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Narrowing yield-gap of rice through soil fertility management in the Lake Victoria Crescent agro-ecological zone, Uganda

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Rice farming is increasingly being encouraged in Uganda because of its potential to double as an income as well as food security crop. However, existing data shows that current farmer' yields are less than half of the expected average, partly due to inadequate soil fertility management interventions. Using a survey of rice farmers in the Lake Victoria Crescent Agro-ecological zone (LVC-AEZ) of Uganda, we assessed socio-economic drivers of soil fertility management interventions and how these relate to soil productivity and rice yield, with particular emphasis on mineral fertilizers. Results showed a wide range of soil fertility management practices being used and these include mineral fertilizers, manure application, crop rotation, soil erosion control and intercropping. Experience with rice farming, participation in farmers groups and land size positively and significantly affect the choice to use mineral fertilizers as a soil fertility management. The amount of mineral fertilizer is likely to increase if farmers use it for top dressing, and if they also practice other soil conservation practices. Similarly, farmers that use organic materials are likely to use less mineral fertilizer. Data also showed that under the archetypal farmers' conditions, increasing amount of mineral fertilizer explains only 3% of rice yield increase, suggesting that Integrated Soil Fertility Management (ISFM) is inevitable to narrow the yield gap of rice in this region. This study lends support to recommendations that policy actions focus on improving access to quality extension advisory services to farmers in addition to increasing saving and credit schemes and communications infrastructure in order to stimulate fertilizer access. Research and extension on site-specific nutrient constraints is necessary to improve soil fertility management interventions.

Key words: Rice yield, soil fertility, mineral fertilizers, Lake Victoria Crescent, Uganda.

INTRODUCTION

Growth projections by the Uganda's Ministry of Agriculture indicate that if agriculture continues to grow at the current average of 3.0%, the country will exceed the Millennium Development Goal (MDG) of halving poverty by 2015 (MAAIF, 2010). However, with increased investments in agriculture to pursue growth at 6% per year as targeted by the Comprehensive African Agriculture Development Program (CAADP), Uganda will not only surpass the MDG target of halving poverty by 2015, but will also reduce the number of the absolute poor by 2.9 million, from 10.15 to 7.25 million. A study by the United States Agency for International Development (USAID, 2010) noted that Uganda, which contains nearly half of arable land in East Africa, can at its full potential, feed

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seven times its current population, or nearly twice the current population of East Africa (FTF, 2010). Therefore, under the Development Strategy and Investment Plan (DSIP), the government of Uganda is pursuing increasing investments in agriculture as a sure way of effectively reducing poverty and fostering economic growth (MAAIF, 2010).

Despite these opportunities for agricultural-led growth, Ugandan farm productivity is one of the lowest in Africa, and while 75% of the country is arable, only 30% is under cultivation. Uganda faces declining soil fertility, and use of commercial mineral fertilizer is extremely low, currently at a national average of only 1 kg/ha, among the lowest in the world (Bekunda et al., 2010). The World Bank (2006) observed that increasing fertilizer use can increase production by up to 40%, as observed in parts of Asia and Latin America. Clearly then, improving soil fertility management programs are central to improving Uganda's agricultural productivity.

Several reports have highlighted the food-security and commercial importance of rice in Uganda (Sabiiti, 1995; Ochollah et al., 1997; Kijima et al., 2006; Hyuha et al., 2007; Kijima, 2008). Through promoting the growing of upland rice (one of the ten priority crops), the government of Uganda is encouraging commercialization of agriculture as a way to increase household income and escape the household-level poverty trap. However, to be able to achieve the poverty alleviation and food-security goals simultaneously, the use of soil fertility management practices is inevitable for sustainability. Farmers' yields are typically less than one-third of their potential, and yields of most major crops have been stagnant or declining since the early 1990s (Deininger and Okidi, 2001; Pender et al., 2004; Bekunda et al., 2010).

Low soil fertility is widely recognized as a major factor limiting productivity of smallholder farmers in sub-Saharan Africa (SSA) (Sanchez et al., 1997; FAO, 2005; Fungo et al., 2010; FAO, 2012; Okoboi and Barungi, 2012) and that rice in Uganda responds well to fertilizer applications (WARDA, 2001; Kijima et al., 2006). Mineral fertilizer use has contributed to increasing production of rice-based systems since the Green Revolution, and the effective use of supplemental nutrients remains vital for essential increases in the production of rice and associated cereal staples to meet rising demand for food security and political stability (Buresh et al., 2010).

Majority of farmers in SSA, due to the high cost of mineral fertilizers in many areas, rely on locally available organic resources to replenish fertility of their soils (Palm et al., 1997; Gregory and Bumb, 2006). Whereas organic resources can undoubtedly make significant contribution to improving soil nutrients and soil organic matter, Omotayo and Chunkwuka (2009) highlighted some of the most important constraints limiting development of organic-based soil nutrient management systems in SSA. These include utilization of large labor force required for both processing and transporting of organic materials in bulk quantities as well as large amounts of organic residues often needed to supply adequate nutrients to soils for successful crop production. Efforts by African governments, under the Abuja Convention, to increase mineral fertilizer use to 50 kg of nutrients per hectare by 2015 have not yielded much for Uganda, which remains at approximately 4 kg of nutrients per hectare.

The causes of low fertilizer application rate include as prohibitively high prices, inadequate technical information to farmers, poor road infrastructure and market access have been widely investigated (Henao and Baanante, 2006; Morris et al., 2007; Ariga and Jayne, 2010; FAO, 2012; Okoboi and Barungi, 2012). Woelcke and Berger (2006) showed that in Eastern Uganda, fertilizer prices have to decrease to 5% of the current price or less in order to achieve non-negative nutrient balances. Nonetheless, non-market barriers that may impend fertilizer use in future exist. Okoboi and Barungi (2012) assessed some of these factors but did not link them to plot-level drivers and yield. In this study, we evaluate the household and plot-level factors influence choice use as well as the amount of mineral fertilizer that a farmer decides to use. We also attempt to show that fertilizer application per se does not increase yield significantly unless it is accompanied by appropriate socio-economic and biophysical drivers. The specific objectives are to (i) identify the soil fertility management interventions implemented by rice farmers (ii) determine the relationship between the quantity of mineral fertilizer used and rice yield under archetypal farmers' conditions (iii) determine demographic and plot-level factors affecting the choice to use mineral fertilizers as a soil fertility management intervention, the amount of mineral fertilizer used, and the yield of rice in the Lake Victoria Agro-ecological zone (LVAZ) of Uganda.

METHODOLOGY

Study area

Description of study site

The study was conducted in three major rice producing districts (Kiboga, Kayunga and Luwero) in the Lake Victoria Crescent Agro-ecological zone of Uganda (Figure 1). The districts of Kayunga, Kiboga and Luwero were selected for this study because they rank high among rice-growing district in the LVCAZ. From each of these districts, two sub counties that ranked highest in rice production were selected using key informants. The contemporary climate in this area is wet tropical with a mean annual precipitation of 1200 mm (distinctly bimodal distribution), and a mean annual temperature of 23°C at an elevation over 1 km above sea level.

Due to the range in K-feldspar content and variable texture contrast, the soils are classified as a Ferallsols (FAO, 2006) with predominantly sandy clay loams textures. Black and grey clays are also found in the flat (poorly drained valley bottoms), with yellow sands on the sloping bamboo margins. The topography is characterized by hills and ridges that are highly dissected by streams and drainage ways. The main economic activity of the people in the sampled districts is subsistence farming of bananas,

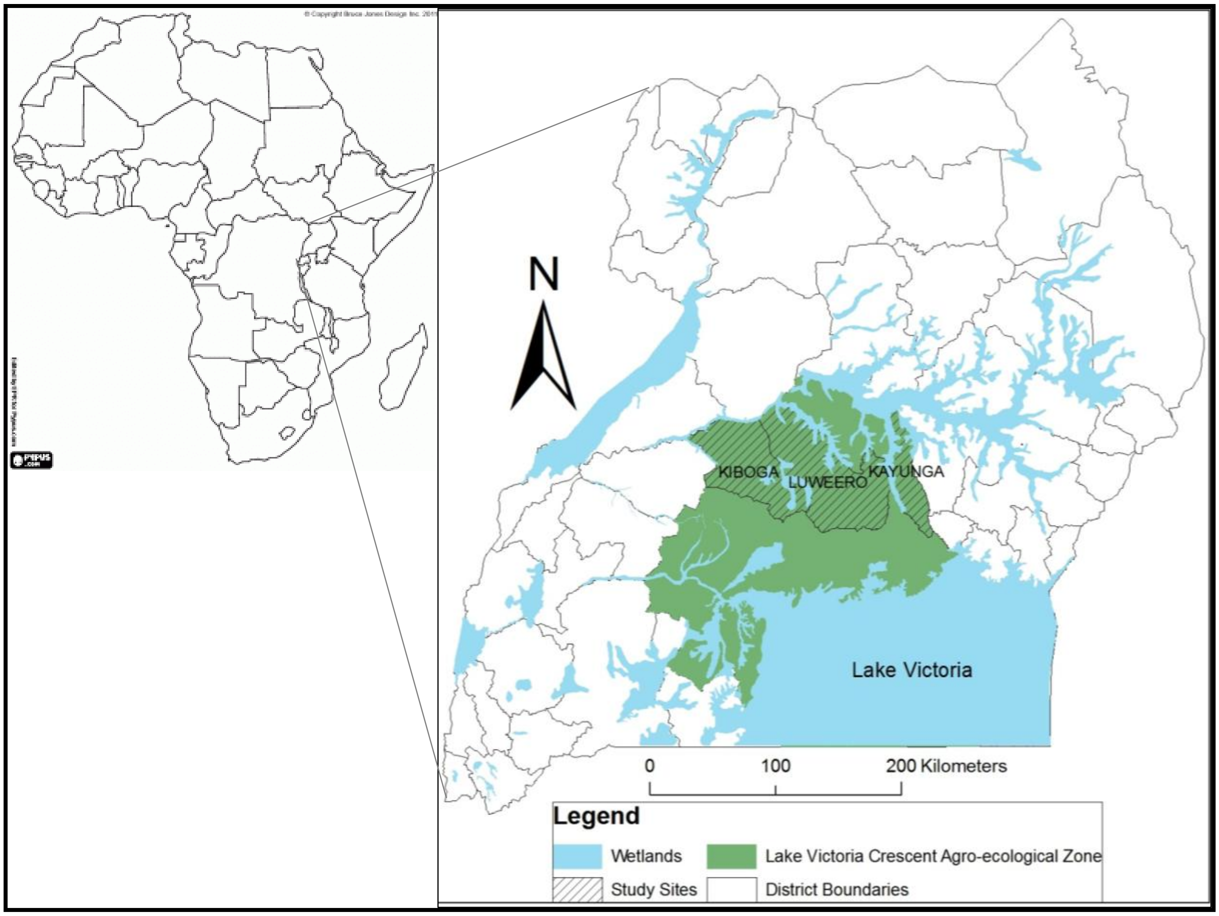

Figure 1. Districts were rice farmers were sampled in the LVCZ of Uganda.

beans, maize, rice, potatoes, cassava among other crops land use types include annual crops, plantation forestry, perennial cropping such as bananas, coffee and agro forestry. Large expanses of grazing lands are common in Luwero and Kayunga districts.

Sampling procedure and data collected

A cross-sectional survey was conducted with rice farmer from the selected sub counties. A sampling frame consisting of all rice farmers in the study villages, was generated with the help of Local Council I chairpersons, who helped to list the names of households in their jurisdiction. Using a list of random numbers, 60 rice farmers were selected from each district to represent approximately 40% of the study population in each district. Face-to-face interviews were held with the selected farmers using a structured questionnaire. Nine questionnaires were dropped because of incompleteness, leaving a total of 171 cases.

Data analysis

Amount of fertilizer used was obtained by computing the average of the application rates reported per season. Total yield was determined as the sum of the two previous seasons. Descriptive statistics of the demographic, fertilizer and yield variables were computed. We used a Probit analysis to determine the influence of socio-economic characteristics on the choice to use mineral fertilizers. A Tobit model double-censured at minimum and maximum was used to assess the factors influencing the probability of increasing the amount of mineral fertilizer used by the farmers and rice yield. The variables used in these econometric models are shown in Table 1. Linear regression analysis was used to show the relationship between amount of fertilizer and yield of rice. All statistical analyses were conducted using Stat 12 statistical software.

RESULTS AND DISCUSSION

Demographic characteristics

The average age of the household heads sampled in this study was 39 years and their level of education is approximately 8 years of formal schooling (Table 2). The number of years they have been cultivating rice ranges from 1 to 20 with an average of 5 years, indicating that majority are arguably well experienced. This is attributed to the fact that upland rice was introduced in Uganda in about 2002 and this was followed by a rapid uptake of the crop owing to its commercial viability and support from the government (through the vice presidential initiative). However, previous studies (Kijima, 2008) indicate that

Table 1. Estimators used in Probit and Tobit models for fertilizer used among rice farmers in LVCAZ of Uganda.

Variable code	Variable	Responses	Data type
Fertuse	Defines whether the farmers use mineral fertilizer in the rice crop. This is the response variable in the Probit model	0 = Not use 1 = use	Binary
Fertrate	Rate of fertilizer used by farmer. This is the response variable for the Tobit model on amount of fertilizer used.	Continuous	Scale
Rice yield	Indicates the yield of rive obtained by the farmer. This is also a response variable for the Tobit model on yield of rice.	Continuous	Continuous
District	Location by district where the farmer is found	1 = Luwero 2 = Kiboga 3 = Kayunga	Categorical
Sex	If the respondent is a male or female	0 = Female 1 = Male	Binary
Age	Number of years	Counts	Discrete
Education	Number of years in formal education	Counts	Discrete
Experience	Number of years growing rice	Counts	Discrete
Extension	Number of visits by agricultural extension officer of the previous year	Counts	Discrete
Groups	Membership of farmers' associations;	0 = Non-member 1 = Member	Binary
Incomecrop	If rice is an income crop or a subsistence one	0 = Subsistence 1 = Income	Binary
Acrage	Size of land under rice cultivation in hectares	Continuous	Continuous
Locate	Indicates whether the plot is upland or wetland	0 = Swamp 1 = Upland	Binary
Timing	Timing of fertilizer application - whether at planting or as top dressing	0 = At planting 1 = Top dressing	Binary
Use organic	Whether the farmers uses organic fertilizer or not	0 = Don't use; 1 = Use	
Other practice	Use of other soil conservation practices such as crop rotation, erosion control, intercropping, etc.	0 = No 1 = Yes	Binary
Seed	Have any problem accessing good quality seed?	0 = No 1 = Yes	Binary

within 2 years, the drop rate was high and this was attributed to opportunity cost and food security risk faced by households.

Majority of the households sampled were male-headed (Table 3). Approximately, 78% of the respondents have had contacts with extension agents and/or received some training on rice cultivation. Rice is the major income/commercial crop of approximately 70% of the respondents. The number of farmers having rice in paddy is just 10% above the number in uplands. Sixty-four percent (64%) of the respondents belong to rice farmer groups in which they access credit, jointly sell and

Table 2. Continuous variable characteristics rice farmers in the LVC-AEZ of Uganda.

Variable	Minimum	Maximum	Mean	Standard deviation
Rate of mineral fertilizer applied	0	50	4.3	11.7
Age of farmer	19	89	39.0	12.5
Number of years is formal education	0	15	7.6	4.1
Number of years of growing rice	1	20	5.1	3.8
Total size of rice fields cultivated	0.1	8.5	2.1	1.6

Table 3. Categorical variables characteristics of rice farmers in the LVC, Uganda.

Variable	Codes	Frequency	Percent
District	Kayunga	57	33.3
	Kiboga	54	31.6
	Luwero	60	35.1
Sex of farmer	0	13	7.6
	1	158	92.4
Visit by agricultural extension officer in previous year	0	37	21.6
	1	134	78.4
Membership to any farmers' groups/associations	0	109	63.7
	1	62	36.3
Rice as income crop	0	52	30.4
	1	119	69.6
Use of organic (e.g. manure) fertilizers in the rice fields	0	102	59.6
	1	69	40.4

procure rice seed.

Soil fertility management practices

When asked the farmers whether they were taking any efforts to conserve soil fertility, 44% answered in affirmative. Methods that farmers reported include application mineral fertilizers, manure (mainly from composts, kitchen residues, and animal refuse and housing), practicing crop rotation, fallowing, mulching and terracing for soil erosion control. Farmers also reported to be intercropping as well as rotational cropping of rice and leguminous crops such as beans and cow peas in order to maintain soil fertility. This approach has been found to contribute to improvement of soil N pools through biological N-fixation (Akinnifesi et al., 2009; Bekunda et al., 2010) as also improves soil organic matter if farmers incorporate the plant residues in the fields. The contribution of the intercropping practices is being investigated under controlled experiments (Models I and II) under this project in order to identify and recommend appropriate cropping mixtures and plant populations.

When asked about the perception of the trends in soil fertility, approximately one third (36%) believe the trend in negative, 19% think it is positive and 15% think it is constant. The remaining farmers do not know. This indicates that there is still limited acknowledgement of the negative nutrient balances in the region and partly contributes to low fertility management interventions among farmers.

Types of mineral fertilizer used

Approximately 27% of the farmers use mineral fertilizer in their rice fields. Of these, almost one-half (49%) of the farmers applying mineral fertilizers employ Urea and about one-third (34%) use Diammonium Phosphate (DAP) as soil nutrient sources (Figure 2). Other mineral fertilizers used include NPK (blended Nitrogen:Phosphorus:Potassium), Rapidgrow and

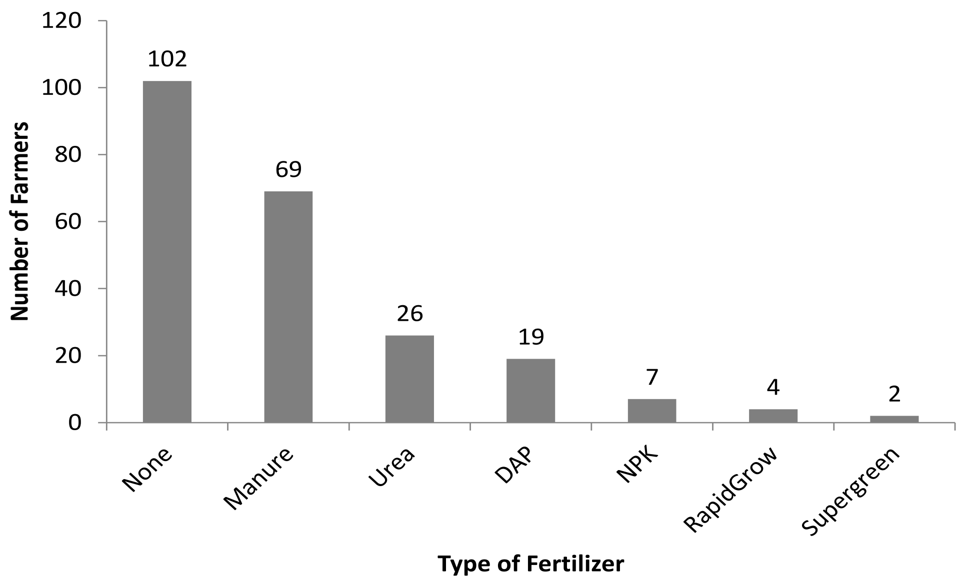

Figure 2. Type of fertilizer applied by rice farmers in the LVC-AEZ, Uganda.

Supergreen in addition to manure (green, compost and Farm Yard) of varying quantities. Twenty farmers apply more than one type of fertilizer, predominantly Urea in combination with DAP in almost equal proportions. The low application rates of mineral fertilizers could partly explain the high opportunity cost of rice farming that Kjima (2008) observed and subsequent drop-out from the practice by farmers in central Uganda. These low mineral fertilizer rates are reflected in several reports that show Uganda to be among the countries with the lowest rates of mineral fertilizer use in Africa (~3 kg of nutrients per ha).

Nitrogen is a highly mobile nutrient and for this matter, the most limiting nutrient in most soils. This is particularly true for highly weathered, low-organic matter Oxisols and Ultisols in the sites where this study was conducted. Application of nitrogen fertilizers is therefore a highly recommended nutrient soul N-source. The soils where the study was conducted are also characterized by low pH and high level of clay minerals that result in P-fixation (Chenery, 1954; Aniku, 2001; FAO, 2005; Fungo et al., 2011a). Hence, application of P is also highly recommended. It is good to note that a significant proportion of those applying mineral fertilizers apply both N and P sources probably due to useful knowledge provided to them by extension staff.

Application rates of mineral fertilizers

The average application rate of fertilizer (all types combined) is 17.2 ± 4 kg/acre. The amount applied in the highest rate is NPK, followed by DAP and Urea is least applied. The amount applied per fertilizer type was significantly different ($F_{2, 41}$, $P<0.001$) (Figure 3).

The recommended rate for N and P nutrients is 120 kg/ha for the area where this study was conducted. However, the highest application rate noted in the study was only about 5 kg N /ha (for NPK = 17:17:17), 11 kg N/ha (for DAP and Urea). Compared to the national average, this is in fact relatively high. However, it means that to be able to meet the target of 50 kg/ha as set by the Abuja declaration, there is need to quadruple the current application rates. This represents a very significant gap required to fill within a 3-year period between 2012 and 2015.

Timing of fertilizer application

Approximately 80% of the farmers who apply mineral fertilizer do so in a single application at planting by broadcasting (Figure 4). The rest apply either before, after planting, or a combination of the two.

This timing is acceptable for most conditions but it is important for extension provided to emphasize the need for incorporating the fertilizer in the soil after broadcasting as this may reduce on the loss due to volatilization if left exposed, especially for Urea on low pH soils. As this was not seen by many, extension staff should also advise farmers to use alternative application methods such as banding (application in bands or pockets near the plant) to ensure more efficiency.

Yield gap after mineral fertilizer use

The average rice yield is 1.1 ± 0.17 tons/ha among

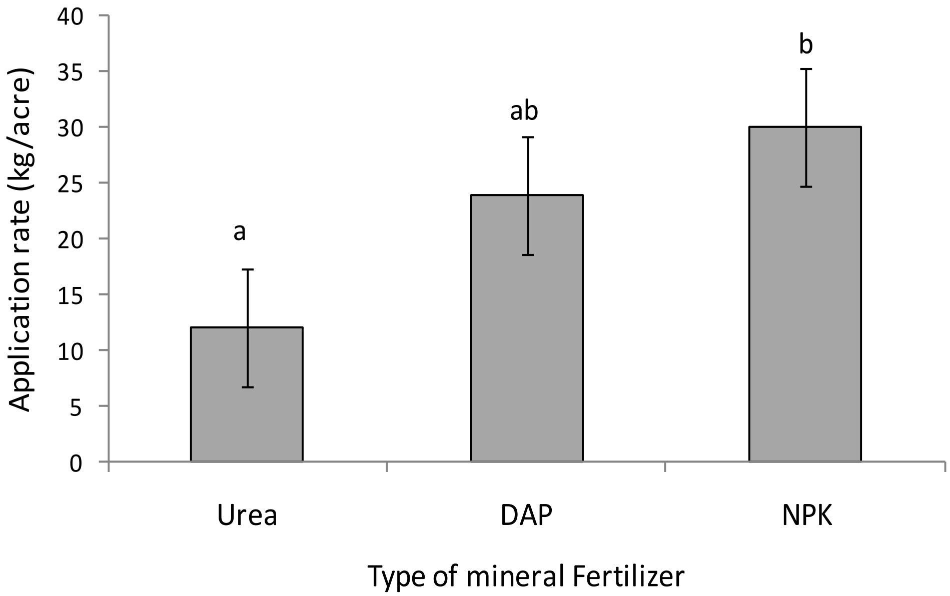

Figure 3. Rate of fertilizer application by type of fertilizer applied by rice farmers in the LVC of Uganda.

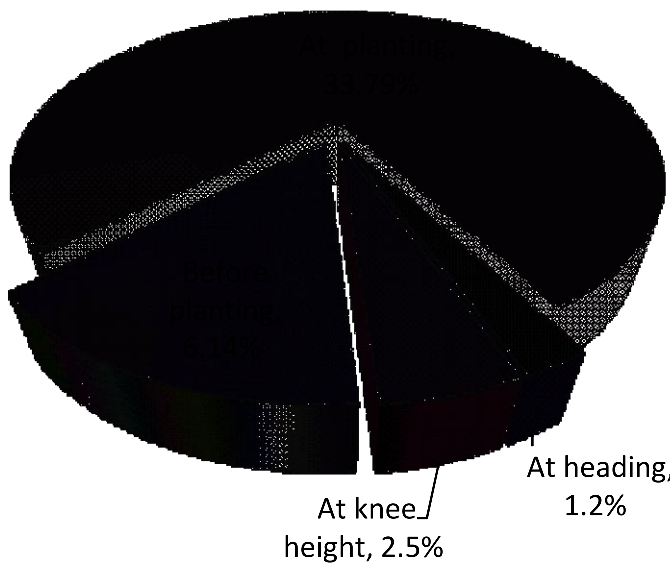

Figure 4. Timing of application of fertilizers by rice farmers in the LVC of Uganda.

farmers in this region. This is only about half of the potential yield in the region of approximately 2.2 t/ha (Kijima, 2008). Increasing fertilizer use alone explains only 3% of yield increase (Figure 5). Also, there are several farmers that get relatively higher yields with no fertilizer input. This is attributed to the several other factors that are likely to influence fertilizer-yield response. These factors are both biophysical (such as soil type, organic matter and soil moisture status) as well as socio-economic (such as choice of timing and application method, implementation of allied conservation practices such as erosion control and irrigation water management). These results suggest that increasing mineral fertilizer alone per se will not narrow the yield gap of rice significantly, and that improving other soil management practices is required to narrow the yield gap of rice in this region of Uganda. Woelcke and Berger, (2006) found that the overall effect of fertilizer price

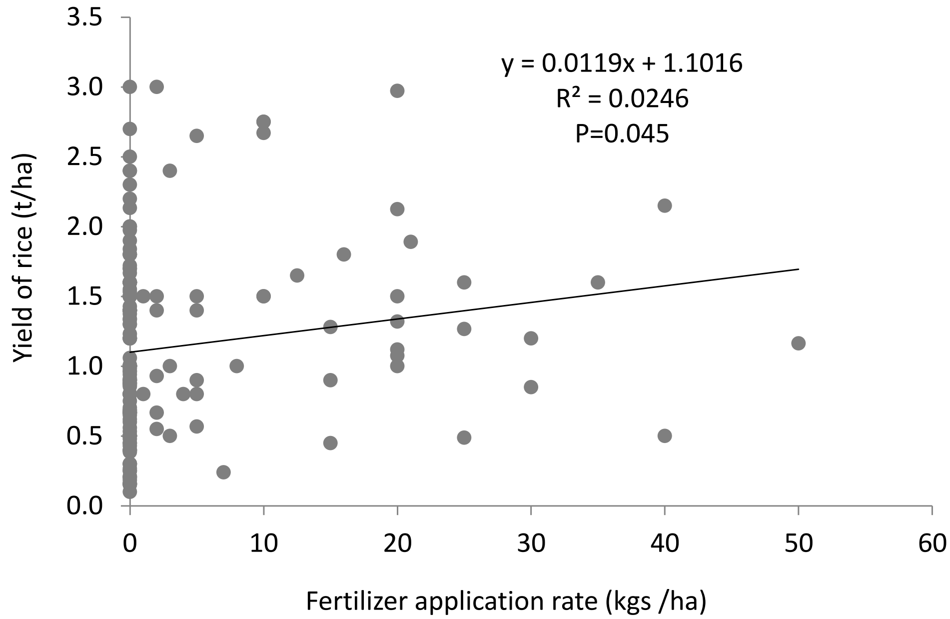

Figure 5. Rice yield of farmers in relation fertilizer amount among rice farmers in the LVCZ of Uganda.

reduction on household income is very modest, reaching a 5.5% increase when fertilizer prices are reduced to 5% of the current price. The authors further argued that the extreme fertilizer price reduction needed to induce farmers in Eastern Uganda to switch to a more sustainable intensification of agricultural practices, policy options focusing only on input market improvements would probably not be a promising strategy. However, even direct fertilizer subsidies alone will probably not provide sufficient incentives for the semi-subsistence farm households to adopt improved practices. These observations underscore the need for more holistic and high quality extension service system, particularly in Integrated Soil Fertility Management (ISFM).

Determinants of choice to use mineral fertilizer

The results of the econometric models of the choice to use mineral fertilizers, amount used and yield response are presented in Table 4. The probability of farmers using mineral farmers in Kiboga is higher than for those in Luwero, and those in Luwwo are more likely to use mineral fertilizer than those in Kayunga. Similarly, farmers who use some organic fertilizers have a lower probability of using mineral fertilizers, probably because they think sufficient nutrient supply is met by added organics. This is might in line with the argument of Okoboi and Barungi (2012) that it appears that the somewhat weaker position of women in Uganda in relation to financial resources and supportive extension services to use inorganic fertilizer might have led them to embrace organic fertilizer as the alternative. The results also show that older farmers are less likely to use mineral fertilizers that younger ones. Age of the farmer as well as the number of years of experience in rice cultivation negatively affect the probability for using fertilizers. This is difficult to expect as more educated farmers seem to understand the relevance of fertility management compared to illiterate ones. However, it is possible that these educated/experienced farmers and was also observed in Kenya (Ariga and Jayne, 2010).

There is a higher probability of male farmers using fertilizers compared to female counterparts (Table 4). These result are similar to those reported by Okoboi and Barungi (2012) and this is attributed to the usually subsistence nature of female farmers compared to commercial-oriented male counterparts, augmented by the financially weaker position of female farmers. Farmers who grow rice as an income crop tend to have higher propensity to use mineral fertilizer as they would be cautious to ensure good yields.

The larger the size of land under rice, the higher the probability of using mineral fertilizer. This is attributed to the fact that most farmers with large gardens are generally commercial-oriented and would like to maximize yield. Investing in mineral fertilizers on small plots by already resource-poor farmers is unlikely. Land consolidation such as that implement in Mubuku (in Kasese district, western Uganda) can increase minimum acreage per crop, increase fertilizer use and hence yield. Such programs should be encouraged and such incentives as farm implements and joint extension may be more relevant under such arrangements. More

Table 4. Regression coefficients of factor affecting choice to use, quantity of mineral fertilizer used and yield of rice by farmers in the LVCAZ, Uganda.

Variable	Choice to use (Probit)			Amount used (Tobit)			Yield of rice (Tobit)		
	Coefficient	z	P-value	Coefficient	t-value	P-value	Coefficient	t-value	P-value
District	0.184	1.21	0.023	2.352	0.99	0.032	0.088	1.39	0.017
Sex	0.687	1.33	0.019	-3.154	-0.44	0.066	0.357	1.87	0.006
Age	-0.004	-0.4	0.069	-0.098	-0.57	0.057	0.002	0.53	0.059
Educ	-0.008	-0.25	0.080	-0.301	-0.60	0.055	0.014	1.08	0.028
Experience	0.020	0.55	0.058	0.185	0.36	0.072	0.022	1.55	0.012
Extension	-0.169	-0.56	0.058	-1.680	-0.35	0.073	0.095	0.76	0.045
Groups	-0.146	-0.53	0.060	-2.032	-0.48	0.063	-0.072	-0.68	0.050
Incomecrop	0.366	1.28	0.020	5.808	1.32	0.019	0.175	1.59	0.011
Acrage	0.072	0.85	0.040	0.280	0.22	0.083	0.072	2.15	0.003
Locate	-0.194	0.60	0.055	1.586	0.30	0.076	-0.083	-0.62	0.054
Timing	0.008	1.02	0.031	0.132	1.05	0.029	0.002	0.63	0.053
Useorganic	0.064	0.24	0.081	-0.670	-0.16	0.087	0.179	1.64	0.010
Otherpract	0.495	5.76	0.000	6.942	5.63	0.000	0.063	2.00	0.005
Seed	0.325	0.95	0.034	2.401	0.43	0.066	0.129	0.94	0.035
N			171			171			171
LR			55.6			54.81			25.63
Log likelihood			-73			-241			-165
R-squared			0.028			0.010			0.007
Left-censored			NA			124			1
Uncensored			NA			46			167
Right-censored			NA			1			3

NA = Not applicable.

experience in rice growing increases the probability of a farmer using mineral fertilizers possibly because the farmers recognizes the yield gap when fertilizer is not used.

Interestingly, factors such as visit by extension staff have severally been shown to increase improved land management practices (Feder and Slade, 1984; Igodan et al., 1988; Strauss et al., 1991; Akramov, 2009). However, our study suggests otherwise. These data point to the need to consider the quality of extension services rather than the number of visits per se. Strauss et al. (1991) demonstrated that improving the quality of extension staff is important in terms of adoption of rice and cowpeas cultivation practices in Brazil. The quality of services that extension staff provides may not be appropriate for soil fertility management practices. This is possibility because extension staff predominantly with agronomy or extension background focuses on selected crop management practices like seed section, pest and disease management, weed control, paying little attention to soil fertility management practices. Thus, farmers are more likely to spend their already meager resources on pests and seed, thereby reducing the propensity of purchase mineral fertilizers. With this done, farmers have the impression that all is well and especially that soil infertility does not have as obvious symptoms as, for example, pest and disease. Future strategies may require deliberate effort to promote education of soil science professionals that will improve the current shortage of technical staff in soil science countrywide. Besides, rice is a relatively new economic crop in the area, and which extension staff has not largely ventured into.

Members of farmer groups usually have some access to credit facilities as well as knowledge-sharing, and market linkages. Whereas some studies (Sheikh et al., 2003; Keil et al., 2005; Sebopetji and Belete, 2009) indicate a positive relationship with adoption of several land management practices. However, the credit obtained from these groups is hardly sufficient to meet the many needs that include pesticides, labour, transport and fertilizers. Ganesan et al. (2013) found that rural farmers perceived information on pest and disease control as most important of the information needs. Credit accessed might be used for pest control and seed acquisition, leaving none for fertilizers. This might explain the negative relationship observed in our study. Plots on upland are less likely receive mineral fertilizer. This might be related to the lack of extension knowledge, or simply the high cost of mineral fertilizers.

The probability of applying more fertilizer is higher if the rice field is upland compared to a lowland plot. The conventional rice growing fields are those in wetlands and farmers conventionally do not apply fertilizers. In the new upland varieties, farmers that participated in initial extension activities receives some training on appropriate management practices including fertilizer application. This training might have encouraged some upland farmers to apply fertilizers compared to their conventional lowland counterparts. However, the data showed that exposure to extension services does not affect use of mineral fertilizers, suggesting that the application of fertilizer upland rice field more than to lowland is a farmer-perception issue. Farmers that practice other soil management practices such as erosion control, mulching and intercropping are more likely to use more fertilizer possibly because they have good understanding of the need to manage the soil in order to obtain good yields.

Less fertilizer is likely to be used if the farmer has problems accessing seed material. This result does not support our supposition that farmers that have problems accessing seed would be more cautious in cultivation practices to ensure good yields. This could be due to notion of the poverty trap (Azariadis and Stachurski, 2005); if accessing seed is difficult, then so will be the fertilizer.

Determinants of amount of mineral fertilizer used

Location, main purpose of rice growing, timing of fertilizer application and tendency to use other soil conservation practices positively and significantly increase the probability of using more mineral fertilizers by rice farmers in the LVCZ. The amount of fertilizer used is likely to be higher in Kiboga compared to Luwero or Kaynga. Compared to Kayunga, Kiboga district is more humid and crop production is more dominant compared to Luwero and Kayunga which are drier and dominantly cattle rearing areas. The use of mineral fertilizer is therefore likely to be higher in Kiboga than Luwero or Kayunga. As stated above for income crop and timing, higher quantities of fertilizer are more likely to be used on rice grown mainly for commercial value and are likely to receive higher doses of mineral fertilizer than that grown for subsistence.

Even though fields located upland are less likely to receive fertilizer, the amount applied if ever, is likely to be higher compared to the low land fields. Farmers may have thought that the new varieties of rice that they are growing are high yielding and would do so without use of mineral fertilizers. So, the tendency to use them was neglected. This situation compounds already existing limited use of mineral fertilizers. More sensitization needs to be done to ensure that all appropriate practices are undertaken to realize the full potential of the new rice varieties. Extension service in Uganda is at 20% (Okoboi and Barungi, 2012) and skewed to NAADS-supported farmers. This implies that the few times that the staffs appear are meant for very critical challenges such as disease outbreak and popularization of new practices/technologies. For those that have recognize the need to apply mineral fertilizer possibly applied more following the training provided during promotional activities of NERICA rice varieties.

Determinants of rice yield

Age of farmer, participation in farmer groups, and early application of fertilizer and landscape position of the rice field are the only factors that were not shown to increasing the yield of rice. As was expected, all the other factors positively and significantly increase the yield of rice. In fact, participation in farmer groups and planting on upland fields, have negative coefficients, suggesting that they negatively influence rice yield. To the best of our knowledge, there are no farmer groups specific to rice farmers in the area. Although several studies report farmers groups as avenues for exchange of agricultural information and knowledge, they may, if not well guided, take too much of the farmers' productive time and reduce their productivity. The factors that consistently increase the choice to use, amount used and increased yield are experience, commercial orientation, acreage and use of other soil conservation practices. These factors should be the focus of household-level interventions to improve rice productivity in the LVCZ of Uganda. Experience maybe compensated by more intensive extension support to farmers, while improving marketing opportunities through Participatory Market Chain Approach that can stimulate technological and institutional innovation in locally relevant agricultural commodity chains (Horton et al., 2010).

CONCLUSIONS AND RECOMMENDATIONS

In this study, we have shown that rice farmers practice a wide range of soil fertility management practices and these include mineral fertilizers, manure application, crop rotation, soil erosion control and intercropping. Sex, land size, commercial orientation, timing, and tendency to use other conservation practices and access to seed are the factors that positively and significantly affect the choice to use mineral fertilizers as a soil fertility management. The amount of mineral fertilizer is likely to increase if farmers use it for top dressing, are commercially oriented, and if they also practice other soil conservation practices. The amount of mineral fertilizer used is likely to increase if farmers are commercially oriented, use other practices, and use the fertilizer mainly for top dressing. On the other hand, older farmers, planting on upland fields, those that participate in farmers groups, were shown to have less yield of rice compare to others doing otherwise. Similarly, farmers that use organic materials are likely to use less mineral fertilizer. Data also showed that under the archetypal farmers' conditions, increasing amount of mineral fertilizer explains only 3% of rice increase, suggesting that ISFM is inevitable to narrow the yield gap of rice in this region. We recommend that policy actions should focus on improving access to good quality extension advisory services to rice farmers, increase investment in saving and credit schemes, and improve communications infrastructure in order to stimulate fertilizer access and hence use by rice farmers. Further research on productivity under alternative management practices such as intercropping should inform selection of locally affordable but sustainable fertility management options for the resource-poor and food insecure farmers of the LVCZ.

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