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DEVELOPMENT AND UTILIZATION OF A DECISION SUPPORT TOOL FOR THE OPTIMIZATION OF FERTILIZER APPLICATION IN SMALLHOLDER FARMS IN UGANDA

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ABSTRACT

This paper presents the development and pilot of the Fertilizer Optimization Tool (FOT), a decision support tool for use by extension agents in advising smallholder farmers in Uganda in applying optimum (rather than maximum) fertilizer by considering the farmers' financial abilities. The FOT is made up of three components which includes, the optimizer tool, the nutrient substitution table, and a fertilizer calibration tool. The FOT was developed using field trial data collected on specific agro-ecological zones and mapped using global positioning systems in 13 Sub-Saharan Africa countries. The FOT provides site- and farmer-specific fertilizer recommendations, providing both economic and environmental benefits. Results are based on a survey of 241 households, 57 technical personnel and tracking of 33 FOT users over a 3-season period. Results show a progressive shift in farmers' attitude towards the value of fertilizer. More FOT users (71%) disagreed with the statement that fertilizers destroy soils, compared with non-FOT users (52%). Crop yields (tons/ha) were significantly higher for crops receiving fertilizers compared to those not. While it is generally accepted that using fertilizer improves crop response and achieves better yields, the value of FOT was reported in terms of rationalization of investment by farmers. The average seasonal investment was approx. $43, giving a return on investment of over 107%. Given the evidence generated from Uganda, there is a need for considering out scaling the FOT technology to other countries in Africa, which are faced with the same challenges of low fertilizer use among smallholder farmers. Using the mobile FOT app provides a further cost-effective opportunity to out scale the approach to benefit more smallholder farmers in sub-Saharan Africa. Further development of the FOT is suggested, particularly in the wake of increased focus on multi-nutrient fertilizer blends, and the need to adjust for soil PH, moisture, and long-term impacts of nutrient substitution.

Key words: decision support tool, fertilizer optimization tool, precision agriculture, site-specific fertilizer recommendations

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INTRODUCTION

Crop yields are increasing fairly slowly [1] to meet the forecasted demand for food, attributed in part to low and declining soil fertility. Inorganic fertilizer is one of the agricultural technologies with a great potential for increasing the productivity of smallholder farmers [2], but use of fertilizers, and soil fertility management in general, remains low. Fertilizer use in Africa was 11 kg per ha in 2014, which is still below the Abuja Declaration target of 50 kg per ha, and about 10 times less than the world average [3]. Within East Africa, Uganda has the least fertilizer use intensity, averaging 1kg of nutrients per hectare, compared to 35kg in Kenya, 22kg in Malawi and 13kg in Tanzania [4, 5]. Besides, other factors such as climate change, soil erosion, rapid urbanization, and conversion of farm land to settlements diminish arable land, further challenging sustainable food production efforts. Given this scenario, there is a scientific consensus that farmers must grow more on the land they currently operate through "sustainable intensification", which has the overreaching goal of increasing food production from existing farmland while minimizing the pressure on the environment [6]. This involves the application of precision farming tools, such as global positioning system fertilizer dispersion, advanced irrigation systems, and environmentally optimized crop rotations. The adoption of precision agriculture, however, has been slow due to factors including cost, high variability of the smallholder farms, and limited development of proper decision-support systems and tools [7].

Most of the current fertilizer recommendations focus on a few crops and primarily aim to maximize yields, with little consideration for the farmers' financial abilities and general return on investment. These recommendations are also widely applied with little consideration for specific agro-ecological zones (AEZ), farm-specific conditions and crop- specific nutritional needs. This has led to inappropriate applications, which often result in an over- or under-supply of fertilizers [8]. As such, the profit margins of using fertilizer is often too low to attract investment by poor farmers who require high returns on their constrained investments [9]. This also leads to environmental pollution, which in the long run does not contribute to sustainable agriculture [10]. Smallholder farmers on average allocate less than US$ 100 on all farm inputs including labour for various farm enterprises. It is, therefore, critical that farmers are supported to make decisions on how to allocate their resources, including decisions on the type of fertilizer to use and the most optimal crops to apply it to.

Driven by this gap, as well as the need to respond to AU Abuja Declaration, the project "Optimizing Fertilizer Recommendations in Africa" (OFRA) funded by AGRA developed the Fertilizer Optimization Tool (FOT). Fertilizer Optimization Tool is a decision support tool which maximizes the farmers' returns on the use of fertilizers. The tool makes recommendations based on the farms' locations (agro-ecology) and crop enterprise mix; fertilizer costs; prevailing product prices; amount of money available for fertilizer use; and other integrated soil fertility management (ISFM) practices employed on the farm. The FOT also predicts yield and the economic optimal fertilizer application rates, further motivating farmer investment in agricultural activities. The FOT is made up of the optimizer tool, that works alongside other two complementary components: nutrient substitution table and a fertilizer calibration tool [11]. The nutrient substitution

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table considers farms' cropping systems and the effects of ISFM employed in the previous season [12, 13], while the fertilizer calibration tool is used to convert the recommended fertilizer quantities (expressed as kg of fertilizer per acre or hectare of land), to a more farmer-friendly local measure, for example bottle tops. The FOT is designed in three versions: computer excel, paper version and mobile app providing more versatility for its utilization. The FOT has been developed for 23 countries in Africa [11], and more information can be accessed at http://africasoilhealth.cabi.org/tools/fertilizer-tools/fertilizer-optimisation-tools/

In Uganda, the OFRA project was implemented from 2013 and the FOT was rolled out to extension workers for testing in 2017. This study aimed to understand the farmers' perceptions on use of fertilizers, knowledge and practices with regard to fertilizer utilization, use of FOT, and returns on investment in fertilizer use. The study also documented lessons learned by extension agents and other intermediaries on benefits of FOT-based fertilizer application compared to blanket recommendations.

METHODS

Fertilizer Optimization Tool (FOT) empirical underpinnings

The FOT is based on the desire to have farmers optimise the benefits from every amount of fertilizer they apply. The tool is meant to demystify the notion that you have to invest a lot of finances to benefit from fertilizer use. As such, the underlying challenge is that of optimizing returns from limited quantities of fertilizer that a farmer can afford. The FOT selects nutrient (fertilizer) input levels from a given feasible region as determined by the financial constraint in such a way as to optimise the net returns to fertilizer use. The tool chooses a combination of crop-nutrient levels $x_1, x_2..., x_n,$ which maximize net fertilizer returns subject to farmers budget constraint in a particular season.

The objective function, therefore, is to optimise net returns (π) from the applied nutrients as the difference of expected crop revenue (py), nutrient costs (cx) and expected yield (b) when no fertilizer is applied. In most situations, farmers grow more than one crop in a contiguous or non-contiguous piece of land; in such a case p represents a vector of commodity prices ($p_1, p_2, ..., p_n$). Likewise, farmers apply more than one type of nutrient/ fertilizer in their farm so c represents a vector of nutrient prices ($c_1, c_2, ...c_n$). The objective function and constraints are explicitly stated as:

$$Maximize: \pi = \sum_{i=1}^{i=n}(p_1 y_1 - b_1 - c_1 x_1) \quad (1)$$

$$Subject\ to: c_1x_1 + c_2x_2 +,......,+c_nx_n \leq budget \quad (2)$$

$$x_1, x_2, ...x_n \geq 0 \quad (3)$$

The profitability of different crop-nutrient combinations varies with the value of crops at the point of sale after harvest, the costs of fertilizer nutrients, and the magnitude of each crop's response to an applied nutrient. However, yield sometimes does decrease from a peak with high application rates as it is no longer beneficial to add more fertilizer/nutrient if the response function has reached a plateau [14, 15].

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Study area and data collection

Four production zones in Uganda were sampled - Lake Victoria Crescent, Kyoga plains, Highland ranges, and South Western Farmlands. These locations represented agro-ecological zones where FOT awareness creation previously took place with a relatively large number of trained FOT champions (Extension workers). The number of extension workers trained varied based on local government recruitment, as some districts had very few extension workers compared to others. These locations also represented diversity in farming systems, enterprises and access to markets, which can be generalized across other production zones in the country (Table 1).

The study used a combination of survey and case study designs. Both qualitative and quantitative data were collected for this study. Four key tools/approaches were used: i) household survey questionnaire; ii) key informant interview guide; iii) farmer tracking tool, and iv) farmer in-depth interview guide. The household survey reached a random sample of 241 farmers (only 236 questionnaires were analysed after data cleaning). The farmers were selected randomly from sub counties of operation of the FOT trained extension workers, and gathered information from both farmers who trialled/had used FOT (at least once) and those who had not, so as to understand if there were differences that could be attributed to farmer utilization of FOT. Key informants included an array of technical experts from the Ministry of Agriculture Animal Industry and Fisheries (MAAIF), District Local Governments (DLGs), the National Agricultural Research Organisation (NARO) and Non-Governmental Organisations (NGOs) in order to understand the institutionalization of FOT and the potential for its scale-up. A total of 57 Key informants were interviewed. Household survey and Key informant Interviews (KIIs) were conducted between July and August 2017.

The farmer tracking tool aimed to capture investment and production data based on their use of FOT. The tracking tool captured information on amount of money invested by the farmer, crops grown, acreage, FOT fertilizer recommendations, application amounts and methods, and production obtained. Only 33 farmers had consistently used FOT recommendations for at least three seasons (2017A, 2017B and 2018A[1]), and were thus included in the analysis. Further, farmer impact stories were also gathered from 5 farmers who had used FOT based on farmer experiences and benefits from using FOT and 3 best stories selected for this paper. Table 1 shows the study locations, their characteristics and respondents reached in each.

Data analysis

Qualitative data were analyzed using content analysis method [19], while quantitative data were analyzed using descriptive analysis and presented in tables, proportions and bar charts. Mean comparison test using *t*-test, *z*-test and chi-square were used for quantitative variables with normal distributions and homogeneous variances.

[1] A and B denote long (March-June) and short (October-December) cropping seasons, respectively.

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RESULTS AND DISCUSSION

Respondent's characteristics

Majority of respondents were men (68%) and women respondents comprised 32% (Table 2). Majority of respondents had formal education, at least beyond secondary school (60%). This represented a well-educated community compared to the national average of 73%. Crop farming was the main occupation (54%) of total respondents, followed by mixed farming. Livestock farming and off-farm employment were minimal, about 2% for each. Mean age of the respondents was 44 years, with men being slightly older than women. There were significant differences ($p<0.01$) in gender, education level and primary livelihood activity of respondents by production zone. Education level and economic activities were comparable between men and women, with no significant differences.

Average land holding was 2 hectares, and this varied by production zone, with households in Kyoga plains having the largest farm sizes, and those in Highland areas having the smallest. A majority of respondents (60%) had received training on soil fertility management, and more than 90% (including those not trained per se) used some soil fertility management measures. The most commonly used soil fertility management measure was inorganic fertilizer (60% of respondents). Use of organic materials especially manure and compost were common in Kyoga plains and South Western farmlands. Fertilizers were applied to a variety of crops but mainly maize, beans, sweet potatoes, Irish potatoes, bananas, citrus, and groundnuts.

In terms of utilization of FOT, proportionately more male than female farmers trialled with FOT, though proportions were not statistically significant (Table 3). Except for type of fertility measure used, the rest of the variables were less significant between non-FOT users and FOT users. Fertilizer Optimisation Tool (FOT) users were more likely to use inorganic fertilizer compared to non-FOT users, which in this case may be obvious since the tool promoted the use of inorganic fertilizer. This lack of difference indicated that farmers in the study areas were generally homogenous and there were no striking differences between users and non-users of the FOT tool.

Farmers' knowledge of fertilizer use

The study sought to understand farmers' knowledge on fertilizer use and how this had changed over a five-year period (2013-2017). Farmers were asked a series of knowledge question, to which they gave their subjective rating on a 7-point scale - 1= no knowledge at all and 7= very knowledgeable. Results showed a shift in farmer knowledge, particularly a greater understanding of different stages of fertilizer application, right quantities of fertilizer to apply, how fertilizer quantities affected yield and how to apply fertilizer (Figure 1). A large number of farmers that had no knowledge on many aspects of fertilizer application in 2013, but the number reduced by close to 50% in 2017 after they had taken part in the FOT trainings. Knowledge and information were seen as powerful tools in the process of change. When farmers are empowered and have access to knowledge and information, they train others and help in strengthening of human capital and the production of knowledge [16]. Extension has previously been viewed as the main medium through which technologies and other information reach farmers.

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However, recently there is a focus on the participation of communities in a facilitated innovation and experimentation process.

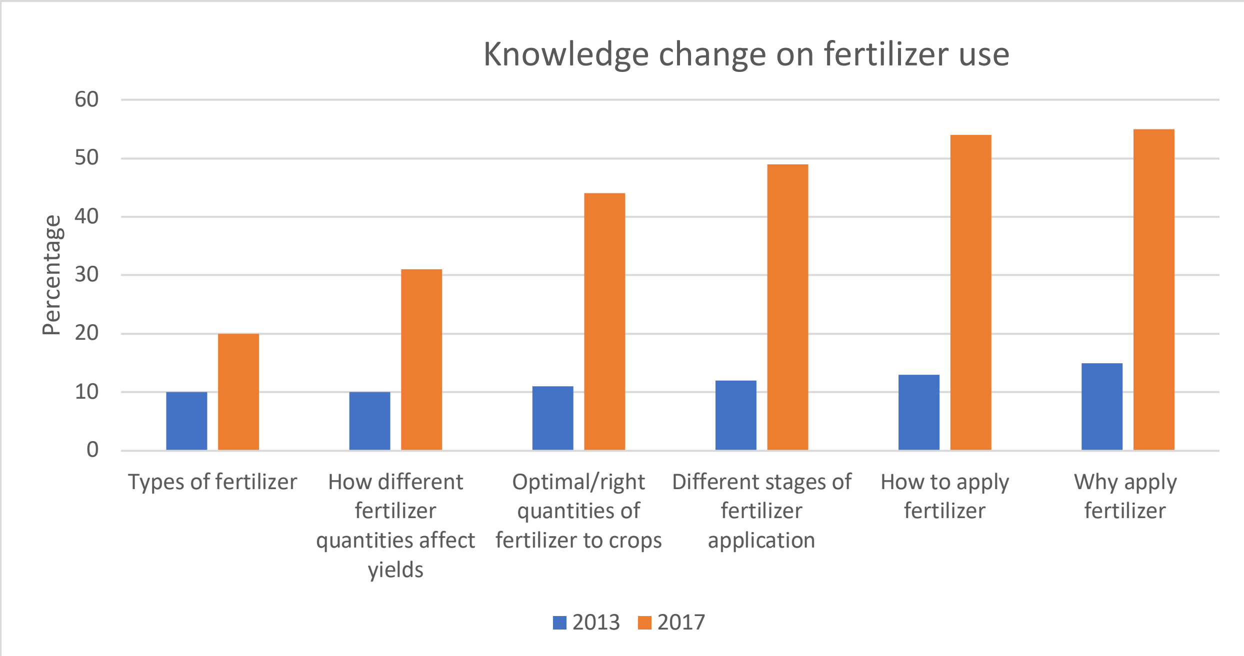

Figure 1: Change in farmers' knowledge of fertiliser use (2013 and 2017)

Farmers' attitudes towards and perceptions of fertilizer use

The survey tool provided attitudinal statements and asked farmers to assess their knowledge status in 2013 and 2017. Responses were coded on a five-point Likert scale; however, during analysis, this was compressed to three levels only – agree, disagree and not sure – to better capture differences across a time gradient and farmer category (FOT user and non-user). The proportion of farmers who perceived fertilizer to be destructive to soil reduced from 50% in 2013 to 29% in 2017 (Table 4). There was also a progressive shift in farmers' attitude towards the value of fertilizer in 2017, with (67% and 78%), respectively agreeing that 'different fertilizers have different yield levels', and 'I know the value of fertilizer and am willing to pay for it', compared to 31% and 29%, respectively in 2013. Across all questions, the number of farmers who were not sure progressively reduced in 2017 compared to 2013.

Comparing FOT users and non-FOT users, there was a marked difference in attitude by the two categories of farmers (Table 5). More FOT users (71%) disagreed with the statement that fertilizers destroy soils compared to non-FOT users (52%), but this was not significantly different (Z= 1.242). More FOT users (84%) reported that they knew the value of fertilizer and were willing to pay for it against a 72% non FOT users (significantly different, $p<0.05$). The slight difference in attitude could be attributed to the training received by farmers using FOT and their involvement in testing the decision support tool as opposed to the non-users.

From the extension worker and Key Informants' perspective, 45% reported that farmers followed fertilizer recommendations, while 55% did not. The reasons they gave for farmers' failure to follow recommendations were: a long-held misconception that fertilizers spoil soils; farmers cannot afford to buy recommended quantities; limited supervision and guidance by technical experts; and farmers consider some application methods to be labour intensive and hectic. In these circumstances, farmers tended to use their own judgment of what quantities to buy and application methods. Broadcasting was the most common method for fertilizer application, and urea the most common fertilizer applied. There was a general agreement that indiscriminate application of urea had greatly contributed to the acidity of soils, particularly in Mt. Elgon areas. Studies in other areas have also shown that high rates and improper timing of nitrogen application have led to significant acidification, resulting in low nitrogen use efficiency and high environmental costs [17].

Farmers' decisions to use fertilizer

The majority of farmers indicated a preference for inorganic fertilizer 60% over organic fertilizer (40%). The key reasons for preferring inorganic fertilizer were: worked better; easily accessible; did not smell; and did not take time to prepare, compared to organic manure/compost. Those who preferred organic fertilizer indicated that it is not costly and stayed in the soil for a longer period of time. Extension worker perceptions were not specific to any type of soil fertility management measure and agreed with farmers' perceptions. Extension workers also mentioned that farmers used organic manure mainly because it is readily available, which was contrary to farmers' perceptions. Empirical evidence also suggested a declining availability and utilization of organic materials such as coffee husks due to plant pests. Also, emerging competitive usage of coffee husks and plant materials as fuel alternative in small scale industries [18] may reduce the potential utilization of organic materials. Similarly, cattle and poultry manure seemed to be on the decline due to the high labour costs involved in their management and application process [19, 20].

Farmers' decisions to use any type of fertilizer was mainly driven by yield expectation (male 32% and female 36%), and fertility of land (male 24% and female 25%) (Figure 2). That was in agreement with Namazzi [4] who reported that a relatively modest investments in inorganic fertilizer by smallholders could dramatically increase their maize productivity in Uganda.

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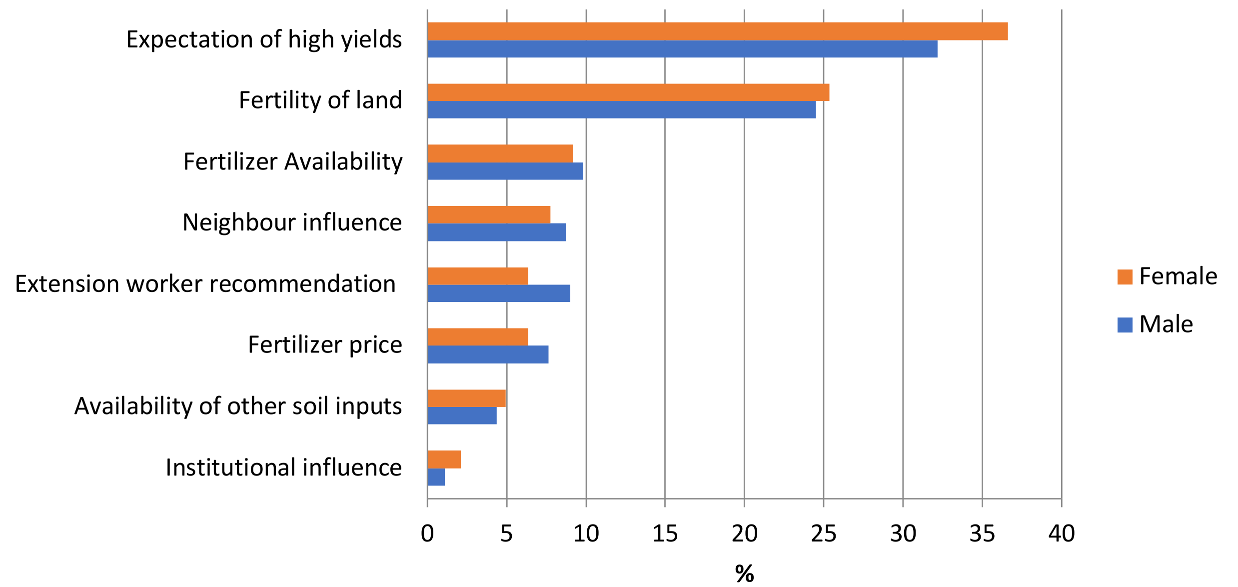

Figure 2: Farmers perceived drivers of using fertilizer (top eight)

Key informants agreed with the farmers that expected yields were one of the key drivers of farmers deciding to apply fertilizer. However, most of the key informants (93%) said that farmers highly relied on extension workers to help them make decisions on how and which fertilizer to apply for their crops (Figure 3).

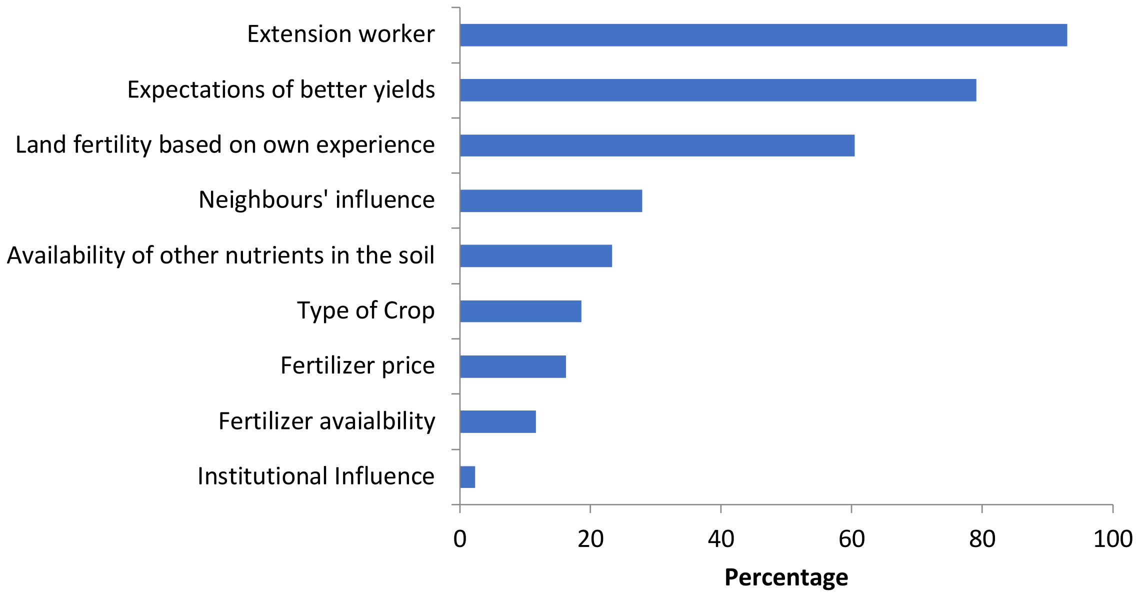

Figure 3: Extension workers' perceived drivers to using fertilizer by farmers (top eight)

FOT utilization by farmers

Extension worker tracking tool for 33 farmers in Tororo, Jinja, Busia, Mubende, and Masindi, who consistently participated in FOT trials showed that farmers grew a diversity

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of crops in different seasons, but often dominated by maize, beans, soybean, and groundnuts. Major crops were usually grown in intercrop especially maize and beans, though pure stand was also common. The average land allocation was 0.6 hectares per plot, with maize having a comparatively larger land allocation (0.8 hectares) compared to other crops.

Based on FOT recommendations, farmers mainly invested in inorganic fertilizer in maize (85%), groundnuts (52%) and common bean (48%). These crops also represented more highly commercialized crops in the study regions. For traditionally grown cash and food crops such as coffee and banana, a majority of farmers preferred to use organic matter for fertility management as opposed to inorganic fertilizer, mainly due to the crop's perennial nature. There was limited application of inorganic fertilizer to root crops such as sweet potato, cassava, and yams due to farmers' perceptions that such crops were hardy and did not need additional nutrients and that the fertilizer was directly absorbed in the roots, which rendered them unsuitable for human consumption. This perception was also shared by farmers during the household survey.

Yields (tons/ha) were significantly higher for farms in which fertilizer was applied using FOT recommendations than those in which no fertilizer was used (Table 6). While it was generally accepted that using fertilizer improved crop response and achieved better yields, the value of FOT was reported in terms of rationalization of investment by farmers. Most farmers had a perception that use of fertilizer was uneconomical, which was demystified by FOT even for minimal investments. This could be seen from the low investment by farmers in fertilizer. While the average seasonal investment was UGX 159,632 (Approx. $43), some farmers invested as little as UGX50,000 (USD13). This implied that farmers made production gains from investing in quantities of fertilizer which are less than those recommended for maximum agronomic yield, despite the low investment levels.

Similarly, the value of crop production (measured as volume of production in kg multiplied by the average price paid per kg) was significantly higher for farmers who used fertilizer (FOT recommendations) than those who did not apply any fertilizer (Table 7). The marginal rate of return was estimated at 107%, implying the added benefit from investment in fertilizer more than offset the added cost of investment in fertilizer. Heisey and Mwangi [21] suggest that for significant adoption of fertilizer to occur by smallholder farmers, the marginal rate of return on working capital invested in fertilizer must be at least 100%.

From the farmers' perspectives, FOT was particularly appreciated as a decision-making tool to allow allocation of small quantities of fertilizers to selected crops and achieve high yields. Farmers who had used fertilizer before without FOT had different experiences, as they mentioned that FOT helped them apply only what was needed for plant nutrition avoiding wastage. They considered the approach to be an improvement of their traditional methods where they applied blanket recommendations, as noted by a farmer from Karwok village, Molo Sub County, Tororo district:

"I have used fertilizer for about five years now. Each season, I used to spend about UGX450,000 to buy 50kg DAP and 50kg Urea and 50kg TSP for my maize and

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groundnuts. I have used FOT for 2 seasons now and I have realized that I have used significantly less fertilizer and money than before yet the production is comparable. Last season, I invested UGX100,000 for 1 acre of maize, 1 acre of groundnuts and ½ acre of soybean. The FOT output was 22kg DAP & 22kg Urea for maize, 11kg TSP for groundnuts, and 11kg urea for soybean. For maize, I obtained 16 bags (each 100kg) compared to 10 bags before. This shows that I was wasting my resources." Paul Okingok.

Farmers also appreciated the fact that the tool catered for different categories of farmers based on their purchasing power, giving economically optimum fertilizer recommendation. In addition, FOT took into consideration the changing prices of fertilizer and anticipated farm prices for the produce, to give crop-specific fertilizer recommendations. The main drawback of FOT as mentioned by farmers was the additional labor required to follow the recommended application methods as noted by a farmer in Busumba B village, Dabani Sub County, Busia district:

"The tool indicates how much to spend and how to apply, except one needs to allocate some more labor for the application. I have been used to broadcasting which I can even do in one day. But now with new methods such as banding or point application, I have to hire two people to help me apply fertilizer in my 2.5 acres of groundnuts. Though I acknowledge the saving I made by using the modern method because with broadcasting I could not be precise and was wasting fertilizer." Leo Wandera.

From the extension workers' perspective, the FOT decision tool provided precise recommendations. Extension workers reported an increasing optimism and positive response by farmers in trying out recommendations from FOT after seeing the change in crop yields that were better than when they used blanket recommendations. Increased crop productivity at the household level, had helped convince more farmers to try out the tool. As noted by one of the extension workers in Buwenge Sub County, Jinja district:

"In this area, due to lack of land, most farmers rent land from landlords and as such grow crops in blocks. The five farmers I started with, their crops were visibly different from their neighbors and as such, I have had more people come to me for advice. This season (2018B), at least 30 farmers tried out the FOT recommendations. The crop is yet to be harvested, but the response is good." Alex Mukwanga

Apart from the benefits, extension workers mentioned some challenges. Overall, these were operational and related to how best farmers could be engaged to change their attitude and adopt new technologies. Input access also remained a challenge as some of the recommended fertilizers could not easily be obtainable by farmers such as Triple Super Phosphate (TSP). While the FOT took into consideration cropping history and use of ISFM practices, it did not consider soil PH and predicted weather changes, which affect crop response to fertilizer application. Van Es and Yang [14] justifies the need for higher nitrogen fertilizer rates in a season with higher rainfall.

CONCLUSION

Apart from a shift in farmers' attitude towards fertilizer use in general, attributed to the awareness and training activities, farmers who participated in FOT trial also achieved high returns even on small investment on inputs. Fertilizer can be used sustainably within the framework of integrated soils fertility management (ISFM). Most of the farmers do not use fertilizer since they believe that small amounts of fertilizers cannot have a significant impact on crop yields. The FOT considers farmers' purchasing power, and was shown to improve farm productivity even with limited funds to invest in fertilizer inputs. Given the evidence generated from Uganda, there is a need to consider out-scaling the FOT technology in other countries in Africa where there is low fertilizer use among smallholder farmers. The mobile app of the FOT is another cost-effective opportunity to out-scale the approach to benefit more smallholder farmers in sub-Saharan Africa. Further development of the FOT is suggested particularly in the wake of increased focus on multi-nutrient fertilizer blends, and the need to adjust for soil PH, moisture, and long-term impacts of nutrient substitution.

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Table 1: Locations, their characteristics and respondents reached in a study on use of the FOT in Uganda

No.	Production zone[a]	Biophysical characteristics	Key enterprises	Sample districts	# farmers	KIIs
1	Lake Victoria Crescent	The average rainfall of 1,200 to 1,450 mm, occurring in two rainy seasons. The main season is from March to May and secondary season from August to November. Temperature ranges from 15 – 30 °C; Altitude ranges from 1,000 – 1,800 m ABL. Soils are good to moderate	Robusta coffee, Fisheries, Spices, Floriculture, Horticulture, Vanilla, Cocoa and Dairy	Buikwe, Jinja, Busia	60	13
2	Kyoga plains	Average rainfall range of 1215 mm -1328 mm with two rainy seasons. The main season is from March to May and secondary season from August to November. Temperature ranges from 15 – 32.5 °C; Altitude ranges from 914 – 1,800 m ASL. Soils are poor to moderate. Small-scale subsistence mainly annual crops with some pastoralist.	Fisheries, Apiculture, Maize, Pulses, Beef cattle, Cassava, Goats	Kayunga, Tororo, Amuria, Serere, Soroti	99	26
3	Highland ranges	Rainfall usually more than 1400 mm distributed in two main rainy seasons from September to December for South Western highlands and one long rainy season from March to October with a peak in April and Secondary peak in August for Eastern Highlands. Temperature ranges from 7.5 – 27.5 °C, Altitude ranges from 1,299 – 3,962 m ASL. Soils are mostly young volcanic and are rich in nutrients. Cultivated land is highly fragmented with small plots covering terraced hillsides.	Arabica Coffee, Passionfruit, Vanilla, Dairy / Hides, Spices (Cardamom, White/Black pepper), Maize, and Irish potatoes	Kapchorwa, Kween	37	10
4	South Western Farmlands	Rainfall range of 1,120 – 1,223 mm, with high variability, lowest at about 800 mm in Kasese Rift Valley and highest over 1500mm over slopes of Rwenzori mountains. Two rainy seasons, main season from August to November and secondary season from March to May. Temperature ranges from 12.5 – 30°C, Altitude ranges from 129 – 1,524 m ASL. There is land fragmentation in some parts of the zone and farms are largely small to medium scale and intensive.	Robusta coffee, Tea, Dairy / Hides, Fisheries, Bananas, Vanilla, and Tobacco.	Mbarara, Isingiro	40	8
		Total			236	57

[a]Uganda is divided into 10 Production Zones aiming at targeting investment based on production potential and market access. This zoning has also led to the development of specific investment plans and focus on particular enterprises considered suitable to certain production zones [20]

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Table 2: Respondents' characteristics by production zone, during a study on the use of FOT in Uganda

Characteristics	All respondents (n= 236)	Production zone				Pearson χ2	p-value
		Highland ranges (n=37)	Kyoga plains (n=99)	L. Victoria Crescent (n=60)	S.W. Farmlands (n=40)		
Gender of respondent (%)							
Female	32	43	20	43	32	12.07	0.007
Male	68	57	80	57	68		
Education level of respondent (%)							
No education at all	3	3	1	5	8	27.73	0.006
Primary	37	24	46	33	30		
Secondary	39	32	33	52	43		
Tertiary	21	41	19	10	19		
Primary livelihood activity of respondent (%)							
Crop farming	54	16	57	52	85	45.91	0.000
Mixed farming	43	81	40	45	10		
Livestock farming	2	3	0	3	3		
Off-farm	2	0	3	0	3		
Training in fertility management (%)	62	65	72	70	25	34.45	0.000
Using any soil fertility measures (%)	94	95	90	95	100	5.20	0.158
Soil fertility measures used (%)							
Inorganic	60	66	47	82	51	24.97	0.000
Organic	40	34	53	18	49		
Farmers participation in FOT trials (%)	31	30	42	28	5	24.74	0.000
Received any credit for agriculture (%)	38	22	44	33	45	7.33	0.062
Land owned (Ha)	2.1 (0.3)	1.2 (0.3)	2.9 (0.6)	1.5 (0.5)	1.7 (0.4)	121.18	0.001
Age (years)	45 (0.8)	42 (2.0)	47 (1.4)	46 (1.6)	40 (1.6)	139.33	0.723

Figures in parentheses are the standard error

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Table 3: Characteristics of respondents and their uses of FOT in Uganda

Characteristics	Non-FOT Users (n=164)	FOT Users (n=72)	Pearson χ2	p-value
Gender of respondent				
% Female	77	23	3.45	0.178
% Male	66	34		
Education level of respondent (%)				
No education at all	4	1	9.17	0.328
Primary	36	41		
Secondary	43	31		
Tertiary	17	27		
Primary livelihood activity of respondent (%)				
Crop farming	59	43	9.18	0.164
Mixed farming	38	54		
Livestock farming	2	0		
Off-farm	1	3		
Using any soil fertility measures (%)	93	93	0.14	0.934
Soil fertility measures used by farmers				
Inorganic	55	72	84.33	0.000
Organic	45	28		
Received any credit for agriculture (%)	39	36	0.74	0.691
Land owned (acres)	4.8 (0.4)	5.4 (0.5)	50.03	0.472
Age (years)	45 (1.1)	45 (1.4)	105.20	0.341

Figures in parentheses are the standard error

Table 4: Assessment of farmers change in attitudes on the use of fertilizers, in general, comparing 2013 to 2017

Attitude statement (%)	2013			2017			
	Agree	Disagree	Not sure	Agree	Disagree	Not sure	Z-Score
Fertilizer destroys the soil	50	25	25	29	58	13	-4.666***
Different quantities of fertilizer have different yield levels	32	21	47	67	22	11	7.604***
Applying more fertilizer does not change the yields	24	45	31	89	8	3	14.242***
I do not apply fertilizer because am not aware of it	44	40	16	19	68	13	-5.846***
No guidelines on fertilizer recommendations available in Uganda	25	29	46	22	64	14	-0.769
I know the value of fertilizer and willing to pay for it	30	39	31	78	18	4	10.462***
Fertilizers are costly and returns can't offset incurred costs	73	12	15	57	42	1	-3.644***

Source: Survey data 2017 (n=236)

***, indicates significance at $p<0.01$.

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Table 5: Assessment of farmers change in attitudes on fertilizer use after participating in FOT trials (2017)

Attitude statement (%)	Non-FOT users (n=164)			FOT users (n=72)			Z-score
	Agree	Disagree	Not sure	Agree	Disagree	Not sure	Agree
Fertilizer destroys the soil	34	52	14	21	71	8	1.242
Different quantities of fertilizer have different yield levels	68	19	13	72	23	5	-0.661
Applying more fertilizer does not change the yields	9	88	4	4	93	3	0.046
I do not apply fertilizer because am not aware of it	17	80	4	17	83	0	0.000
No guidelines on fertilizer recommendations available in Uganda	15	72	13	9	87	4	0.551
I know the value of fertilizer and willing to pay for it	72	20	8	84	16	0	1.978**
Fertilizers are costly and returns can't offset incurred costs	18	76	5	8	89	3	0.844

Source: Survey data 2017
** indicates significance at 5% level

Table 6: Crops where farmers have invested in fertilizer based on FOT recommendations

Crop	% of farmers	Av. land allocated (Ha)	Yield (tons Ha) without FOT	Yield (tons/Ha) with FOT
Beans	48	0.6 (0.3)	0.1926 (13.8)	0.3478 (20.9)
Groundnuts	52	0.2 (0.2)	0.1800 (39.2)	0.2720 (32.6)
Maize	85	0.8 (0.5)	0.4843 (38.1)	1.1005 (94.5)
Soybeans	15	0.6 (0.4)	0.1503 (13.4)	0.2155 (15.5)

Figures in parentheses are the standard error
Source: Extension worker tracking tool (n=33)

Table 7: Return on investment on fertilizer use (average)

Variable	No fertilizer applied (A)	FOT recommend (B)	Difference (B-A)
Value of produce (UGX)	686,008 (102,668)	1,507,615*** (277,542)	821,606 (295,923)
Gross margin (UGX)	686,008 (102,668)	1,421,198** (310,401)	735,189 (326,939)
Marginal rate of return (%)	107.17		

***, ** indicates significance at 1% and 5% level of precision
Figures in parentheses are the standard error
Source: Extension worker tracking tool (n=33)

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