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The Adoption and Impact of Improved Maize and Land Management Technologies in Uganda

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Abstract

In spite of the fact that the Ugandan National Agricultural Research System has developed and released several production-enhancing technologies over a century, yields of most major crops at the farm level have been low. Given that about 80 percent of Uganda's labor force is employed in agriculture, the scope for sustainable poverty reduction in Uganda depends very much on improving agricultural productivity. It is in this context, this paper examines why there has been poor adoption of production-enhancing technologies in the production of maize, which is a major crop in Uganda and what the impacts of the exiting production environment are on factor payments. This study reveals that farmers do not pay proper attention to soil fertility management, which acts as a major constraint to increase yields. The analysis also indicates the need for vibrant rental market for land to provide access to landless tenants who are found to be the economically efficient.

Keywords: *Production-enhancing technologies, maize, land management, poverty reduction.*

1. Introduction

Over the past decade, Uganda's agricultural sector, the mainstay of the economy, has grown at an average rate of 4% per annum[1]. However, this growth has not come from increased productivity, but rather from increased area under annual crops, and from the rehabilitation of formerly abandoned

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[1] The sector grew by 4.8% in the 2000/2001 financial year (MFPED, 2002).

fields of perennial crops, such as coffee, which was in response to higher prices that followed market liberalization. The yield for many crops has stagnated or declined throughout much of the 1990s (Sserunkuuma *et al.*, 2001) and it is partly for this reason that, notwithstanding the impressive rate of economic growth of over 6% per annum in the past decade, poverty is still severe in rural areas where 96% of Uganda's poor live (MFPED, 2002), depending mainly on agriculture for their livelihood.[2]

The heart of the poverty problem is that over 80% of Uganda's labor force is employed in agriculture, a sector receiving less than half of the total income (GDP) in the economy, and this has been largely attributed to low productivity of the sector (MFPED, 2002). Given this linkage between agricultural productivity and poverty, and because agricultural growth can be accelerated substantially by the use of modern farming methods, the scope for sustainable poverty reduction is intimately linked to the ability to transform agriculture to increase productivity. Therefore, the agricultural sector presents a great opportunity for poverty reduction in Uganda.

In recognition of this potential, the government of Uganda recently launched a plan for the modernization of agriculture (PMA), with a mission to eradicate poverty by transforming subsistence agriculture to commercial agriculture through re-orienting the poor subsistence farmers' production towards the market[3]. Government has also recognized that PMA's success depends on the uptake of improved agricultural technologies by a significant proportion of farmers so as to increase total factor productivity and farm income (Government of the Republic of Uganda, 2000). In this regard, the government has among other things resolved to support the generation, dissemination and adoption of productivity-enhancing technologies.

A number of productivity-enhancing technologies (including high-yielding crop varieties and land management techniques) have been developed and released by the Ugandan National Agricultural Research System (NARS) during the past 100 years of agricultural research in Uganda. However, because of the low uptake of these technologies, farmers' yields of most major crops are low (typically less than one-third of potential yields found on research stations) and have stagnated or declined throughout much of the 1990s (Sserunkuuma *et al.*, 2001). As a result, it is argued that agricultural research has had low impact in terms of productivity enhancement and poverty reduction. This paper analyzes the adoption and impact of improved maize varieties and recommended land management technologies on maize yield and factor payments.

The remaining part of this paper is organized as follows: Section II reviews the trends of maize production and technology advancement in Uganda. Section III presents the research questions and hypotheses as well as the methods used to address them. In section IV, the level of adoption of improved maize varieties and its impact on factor payments is determined. Section V tests hypotheses about the determinants of adoption of improved maize and land management technologies, and determines their impact on maize yield. Section VI concludes the paper with a discussion of policy implications.

2. The trends of maize production and technology advancement in Uganda.

Over the past three decades, an average land area of 384,000 ha has been allocated to maize; and production has averaged 522,000 tons with a grain yield of 1.3 ton per ha (Kasenge *et al.*, 2001). The overall trend of production, area and yield during this period shows that yield has stagnated or declined, and the growth in maize production has primarily been due to area expansion (Kasenge *et al.*, 2001; Pender *et al.*, 2001), (as is indicated in Table 1). The main reasons for the stagnation or decline

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[2] Based on the Uganda National Household Survey (UNHS) data of 1999/2000, 35% of Ugandans are unable to meet their basic needs and are living below the absolute poverty line.

[3] The government of Uganda is committed to reducing the proportion of the population living in absolute poverty from 35% in 2000 to below 10% by the year 2017 (Government of the Republic of Uganda, 2000).

include extensive use of unimproved maize seeds, depletion of soil fertility, erratic rainfall, prevalence of pests and diseases, little improvement in agronomic and post harvest technologies, and limited use of yield-enhancing purchased inputs such as fertilizers and other agrochemicals (Blackie, 1994; Sserunkuuma *et al*., 2001).

Table 1. Trend of change in yield since 1990 or year when began growing crop variety (Mean Rank)

Input	National Average	Agricultural potential zone					
		Unimodal	Bi-Modal Low	Bi-Modal Medium	Bi-Modal High	S. West Highlands	Eastern Highlands
Beans	-0.96	-0.43	-0.73	-0.85	-1.13	-1.39	-0.52
G.nuts	-1.11	-0.39	-1.39	-1.05	-1.32	-1.54	-1.69
Maize	-0.62	-0.52	-0.76	-0.44	-0.6	-1.09	-0.84
Millet	-0.68	-0.16	-0.44	-0.59	-0.93	-1.13	-1.62
Sorghum	-0.56	-0.2	-0.21	-0.23	-0.76	-1.3	-1.00
Cassava	-0.81	-0.29	-1.3	-0.86	-0.81	-0.89	-1.67
Sweet Potato	-0.74	-0.28	-0.99	-0.43	-0.95	-1.22	-1.38

Means and errors are corrected for sampling stratification and sampling weights. Values represent the average of rank data where 0=no significant change; +1=minor increase; +2=major increase; -1=minor decrease; and –2=major decrease.
Source: Pender *et al.* (2001).

NARS during the past three decades released several varieties of maize, including Kawanda Composite A (KWCA) (released in 1971); Longe 1 (an open pollinated variety released in 1991); Uganda Hybrids (A to D) of Longe 1 released in 1999; Longe 4 and 5 (open pollinated varieties released in 2000), and their hybrids Longe 5H and Longe 6H released in 2002 (NARO/IDRC/CAB International, undated). A few hybrids from Kenya and Zimbabwe have also been available on the Ugandan market. On-farm trials for improved maize seeds and fertilizer technologies conducted between 1999 and 2001 by an NGO (Appropriate Technology-Uganda) indicate significant yield differences between improved and traditional maize varieties, with and without fertilizers. The yield gap ranges between 2 to 3.5 tons per he (see Table 2).

Table 2. On-farm trials for maize yields (improved vs. traditional) with and without fertilizers

Yield	Trial year	Improved varieties	Traditional varieties	Gap
Yield without fertilizer (Kg/ha)	2001	6,341 (N=266)	2,828 (N=51)	3,513*
Yield without fertilizer (Kg/ha)	2000	7,077 (N=153)	3,517 (N=27)	3,560*
Yield without fertilizer (Kg/ha)	2000	5,028 (N=188)	2,216 (N=27)	2,812*
Yield without fertilizer (Kg/ha)	1999	5,090 (N=907)	2,829 (N=128)	2,261*
Yield without fertilizer (Kg/ha)	1998	6,916 (N=571)	4,646 (N=74)	2,270*

*Difference in means is significant.
N=Number of observations.

However, as will be shown later, recent household and plot survey data show much lower yields from farmer-managed maize plots than those quoted above, suggesting limited adoption of yield-enhancing technologies.

3. Research questions, hypotheses and methods

Research questions

The research questions addressed by this paper relate to the stagnant or declining yields for most crops (maize inclusive) observed throughout much of the 1990s (Sserunkuuma *et al.*, 2001), notwithstanding the presence of yield-enhancing technologies on the market. Low yields in the midst of such technologies suggest low technology adoption. It is possible for modern technologies not to be adopted if they are of low profitability, that is, if the returns do not justify the effort required. However, because profitability is necessary but not sufficient condition for adoption to take place, other ("non-profit") factors could deter the adoption of profitable technologies. Therefore, the questions addressed by this study are:

Does it pay to switch from traditional to improved varieties of maize?

Assuming an affirmative answer to question (1), why then do some farmers adopt improved maize and yield-enhancing land management practices and others do not?

What impact does the adoption (or lack of it) of improved maize and land management technologies have on maize yield?

Research Hypotheses

This study is built on the hypothesis that the opportunities and constraints for sustainable development depend upon the comparative advantages that exist in a particular location, and that the agricultural and land management technologies that are most profitable and sustainable in a given location are also likely affected by the comparative advantages of that location (Pender *et al.*, 2001). Thus, the nature of agricultural and land management problems and the appropriate means of addressing them in a particular location are hypothesized to depend upon factors that determine the comparative advantage of that location, which in turn determines the returns to investment in technologies aimed at solving these problems, and whether or not such investments will actually be made.

Many factors determine the comparative advantage of a given location; these factors operate at different scales (plot, household, village, region, nation and international). The village level factors, among others, include agricultural potential, access to markets and infrastructure, population density, presence of technical assistance programs run by government, and non-government organizations. These factors affecting comparative advantage also influence land management. For example, access to markets and roads has a direct effect on the profitability and use of alternative crop and land management technologies. In densely populated areas of Uganda with good market access and high rainfall (high agricultural potential), the most profitable activities include intensive production (use of modern technologies) of high value perishable annual crops such as vegetables and perennial crops such as coffee and bananas, and of low value storable annual crops such as maize and beans (Pender *et al*, 2001). In less densely populated low market access areas, expansion of subsistence food production through increased acreage and using traditional methods is likely to be more common and the adoption of purchased agricultural inputs such as fertilizer and improved seed is likely to be lower.

Government policies, programs and institutions may also influence agricultural and land management practices. Programs that provide technical assistance in agriculture and land management may have different effects, depending on the focus of their activities. In some cases, these programs may promote increased use of purchased inputs, such as improved seeds and fertilizer. In other cases, technical assistance programs may promote low external input technologies such as manuring, composting and incorporation of crop residues into the soil. The net impact of such programs on land management is an empirical question investigated by this study.

If factor markets do not function efficiently, there may be significant differences among households in their land management practices and agricultural productivity (de Janvry *et al*; 1991). This is because of differences in household endowments of physical assets (such as land and livestock), human capital (such as education, family labor, farming experience and training) and social capital (such as participation in organizations and family and ethnic relations), that may also determine the agricultural and land management practices pursued by particular households. Households with greater endowments of productive family labor per unit of land may be able to farm the land more intensively and or be better able to conduct critical operations at the right time than other households. Such households are more likely to adopt labor-intensive land management practices such as application of manure, which contributes to improved soil fertility. Households with more education or other forms of human capital (such as experience in farming or informal training in agriculture) may have greater farm management capacity or ability to understand and use new technologies. On the other hand, more educated farmers may be less likely to invest in inputs or labor-intensive land management practices, since they may be able to earn higher returns from their labor and capital if used in off-farm activities.

The types of land management practices pursued also depend on the types of commodities produced at the household level. Where livestock production is occurring, there is potential for integrating livestock with crop production by using draught animals for tillage and recycling animal waste to the soil through manuring and composting, which contributes to improvement in soil fertility and crop yields. Farmers with more livestock are likely to use more animal manure than those with fewer animals because of the differences in livestock endowment, and the low value to volume ratio of manure, which makes it less transportable and tradable. Livestock may also be sold to obtain money for buying fertilisers or other inputs to improve soil fertility, just like other physical assets may be liquidated or used as collateral to get cash for buying yield-enhancing inputs.

Plot-level factors such as types of soil, topography of the land, ownership and tenure security held over the land may influence land management problems and the appropriate means for addressing them. Land tenure on a plot can affect land management and productivity for several reasons. If there is tenure insecurity, there will be little incentive to invest in land improvement (Feder *et al*, 1988). This, however, may not be the case if tenure security can be increased by investing in land (Otsuka and Place, 2001), in which case, there may be no less investment on plots having insecure tenure. To the extent that land sales or lease rights enable households to recoup the value of land improvements, owners with more complete property rights may be more likely to invest in land improvement. Distance from the plot to the farmer's residence, nearest road or market can also affect land management. Plots that are further away from the residence may receive less bulky and hard-to-transport inputs, such as manure and crop residues. Distance may also have a negative influence on commodity prices received by farmers and a positive influence on the input prices they pay, thereby discouraging land improvement investments. The relationships hypothesized above are tested using the methods described below.

Research methods

As already mentioned, the central hypothesis for this study is that agricultural potential, market access and population density are key factors determining the comparative advantage of a location, which in turn affects the profitability of agricultural and land management practices in that location. Based on this hypothesis, the study area was mapped into development domains by overlaying the three dimensions of agricultural potential, market access and population density using available secondary information (Ruecker, 2001)[4].

Agricultural potential was classified based upon the agro-climatic potential for perennial crop production, using the average length of growing period, rainfall pattern (bimodal vs. unimodal), maximum annual temperature, and altitude. Potential for annual crop production was also mapped, and the maps were found to be very similar. Seven agro-climatic zones were identified within the study area: the high, medium and low potential bimodal rainfall areas at moderate elevation, the high potential bimodal rainfall southwestern and eastern highlands, and the medium and low potential unimodal rainfall regions at moderate elevation. The unimodal low and unimodal medium potential regions were combined, with the expectation that similar land management practices are pursued in these areas.

The study area was also classified according to the level of market access and population density. To classify market access, the measure of potential market integration estimated by Wood *et al.* (1999) was used, which is a measure of travel time from any location to the nearest five towns or cities, weighted by the population of the towns or cities. Population density was classified based upon rural population density of parishes in 1991 (greater or less than 100 persons per square km, which is about the average rural population density in Uganda).

All together, 24 development domains were classified, although only 16 are represented in Uganda to a significant extent. It is from these 16 development domains that a sample of 100 LC1s (lowest administrative unit) were randomly selected for conducting village, household and plot-level surveys. seven additional LC1s were purposively selected from southwest Uganda and the Iganga district in areas where technical assistance programs run by the African Highlands Initiative (AHI) and the International Center for Tropical Agriculture (CIAT) are operating to capture the impact of program intervention on agricultural and land management practices and its outcomes. From each of these 107 LC1s, four households were randomly selected for household and plot-level surveys to gather information for the year 2000. These surveys began in November 2000 and ended in July 2001, covering a total of 451 households and 1677 plots. Data gathered from this survey was analyzed using univariate and multivariate methods to address the research questions of this study.

To address the first question (about whether it pays to adopt improved maize varieties), factor payments and factor shares of the gross value of maize output for improved and traditional maize varieties were computed and compared using t-test of difference in means. Returns to farmers' land and management were measured using residual payments after deducting the cost of material inputs, capital services and labor (including the imputed value of family supplied inputs). The difference in residual payments between traditional and improved varieties is used to measure the net return (profit) to the farmer from adopting improved varieties.

To determine the factors influencing choice of maize varieties and land management technologies and their impact on maize yield, a system of equations was used because the direct inclusion of endogenous variables (land management and maize seed technologies used) in the model measuring their impact on maize yield would produce biased estimates, due to the correlation of the error term with the endogenous explanatory variables. To solve the endogeneity problem, a two-step approach that uses predicted values of the endogenous explanatory variables was used. The first step involved estimation of logit models, in which the endogenous explanatory variables (land management practices and maize seed technologies used) were regressed against a set of community, household and plot-level factors to produce predicted values. Included among the household-level regressors in the logit models is ethnicity of the household used to represent fixed cultural factors that are assumed to have a direct effect on the choice of land management and maize seed technologies, but not on maize yield.

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[4] The study covered approximately two-thirds of Uganda excluding the insecure parts of the west, northwest, north and northeast. The districts included are: Kabale, Kisoro, Rukungiri, Bushenyi, Ntungamo, Mbarara, Rakai, Masaka, Sembabule, Kasese, Kabarole, Kibale, Mubende, Kiboga, Luwero, Mpigi, Nakasongola, Mukono, Kamuli, Jinja, Iganga, Bugiri, Busia, Tororo, Pallisa, Kumi, Soroti, Katakwi, Lira, Apac, Mbale, and Kapchorwa.

To ensure that the system of equations is identified, the dummy variables for ethnicity used to predict land management and maize seed choices were excluded in the second step, in which the predicted values of these variables were used together with exogenous regressors in the Generalized Least Squares (GLS) model explaining variation in maize yield across the households. The econometric framework for the study is summarized as follows:

1) $Y_{hp} = Y(LM_{hp}, MV_{hp}, X_v, X_h, X_p) + e^1_{hp}$

2) $LM_{hp} = LM(MV_{hp}, X_v, X_h, X_p) + e^2_{hp}$

3) $MV_{hp} = MV(LM_{hp}, X_v, X_h, X_p) + e^3_{hp}$

where Y_{hp} denotes the yield of maize (tons/acre) for household h on plot p (the subscripts are hereafter dropped where unnecessary for clarity); LM is a vector of land management practices; MV is the maize variety used (traditional or improved); X_v, X_h and X_p are vectors of village, household and plot-level exogenous factors affecting yield, land management practices and maize production technology; e^1, e^2 and e^3 represent unobserved factors affecting these decisions.

The village level explanatory variables (Xv) used in this study are agro-climatic zones, population density, market access and altitude. Household level factors (Xh) include endowment of physical capital (ownership of land, livestock and farm equipment); human capital (education and age of household head, and family size); access to technical assistance (participation in longer term training programs or short term extension visits), credit; and ethnicity of the household (for equations 2 and 3, but not 1). Plot level factors (Xp) include land rights status (land tenure) of the maize plot, the distance of the plot from the farmer's residence, nearest roads and markets, and method of acquisition of plot.

The analysis was preceded by diagnostic tests. The distribution of variables was checked using coefficients of kurtosis and skewness, and potential errors were corrected using appropriate transformations suggested by STATA (ladder command). Multicollinearity was checked using a correlation matrix and the variance inflation factor (VIF) and was corrected by dropping one of the highly correlated variables. Heteroscedasticity was detected using the Cook-Weisberg test and was corrected using robust standard errors for the logit models. In estimating the yield function, the GLS model was chosen over the ordinary least squares (OLS) model because it gives more efficient estimates of coefficients (by minimizing the weighted sum of residual squares) in the presence of heteroskedasticity and auto correlated disturbances, which is quite common with cross-sectional data. Model specification was checked using the link test STATA command and all models passed the test.

4. Adoption of improved maize varieties in Uganda and their impact on factor payments

Maize production has been actively promoted by several programs and organizations (such as Sasakawa-Global, 2000) as a package of improved seeds and fertilizer. This has caused its expansion to all zones of Uganda. Of the 1677 plots surveyed, 754 (45%) were planted with maize, and out of these, 458 (62%) plots were planted with improved varieties of maize (see Table 3). This is corroborated by the community survey, in which 61.6% of households in the surveyed 107 LC1s reported using improved seeds for at least one crop (Pender *et al.*, 2001), and maize is one of the crops for which successfully improved varieties have been introduced in recent years. Overall, 62% of the area under maize is planted to improved varieties, but there is no significant difference in the average area planted with improved (2.5 ha) and traditional (2.3 ha) varieties at the household level. However, the yield difference is significant, with improved varieties yielding 65% higher than traditional varieties, on average (see Table 3). This, however, should not conceal the fact that there is yet a bigger gap between yields when one compares the survey data (1 to per ha for improved and 0.6 ton per ha for traditional) with data from on-farm trials for maize seeds without fertilizer (see Tables 2 and 3), for which maize yield is five times that reported in the survey data.

However, even with the low yields reported in the survey data, there still are some gains (albeit marginal) ensuing from the adoption of improved maize varieties. Factor share analysis shows a significant difference in residual payments (after deducting the cost of material inputs, capital services and labor) of US$ 31.6 per ha attributed to switching from the production of traditional to improved maize varieties (see Table 4).

The yield gap (between survey and on-farm trials data) could be attributed to several factors including recycling of improved seeds by farmers, which causes "genetic depreciation" and loss of desired attributes such as yield potential, pest and diseases resistance (Morris *et al.*; 1999), measurement error arising from the fact that a lot of maize is harvested green, yet farmers tend to report harvests of dry maize only during crop surveys as it is easier to remember. This is because of the inability of farmers to recall with a reasonable degree of accuracy how much they harvested several months back, and limited use of yield-enhancing inputs such as fertilizers and mechanization.

Apart from improved seeds (which is also sometimes recycled leading to loss of genetic potential), maize production in Uganda is characterized by low input use (and hence low output) as is the case with most other crops. Table 4 shows that labor payments (hired and imputed value of family labor) account for the largest share (90% for traditional varieties and 61% for improved varieties) of gross value of maize output. Material inputs, which mostly consist of seeds, account for only 5-6% of the value of maize output. There is equally limited use of capital services (draught animals and tractors) in maize production, accounting for 2-6% of the maize value. The proportion of households using draught animals (16.8% for improved varieties and 3.0% for traditional varieties) and tractor services (2.6% for improved varieties and 1.0% for traditional varieties) is low. The proportion of households using inorganic fertilizer (7.4% for improved varieties and 1.0% for traditional varieties) and manure (6.8% for traditional varieties and 4.8% for improved varieties) on maize fields is also very low. It is only mulching, incorporation of crop residues and crop rotation that are relatively more common on maize plots (see Table 5), but it is doubtful if these practices are sufficient to maintain soil fertility or replace soil nutrients lost through harvesting and other avenues of nutrient loss.

The implication of these findings is that many farmers are adopting high-yielding maize varieties that mine more nutrients (than low yielding varieties) without using external inputs (high or low) to replenish the lost nutrients. In addition, maize provides poor soil cover during erosive periods and a significant proportion of maize is sold to the market in many places, which accelerates nutrient depletion. Thus, the expansion of maize production without fertilizer use and soil conservation has likely accelerated land degradation, and this could be the reason why several land resource conditions are worsening and yields for most crops (including maize) are declining more in the cereals expansion pathway than in other pathways (Pender *et al.*, 2001). Following sections examine factors influencing household decisions to use (or not to use) improved maize and land management technologies, and how this affects on maize yield.

5. Determinants and impact of adoption of improved maize and land management technologies on maize yield.

The five most common land management practices used by farmers on maize plots include inorganic fertilizers, animal manure, incorporation of crop residues and household refuse, mulching and crop rotation (see Table 5). The choice of which one to use depends on many factors. The use of inorganic fertilizers is most common in the unimodal agro-climatic zone and eastern highlands, but least common in the bi-modal low rainfall zone. This is largely because the eastern highlands farmers have better access than other zones to lower cost fertilizer from Kenya (Pender *et al.*, 2001), and because the northern region (unimodal zone) receives a lot of program support linked to the adoption of fertilizers from NGOs (Nkonya and Kato, 2001). Animal manure use is most common in the southwestern highlands, but least common in areas of bimodal-medium rainfall.

Table 3. Yield (kg/ha) and area (ha) planted to maize in 2000

	Entire year			First season			Second season		
	TVs (N=296)	IVs (N=458)	Gap	TVs (N=140)	IVs (N=268)	Gap	TVs (N=156)	IVs (N=190)	Gap
Yield	645	1065	420*	657	1120	463*	633	987	354*
Area (ha)	2.3	2.5	0.2	2.5	2.5	0	2.2	2.6	0.4
% area planted to IVs	0.62			0.65			0.59		

*Difference in means is significant. N=Number of observations.

Table 4. Factor payments (US$) and share (%) of gross value of maize output per ha in 2000

	Entire year			First season			Second season		
	TVs (N=296)	IVs (N=458)	Gap	TVs (N=140)	IVs (N=268)	Gap	TVs (N=156)	IVs (N=190)	Gap
Gross value of output	71.2 (100%)	117.3 (100%)	46.1* (100%)	75.2 (100%)	123.3 (100%)	48.1* (100%)	67.7 (100%)	109.0 (100%)	41.3* (100%)
Current inputs	4.1 (6%)	6.3 (5%)	2.2* (5%)	4.8 (6%)	6.7 (5%)	1.9* (4%)	3.5 (5%)	5.7 (5%)	2.3* (5%)
Capital services	1.1 (2%)	6.2 (5%)	5.1* (11%)	1.2 (2%)	6.9 (6%)	5.7* (12%)	1.1 (2%)	5.2 (5%)	4.1* (10%)
Labor payments	64.3 (90%)	71.5 (61%)	7.2 (16%)	72.6 (97%)	73.2 (59%)	0.6 (1%)	56.7 (84%)	69.0 (63%)	12.2* (30%)
Total cost	69.5 (96%)	84.0 (72%)	14.5* (31%)	78.6 (105%)	86.8 (70%)	8.3 (17%)	61.3 (91%)	79.9 (73%)	18.6* (45%)
Residual payments	1.8 (2%)	33.4 (28%)	31.6* (69%)	-3.4 (-5%)	36.4 (30%)	39.9* (83%)	6.4 (9%)	29.0 (27%)	22.6* (55%)
Price (Ushs/Kg):	**TVs**	**IVs**		**TVs**	**IVs**		**TVS**	**IVS**	
Maize grain	170.2(2.336)#	173.9(2.333)		174.7(3.412)	175.1(3.342)		166.3(3.181)	172.1(3.072)	
Maize seed	334.4(17.559)	854.9(39.42)		335.3(25.88)	1027.9(57.5)		333.5(24.07)	611.0(43.85)	
Urea 630 **CAN** 550 **DAP** 610									

(1US$ = 1508 USHS in 1999/2000). #Numbers in parentheses are standard errors of prices. N= Number of observations.

* Difference in means is significant.

Table 5. Percentage of households using inputs and land management practices on maize plots in 2000

Input Type	Entire year		First season		Second season	
	TVs (N=296)	IVs (N=458)	TVs (N=140)	IVs (N=268)	TVs (N=156)	IVs (N=190)
Draught animal services	3.0*	16.8*	3.6*	18.7*	2.6*	14.1*
Tractor services	1.0*	2.6*	0.7*	4.1*	1.3*	0.5*
Inorganic fertilizers	1.0*	7.4*	1.4*	10.5*	0.6*	3.2*
Animal manure	6.8	4.8	6.4	6.3	7.1*	2.6*
Crop residue/Household refuse	19.9	20.3	18.6	21.6	21.2	18.4
Crop rotation	47.3	45.0	48.6	43.7	46.2	46.8
Mulching	17.9	14.2	16.4	12.7	19.2	16.3

* Difference in percentages is significant.
N=Number of observations

According to the regression results shown in Table 6, mulching and crop rotation are most common in the southwestern highlands and bimodal-low rainfall zone, while the incorporation of crop residues and household refuse into the soil is most common in the unimodal zone, but least common in the eastern highlands. Low market access has a positive impact on the use of low-input land management practices (use of manure, mulching and crop residues) as hypothesized, but has no negative effect on inorganic fertilizer application, a high-input practice. This suggests a need to promote inorganic fertilizer use, particularly in areas of good market access where maize is grown primarily for sale and the returns from fertilizer use are likely higher, to prevent nutrient depletion. Areas with low population density are less likely to rotate crops and incorporate crop residues and household refuse to improve or maintain soil fertility, probably because this can be achieved through other means such as fallowing, made possible by the low pressure on land. Higher altitude is associated with higher use of manure and incorporation of crop residues and household refuse, but lower mulching and crop rotation, likely because of the high population in high altitude areas (highlands), which reduces farm sizes and the possibility of rotating crops.

Distance to the nearest market is positively associated with crop rotation (probably because there is enough land to do so further away from the markets) and the use of animal manure. Manure use is higher further away from the markets probably because it is more driven by supply rather than demand. Whereas the demand for manure may be high in areas that are closer to markets because of the price incentive, its supply is limited by the low population of livestock in such areas and the high cost of transporting it (because of its low value to volume ratio) from high livestock population areas (remote areas), which limits its use in areas close to markets. Indeed, in remote areas where demand for manure is expected to be low, the supply is quite high and this seems to encourage manure application to maize plots. This finding is corroborated by Sserunkuuma (1999).

Farm size is negatively associated with manure use, incorporation of crop residues and crop rotation, suggesting that the use of such practices is more common on smaller farms. This finding is consistent with Boserup's (1965) hypothesis of population-induced intensification, through use of labor-intensive land management practices when land becomes scarcer and farm sizes reduce as a result of population pressure. Livestock ownership is associated with higher use of animal manure (as hypothesized) and incorporation of crop residues, but less use of crop rotation. Higher value of farm tools and equipment owned by the household negatively affects inorganic fertilizer use but enhances the use of animal manure, mulching and crop rotation.

Households whose heads have had post-secondary education are more likely to use inorganic fertilizer, while those whose heads have had primary and secondary education are less likely to use manure and crop residues compared to households headed by illiterates. This may be due to the higher labor opportunity costs of more educated farmers, discouraging them from using labor-intensive technologies, such as application of animal manure and crop residues. However, households with larger families (higher endowment of family labor) are more likely to use manure and crop residues because of the labor-intensive nature of these practices, but are less likely to use inorganic fertilizers. For similar reasons, households headed by older (and likely less energetic) people are less likely to use manure and crop residues, but more likely to use inorganic fertilizers.

Participation in agricultural training and short-term extension programs is associated with higher use of inorganic fertilizers, animal manure, and mulching. This underscores the need for technical assistance in the form of training and extension to increase farmers' awareness of the land management problems they face and the appropriate means of addressing them. Access to formal credit is associated with a lower likelihood of inorganic fertilizer use but higher likelihood of manure use. This suggests that areas with access to formal credit sources (which are mostly urban areas with banks or areas with a high concentration of credit focused NGOs) are less likely to invest in inorganic fertilizers, probably because of having access to alternative opportunities for income generation off farm, or because the NGOs offering credit in those areas also promote low external input agriculture (manure use) and discourage inorganic fertilizer use. Further research on the effect of credit on investments in land improvement is needed.

Table 6. Determinants of land management practices on maize fields (Logit regressions)@

Variable	Inorganic	Animal manure	Crop residues &	Mulching	Crop rotation
Use of improved maize seed	4.112*	0.447	0.222	0.303	0.256
Agro-climatic zone (c.f. Bimodal-High)					
Bimodal-Low	-3.990**	-0.614	-0.287	0.854*	1.115***
Bimodal-Medium#	---	-6.212***	-0.159	-1.704***	0.367
Eastern Highlands	13.324**	0.024	-1.206*	1.124	0.975
Western Highlands#	---	24.326***	-0.558	2.272**	1.591***
Unimodal	10.486***	-3.453	0.880*	-0.136	0.362
Low population density	4.824	-1.129	-1.009***	-0.478	-1.369***
Altitude	-0.006	0.005**	0.002**	-0.002***	-0.002***
Low market access	3.840	4.145***	1.269***	1.277***	1.642***
Distance (in miles from maize plot to)					
Residence	2.233***	-0.089	0.264	-0.049	0.117
All-weather road	0.891	0.858***	0.526***	-0.130	-0.097
Seasonal road	-2.319**	-2.426***	0.450*	0.627*	-0.045
Nearest market	2.801**	1.175***	-0.256	0.082	0.323**
Assets					
Land owned (Acres)	0.415	-0.444*	-0.240***	-0.151	-0.153**
Value of livestock (Ushs)	0.145	0.564***	0.099**	-0.006	-0.059**
Value of farm tools (Ushs)	-0.752***	0.144*	-0.032	0.126***	0.034*
Education of Household Head (c.f. no formal education)					
Primary	2.185	-2.179**	-0.613*	-0.135	-0.178
Secondary	1.526	-2.728***	-0.254	-0.102	-0.351
Post-secondary	10.792***	-1.918	0.904	0.983	-0.545
Age of Household Head	0.294***	-0.050*	-0.029***	-0.0001	0.038***
Household (family) size	-2.757**	1.651***	0.330*	-0.184	-0.067
Participation in technical assistance programs					
Agricultural training	5.312***	0.498	-0.052	0.677**	0.289
Agricultural extension	4.051***	1.284**	-0.029	1.132***	0.047
Availability of credit in the village					
Formal credit	-3.753*	4.142***	0.464	-0.337	0.020
Informal credit		-1.607*	1.498***	0.228	-0.433
Tenure of plot (c.f. freehold)					
Leasehold	-12.516***	-2.498*	1.896***	1.422***	0.637
Mailo	-2.108	-5.278***	0.526	0.850*	-0.416
Customary	1.842	-2.845***	0.283	0.233	0.737***
How plot was acquired (c.f. purchased)					
Rented for fixed payment	13.054***	0.452	-0.284	0.031	0.036
Borrowed#	---	---	1.043**	0.001	-0.014
Received as gift/inheritance	-4.820**	0.703	0.561**	0.426	0.013
Ethnicity of Household Head (c.f. Baganda)					
Western people	-8.466**	-22.425***	0.358	-0.443	-0.635
Northern people#	---	4.890*	2.215***	---	-0.976*
Iteso and Kumam#	---	0.914	1.171	---	1.203**
Eastern lakeshore people	-15.509***	-0.457	0.359	-1.116	-0.350
Other Eastern people #	-9.365*	0.662	-0.352	---	-0.376
Constant	-12.333**	-21.558***	-10.725***	-0.525	1.143
N=	**331**	**656**	**693**	**570**	**692**
Prob > chi^2	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

@ Standard errors omitted to avoid overcrowding the table

*,**,*** means statistically significant at 10%, 5% and 1% levels of significance, respectively.

Variable dropped from models where it predicts perfect failure.

N= Number of observations

Land tenure, as reflected in land rights status of the maize plot, as well as the means of acquisition of land affect land management. Compared to freehold, households holding maize plots under leasehold are less likely to apply inorganic fertilizer and manure but more likely to mulch and incorporate crop residues, while those with plots under the customary Mailo tenure system are more likely to use mulching, but less likely to apply manure. Maize plots held under the customary tenure are less likely to use animal manure, but more likely to rotate crops. Inorganic fertilizer use is most likely on maize plots acquired through renting for a fixed payment and least likely on plots received as a gift or through inheritance. This is probably because those who rent land for a fixed payment most likely use it to produce crops intended for sale (commercial oriented) and are, thus, more likely to use fertilizers to increase yield. The incorporation of crop residues and household refuse is most likely on plots acquired through borrowing or inheritance or as a gift.

Although maize production has been promoted as a package of improved seeds, fertilizer, and other improved land management practices, the adoption of improved seeds has no effect on the use of the common land management practices except inorganic fertilizers, but even for this, the effect is weakly significant. This is probably because of stepwise adoption of components of technological packages, with the natural starting point being adoption of improved seeds first (which does not drastically alter the farming practices used by the farmers), and later followed by improved land management practices. This lag in improvement of land management contributes to soil nutrient mining, since the improved varieties lead to higher yields and, thus, higher outflow of nutrients that are not being replaced.

Determinants of use of improved maize seeds

Compared to the bimodal-high agro-climatic zone, the adoption of improved maize seeds is significantly higher in all other zones except the southwestern highlands (see Table 7).The adoption of improved seeds is also higher among households with larger farm sizes and a higher value of livestock and farm tools. Distance from the nearest all-weather road to the maize plot is negatively associated with adoption of improved maize varieties. Maize plots held under the freehold tenure system are more likely to be planted with improved seeds than plots held under leasehold, while plots rented for fixed payment are more likely to be planted with improved seeds than purchased plots, likely because those who rent land tend to be more commercial oriented and are, thus, more likely to use improved seeds to increase yield. Households that use inorganic fertilizers and mulching are more likely to adopt improved maize seeds, while animal manure use and crop rotation are associated with lower adoption of improved seeds. Compared to the Baganda, the western people are less likely to use improved seeds.

Determinants of maize yield

Maize yield is significantly higher on plots planted with improved seeds, and on those where inorganic fertilizers, mulching and crop rotation are used, but is significantly lower on plots where animal manure is applied (see Table 7). This is probably because the impact of manure use critically depends on how it is applied, for example, improper storage and application can limit its effectiveness in replenishing soil fertility (Nkonya *et al.*, 2003), and as mentioned earlier, those using manure on maize plots are less likely to use improved seeds, which contributes to lower yields. Compared to the bi-modal high rainfall zone, maize yield is significantly lower in the bimodal low zone but is significantly higher in the eastern highlands, where the use of inorganic fertilizer is higher. Maize yield is also positively associated with low population density, but is negatively associated with low market access, meaning that high market access areas have higher maize yield, even though (as seen earlier) investments in land management are less common in these areas. Distance from the maize plot to the residence and nearest market negatively affects yield (as expected), while distance from the plot to the nearest all-weather road is positively associated with maize yield.

Farm size and value of farm tools have a negative effect on maize yield, while the value of livestock owned is positively associated with maize yield, likely because of exploitation of the synergies between crops and livestock. The negative relationship between farm size and maize yield

Table 7. Determinants of use of improved maize seed and maize yield

Variable	**Improved Maize Seed**		**Maize Yield**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**
Use of Improved Maize seed	-	-	1.246**	0.616
Land management practices				
Use of inorganic fertilizers	1.128*	1.671	0.370*	1.869
Use of animal manure	-0.845**	-1.970	-3.127***	-6.828
Use of crop residues	0.373	1.219	-0.477	-0.869
Crop rotation	-0.455*	-1.936	5.092***	5.196
Mulching	0.651*	1.865	3.908***	3.232
Agro-climatic zone (c.f. Bimodal-High)				
Bimodal-Low	1.310***	2.811	-1.626***	-4.782
Bimodal-Medium#	1.888***	6.252	---	---
Eastern Highlands	3.439***	2.611	0.993*	1.829
South Western Highlands#	-1.067	-1.388	---	---
Unimodal	1.645***	3.664	-0.388	-1.112
Low population density	-0.648***	-2.427	2.321***	7.660
Altitude	-0.001	-1	0.001	1
Low market access	0.124	0.429	-1.047***	-3.537
Distance (in miles from maize plot to)				
Residence	0.042	0.214	-0.343***	-3.573
All-weather road	-0.407***	-2.807	0.399***	3.950
Seasonal road	-0.389	-1.323	-0.100	-0.641
Nearest market	0.011	0.071	-0.228**	-2.375
Size of Land owned (Acres)	0.166*	1.766	-0.109**	-2.18
Value of livestock owned (Ushs)	0.050*	1.667	0.190***	5.429
Value of farm tools/equipment owned (Ushs)	0.046*	1.769	-0.073**	-1.973
Education of Household Head (c.f. no formal education)				
Primary	0.254	0.729	1.472***	2.950
Secondary	0.353	0.912	2.064***	3.492
Post-secondary	-0.067	-0.083	1.340***	2.393
Age of Household Head	0.013	1.444	0.026***	2.889
Household (family) size	-0.213	-1.439	-0.015	-0.217
Participation in agricultural training programs	0.247	1.047	-0.085	-0.497
Participation in agricultural extension	0.198	0.808	-0.185	-0.837
Availability of formal credit in the village	0.074	0.265	-0.344***	-2.586
Availability of informal credit in the village#	-0.179	-0.506	---	---
Tenure of plot (c.f. freehold)				
Leasehold	-0.938*	-1.832	-3.225***	-4.311
Mailo	-0.373	-0.823	0.302	1.480
Customary	0.328	1.350	-0.575*	-1.831
How plot was acquired (c.f. purchased)				
Rented for fixed payment	1.169***	2.552	2.660***	9.204
Borrowed#	0.395	0.825	---	---
Received as gift or inheritance	-0.233	-0.991	-1.159***	-5.709
Ethnicity of Household Head (c .f. Baganda)				
Western people	-0.816*	-1.662	-	-
Northern people (Acholi, Langi)	-0.682	-1.180	-	-
Iteso and Kumam	0.370	0.529	-	-
Eastern lakeshore people	-0.275	-0.671	-	-
Other Eastern people (Sabiny, Sebei)	0.414	0.329	-	-
Constant	0.304	0.218	-8.621***	-5.104
N	**692**		**296**	

*,**,*** means statistically significant at 10%, 5% and 1% levels of significance, respectively.

Variable dropped from the Maize Yield model due to collinearity.

can be linked to the earlier results showing farm size to be negatively associated with the use of most land management practices. Households whose heads have acquired formal education (primary, secondary and post-secondary) register higher yields of maize compared to those with uneducated household heads, while households headed by older people have higher yields (probably because they are more likely to use inorganic fertilizer). Access to formal credit is associated with lower maize yield, because it is also associated with a lower likelihood of inorganic fertilizer use as seen earlier. Compared to freehold, households holding maize plots under leasehold and customary tenure systems register lower maize yield because they also are less likely to use the recommended land management practices. Compared to purchased plots, the yield of maize on plots acquired as a gift or through inheritance is significantly lower, but the yield on rented plots is significantly higher. This is to be expected because as shown earlier, the use of yield-enhancing inputs (improved seeds and inorganic fertilizer) is significantly higher on rented than purchased plots.

6. Conclusions and Policy Implications

This study analyzed the adoption and impact of improved maize varieties and land management practices on maize yield and factor payments. The results have shown that, although the number of households using improved seeds is fairly high and increasing, and that there are some gains (albeit marginal) ensuing from switching from the production of traditional to improved maize varieties, there is a much bigger gap between yields reported in the survey data and on-farm trials yields, with the former being only one fifth of the latter. This gap is attributed to several factors including the recycling of improved seeds by farmers (and the resultant loss of yield potential) and limited use of yield-enhancing inputs and practices. Although maize production has been promoted as a package of improved seeds, fertilizer and land management practices, there is limited investment in use of fertilizer (organic or inorganic) and other practices among farmers adopting improved maize varieties. Farmers are adopting improved maize varieties that mine more nutrients (than low yielding varieties) without using external inputs to replenish the lost nutrients. In addition, maize provides poor soil cover during erosive periods and a significant proportion of maize is sold to the market in many places, which accelerates nutrient depletion. Therefore, the expansion of maize production without fertilizer use and soil conservation is likely to accelerate land degradation, and this seems to already be occurring more in the cereals expansion pathway than in other pathways of development (Pender *et al.*, 2001). There is a need, therefore, to intensify soil fertility management in the maize expansion pathway of development.

The study findings also indicate that participation in agricultural training and extension programs is positively associated with the adoption of improved maize and land management practices, but is negatively associated with maize yield. This suggests that soil fertility management is being promoted most where maize yield is low in an effort to increase yield, but the level of intensification does not appear to be sufficient to overcome the negative impact of the factors underlying low yields. The positive effect of low market access on the use of low-input land management practices but not on fertilizers suggests a need to promote fertilizer use in areas of good market access, particularly where maize is grown for sale, in order to prevent nutrient depletion.

Livestock ownership is positively associated with the adoption of improved maize varieties and manure. However, the fact that manure use depresses maize yield is surprising but informative. It is an indication of improper management (handling) and application of manure on maize plots, suggesting need for further research on this subject. Having a low population density and large farm sizes has a negative influence on the use of labor-intensive land management practices (such as manuring, incorporation of crop residues and mulching), which is consistent with Boserup's hypothesis of population-induced intensification through use of labor-intensive land management practices.

Finally, it must be pointed out that maize plots acquired through renting for a fixed payment are more likely to be planted with improved maize seeds and to receive inorganic fertilizers (and, thus give higher yields), likely because those who rent agricultural land tend to be commercial oriented and are, thus, more likely to invest in yield-enhancing inputs like improved seeds and fertilizer. If so, efforts to develop a vibrant rental market for land in Uganda are critically needed, to permit access to land for those who have none but are likely to use it more efficiently and profitably. Such a facilitation of the availability of land to land-poor farmers also has the potential to generate employment to the rural labor force which will certainly contribute to the pace of poverty reduction in Uganda.

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