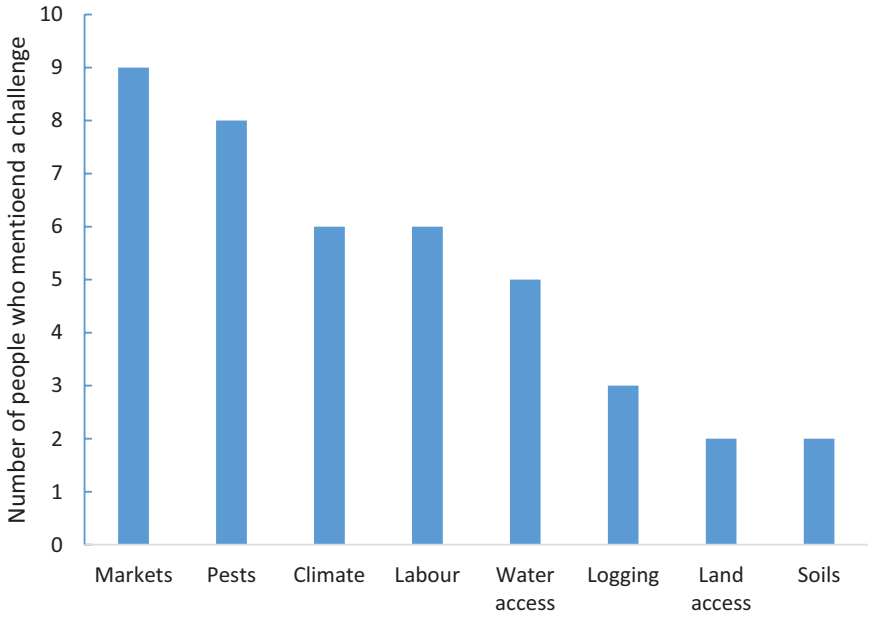


Figure 3. Challenges in agriculture in Ghana.

> *'From my experience the analyses of what rates of fertiliser I need is important as the soil is depleted here. There are no trees here so need to plant to avoid the depletion also. So in total just soil management is important'.* (Interviewee 14, Kenya)

Farmers in Ghana were also asked about the challenges in agriculture, with the results shown in Figure 3. The major challenges cited were again pests, though the market was a lesser concern and instead accessing water for irrigation was a bigger concern to the farmers. The market may be of less concern as farmers are closer to Accra so can easily travel to more markets rather than relying on brokers.

Pests were the main issue cited by interviewees, with yields often affected particularly by armyworms in maize crops:

> *'In farming maize it's the armyworm. We also have these small worms that are warring us so much. They are very harmful to our crops. They crumble the leaves so crops won't be fresh'.* (Farmer Interview 13, Ghana)

Irrigation was also a major issue for farmers. The farmers in Ghana were on an irrigation scheme where they were paying for irrigated land as a service rather than managing it themselves, for this reason they often cited shortages or breakdowns

in supply. The market was less of a concern for farmers, with price variations still prevalent but less extreme than in Kenya.

On the whole interviewees did not cite lacking information for farm management, with most expressing a happiness with the relationship with the extension officer being able to assist them.

> *'There are no challenges. If I get the seeds and the water I know I'll make it no problem and no challenge with the market'.* (Farmer Interviewee 7, Ghana)

Three farmers cited issues with the soil as the project had been using the same land for over thirty years so the soil quality was beginning to degrade and needed regular compost or manure application to maintain health. One farmer wanted to be able to have information about his soil, as he had experienced differential growing rates across his farm. Knowing the market and climate was another area of information cited by interviewees.

Overall, there were a suite of issues seen as important by farmers in Kenya and Ghana that soil testing would not solve. When farmers are operating with scarce resources, it seems unlikely that they would invest the time and money required to begin using the soil testing kits implemented in this project.

Failure fatigue and trust

One of the major issues that emerged through interviews with farmers, was that there was a reduced trust in outsiders providing information or new technologies due to previous failures. This affected both the openness of farmers to soil testing or information technologies, but it also meant much of their communication and information sharing was farmer-to-farmer which would affect the design and adoption of any app.

These issues and perceptions were formed from experiences with previous organisations, sometimes from government and sometimes from private sector, providing soil testing services. The experiences either involved waiting too long for information so farmers had to plant before they received any information and guidance from the soil testing results, or that when the results and advice came it was not possible to act on. For example, one organisation in Kenya recommending switching from Calcium Ammonium Nitrate (CAN), the most commonly used fertiliser, to another brand that was not available locally. In Kenya, 11 out of 20 farmers were aware of the possibility to get soil tested, but only two had done this with government labs. These had never received the results. In Ghana, there was an extension worker serving the irrigation projects, who had access to soil testing kits left by a previous NGO project. These were rarely used however.

> *'You see last year I did this service. They provided information via texts about what to do, inputs in a package and then at the end I only got 20% (of usual yield). I was very disappointed, and it didn't work for me. . .. . ..* (Interviewee 17, Kenya)

> *'No they come do this thing (testing) then they keep (the samples) long. We sent some soil to Ashaiman (area in Greater Accra) but not got results yet'.* (Farmer Interviewee 23, Ghana)

These experiences of previous NGO projects and technologies either failing or leaving them without the results or expected benefits meant that farmers predominantly relied on their own personal networks for information. All interviewees cited working with fellow farmers for information about farm management. This ranged from formalised groups of information sharing to neighbours visiting each other informally:

> *'Yes there is no jealousy in farming. We work together and we share. We have a group and association which is for changing minds and discussions'.* (Interviewee 1, Kenya)

Beyond their own personal networks of farmers, farmers often relied on agronomists or brokers for information. Due to the dual role of providing information and selling products, there is an issue of distrust in agronomists and brokers with some farmers, though in the absence of extension officers and with limited use of mobile information they are the main source of new information for farmers:

> *'So getting info from farmer is easier and it's easier to believe. Companies have come and fooled us for long so we don't just use but if other farmers use then we can confirm'.* (Interviewee 3, Kenya)

In one example a farmer used social media to connect with new markets but this did not succeed as the buyers never showed up. This constitutes a large risk in markets that have long transport distances and perishable goods:

> *'The internet market is not good I need to communicate with brokers or farmers. In Facebook there is a group. You say something but no one is online and no one responds so things just rot'.* (Interviewee 12, Kenya)

This technology requires communication between farmers who they do not have an existing relationship with, when much of the farming relationships are heavily personal.

Norms of communication and information sharing

Many farmers in Ghana interviewed were illiterate and did not own smartphones making innovations that used apps for communication inappropriate. Only 6 out of 23 farmers interviewed in Ghana used smartphones. All 20 farmers interviewed in Kenya did have smartphones. Even when farmers did have smartphones, their role was often to enable oral and visual communication between existing networks of farmers. This was either done through phone calls or by sending photos and videos through a WhatsApp group. Text was rarely used by farmers when communicating with the researcher or within their groups, showing the limitations of apps and information interventions based on people reading information, particularly if it is in a second or third language. This was also informally

experienced in disseminating results from soil tests that were conducted as part of the research back to the farmers through WhatsApp, where written result reports were sent but the main use of WhatsApp messaging for them was to send photos.

> *'Information from farmers is practical whereas seminars it is just theory'* (Farmer Interview 13, Kenya)

Discussion

Broken promises

The research found that farmers had already had NGOs, businesses and governments making similar promises to those of the technology studied here. Often the results or information never reached the farmers, or in the worst case when the farmer adopted the recommended measures their yields declined. Taking Rousseau and Burt's definition of trust as 'a psychological state comprising the intention to accept vulnerability based upon the positive expectations of the intentions or behaviour of another' (Rousseau & Burt, 1998, p. 395), these previous experiences of accepting vulnerability only to have negative outcomes, reduced the trust of outsiders amongst the farmers interviewed. This consequently reduced the willingness to adopt and try technologies explored in this research. Taking the example of mobile technology connecting farmers to new markets and enabling them to get the best prices, the importance of interpersonal trust has been neglected. When a farmer in Kenya did use mobile technology to connect to a new seller, the seller did not respond and the sale failed which has larger consequences than getting reliable buyers even if the selling price is lower. This risk is relevant to farmers in Kenya and Ghana where there is little formal contract structure or legal recourse to recover from a failed transaction or to demand a refund for a soil test where the results are never provided. Instead systems of interpersonal trust are developed amongst farmers. This is comparable to the trust networks that emerge in diamond-trading, where the scope for theft or non-delivery of contracts is high but the recourse to deal with the consequences is low meaning there is a need for trust networks (Richman, 2006). This determinant of trust in use of information was also found in a social network analysis of farmer knowledge exchange, where farmers were found to prefer knowledge from trusted individuals and developed experience (Wood et al., 2014). Whilst the researcher in this research was able to disseminate the soil testing results back to the farmers, they often found them inappropriate and difficult to use. This is because the results were written whereas most communication by farmers was either oral or visual, and the test results did not have a clear associated action that farmers could take.

Whilst the project succeeded in an academic sense in demonstrating the viability of the nitrogen testing, it did not meet the expectations of the research participants which could contribute to declining trust for any future projects or researchers. Considering the demonstrated risk of 'research fatigue' when participants have repeated engagements without any experience of change (Clark, 2008), projects need to have better planning and ethical considerations of the participants' expectation and understand the risks if a project cannot meet them. This is both pragmatic to ensure longer term relationships and access to communities, but also ethically important to maintain the principle of 'do no harm'.

Neglecting local context and norms

The technology proposed did not correlate with what the farmers cited as their biggest challenges in either case study, so it may not be an appropriate intervention. This constitutes a failure of top-down planning and thinking that is historically prevalent in the structure of NGO and development projects (Cole et al., 2014; Elliott, 1987; Kohl, 1991)

Farmers often claimed to be able to understand how their crops were responding to the soil, and in the rare cases where they followed recommendations from classrooms or laboratories they reported worse outcomes; they termed these recommendations to be 'theoretical' Wood et al. (2014) also found that farmers prefer experience and empirical knowledge derived from observation and practice rather than rational theoretical knowledge. The types of knowledge investigated by this project involved both a presumption of the gaps in knowledge and format that potentially neglected existing local knowledge. Failures such as these have a long history, for example projects that attempted to introduce 'modern' rice growing strategies to the local 'subak' system of management in Bali in the 1970s led to a crash in yield as it failed to account for local systems of water sharing and eventually caused droughts and conflicts, reducing trust in modern technology (Arthawiguna et al., 2005). In the 1980s projects were reflecting on the failure to integrate farmer knowledge and constraints into NGO agriculture projects (Kohl, 1991), yet the value of indigenous knowledge is still often ignored and researchers are still having to advocate for its inclusion (Adedipe et al., 2004; Nkomwa et al., 2014). A research project in Malawi showed how farmers used indicators such as the shedding of local tree species, behaviour of insects and other indicators to predict rains and planting times successfully (Nkomwa et al., 2014). Similarly, a study in Nigeria found that modern agricultural technologies would only be successful if they took into account the interplay of local knowledge of agricultural systems (Adedipe et al., 2004). Characterising the existing process of information gathering and decision making for farmers and integrating farmers into the design of information services may help to bridge the gap towards providing information systems that are useful.

The development research sector

Bidding for research projects and grants in both the sanitation and agricultural sectors will often require a 'solution' to be part of the proposal, which requires a presumption on the part of

the researcher that a problem exists, often without the opportunity to test this with formative research. This means that research projects are often constrained to testing technical solutions with social research that was carried out alongside the soil testing rather than in advance of it. Projects that are well defined may still turn out to be incorrectly conceived if they are designed with a narrow scope of the problem without understanding the context. This can even damage relationships and induce research fatigue in the populations that the projects claim to be helping. A reformulation of funding calls to ensure that projects are responding to local context, and smaller 'seed' funds that enable researchers to identify such contexts with participatory research may help to prevent these issues.

Positivity bias and disciplinary silos in academia can prevent these lessons being learnt. Funders, the media and the public want a technology that will solve a problem, when the reality is that it needs to be addressed through a multifaceted scheme of interventions. Academics should be more impartial and not promote 'silver bullet' solutions. When initially presenting results from the fieldwork, trust was chosen as a major theme to explore at conferences, with the title 'There's not an app for trust'. At one conference this title was listed as 'There *is* an app for trust' by mistake, and at another, despite listing reasons for the technology not suiting the local context the only questions were about the price and how many tests the author would use per farm, missing that point that the authors were recommending not applying the app at all. When publishing the results, there is also a bias against failure as addressed explicitly in this special issue. In journals that review technology, even those that explicitly claim to be interdisciplinary, there is often an attitude that qualitative data 'isn't science' or 'are just opinions'. In an environment characterised by these issues the technical viability of the soil testing intervention was published as a separate paper (Mallory et al., 2022) potentially exacerbating the adoption of such technologies and echo chambers amongst technology advocates and advocates for understanding context first.

Conclusion

This paper investigated and presents the social context in Kenya and Ghana to understand the potential for adoption of soil testing and information technology in agriculture. Whilst the tools investigated were technically sufficient, the farmers interviewed did not believe that soil fertility was a problem and hence did not see the need for soil testing. In Kenya the biggest challenge that farmers faced was volatile market prices and in Ghana it was pests. Due to a history of previous interventions that did not provide the promised results, farmers tend to rely on per networks rather than external agencies for information. Donors are keen to support new technologies that might provide a silver bullet to improve agricultural productivity whereas the reality is there is a need to understand local contexts and address the challenges that the farmers themselves perceive.

Data availability

The data that support the findings of this study are available on request from the corresponding author, AP. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

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Author contributions

Dr Adrian Mallory: Conceptualisation, Methodology, Invistigation, Writing – original draft. Dr Ruben Sakrabani: Funding acquisition, Conceptualisation, Methodology, Writing – review and editing. Dr Alison Parker: Funding acquisition, Methodology, Writing – review and editing. Dr Paul Hutchings: Writing – review and editing.

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