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Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania

Aloyce R.M. Kaliba, Hugo Verkuijl, and Wilfred Mwangi

ABSTRACT

This paper examines factors influencing the adoption of improved maize seeds and the use of inorganic fertilizer for maize production by farmers in the intermediate and lowland zones of Tanzania. The results indicate that availability of extension services, on-farm field trials, variety characteristics and rainfall were the most important factors that influenced the extent of adopting improved maize seeds and the use of inorganic fertilizer for maize production. Farmers preferred those varieties which minimize field loss rather than maximizing yields. Future research and extension policies should emphasize farmer participation in the research process and on-farm field trials for varietal evaluation and demonstration purposes.

Key Words: *Adoption, agroecological zones, improved maize seeds, new technology, Tanzania.*

Farmers' adoption of a new technology, such as improved maize seeds, is a choice between traditional and new technology. Farmers' decision to adopt or not to adopt is usually based on the profitability and risk associated with the new technology. Before adoption, farmers have to be assured of the expected marginal

gains and associated risk. The farmers' concern with marginal gains and risk in turn affects the adoption of the new technology. Most adoption studies under small holder production systems show that farmers are risk averse and follow a technological ladder in the adoption process. They will first adopt simple components and then move to complex ones, and from cheaper to more costly technologies. The process allows farmers to evaluate available alternatives to avoid incurring unnecessary costs. Experimentation before adoption enables farmers to choose technologies that are less variable in outcomes and those that do not disrupt but enhance existing farming systems (CIMMYT, 1988).

Output variability is a major source of production risk under subsistence agriculture, especially when production depends solely on

Aloyce Kaliba is a Ph.D. candidate, Department of Agricultural Economics, Kansas State University, Manhattan. Hugo Verkuijl and Wilfred Mwangi are with the CIMMYT, Economics Program, Addis Ababa, Ethiopia.

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rainfall. Output variability affects both marginal gains and total farm output that influence food security at the household level. Food security is the most important priority for most subsistence farmers. Farmers prefer improved maize seeds that are stable in yield at different level of moisture availability (Moshi *et al.*). Farmers avoid improved maize seeds that are highly variable in terms of yields as they pose food insecurity to households. Risk-management strategies (reduction of yield variability) will therefore impact which variety to adopt or not to adopt. At the household level, risk-management strategies, and thus adoption choices, are then formulated based on socio-economic circumstances faced by the farmer and the characteristics of the technology (CIMMYT, 1993).

This study aims at determining factors that influence the adoption of improved maize seeds and uses of inorganic fertilizer for maize production by farmers in the intermediate and lowland zones of Tanzania. The objective is to generate first-hand information to be used by stakeholders involved in research, extension, and agricultural policy development in Tanzania. The limitation of this study, as with most studies using single-visit cross-sectional surveys, precludes inclusion of some economic factors likely to influence the adoption process. Factors such as price of input and output, taste and preference of individual households, and input distribution and availability may enhance or limit the adoption and diffusion process of the technologies. These variables are not included in the model, not because of their insignificance but because of their unavailability at the household level. However, their absence does not undermine specific policy implications that can be deduced from this analysis.

The plan of the paper is as follows. Section 1 introduces the idea of adoption processes under subsistence agriculture. Major factors associated with the choice of technology are discussed. Section 2 presents a historical background of maize research program in Tanzania. Section 3 discusses available theoretical models that are used in adoption studies and their limitations. Section 4 presents the theo-

retical model and econometric procedure used to estimate factors influencing choice of technologies by farmers. The section also discusses the variables included in the model, focusing on the rationale and their expected marginal effect on the adoption process. Section 5 reviews the source of data and sampling procedures. Section 6 discusses results of the study and Section 7 summarizes the paper and presents recommendations arising from this study.

Background

Maize is the major cereal consumed in Tanzania. It is estimated that the annual per-capita consumption of maize in Tanzania is 112.5 kg. National maize consumption is estimated to be three million tons per year. Maize contributes 60 percent of dietary calories to Tanzanian consumers (FSD, 1992, 1996). The cereal also contributes more than 50 percent of utilizable protein (Due). The crop is cultivated on an average of two million hectares, or about 45 percent of the cultivated area in Tanzania. Realizing the importance of the maize crop in Tanzania, the government has been committing human and financial resources to develop the industry. Research and extension efforts in maize started in 1960. The breeding efforts in the 1960s resulted in the release of Ukiriguru Composite A (UCA) and Ilonga Composite White (ICW).

Between 1973 and 1975, Tanzania experienced a severe food shortage due to drought and the villagization campaign that displaced farmers. The food crisis prompted the nation to launch several campaigns such as 'agriculture for survival' (*kilimo cha kufa na kupona*) with the objective of food self-sufficiency. The country also launched a maize project in 1974 with the assistance of the U.S. Agency for International Development (USAID). Its objective was to promote maize production in pursuit of food self-sufficiency. In the research frontier, a National Maize Research Program (NMRP) was launched with the broad objective of developing cultivars suitable for three major varietal recommendations ecological zones: (i) *high-altitude zone* (with elevation of

above 1500 masl), with a growing period of 6–8 months; (ii) *intermediate zone* (900–1500 masl), with 4–5 months growing period, and (iii) *low-altitude zone* (0–900 masl), with 3–4 months growing period.

To date, several breeding populations have been developed and are being improved through recurrent selection for specific traits (Moshi *et al.*). Since 1974, two hybrids and six open-pollinated varieties (OPVs) have been released. In 1976, Tuxpeno was released for the lowland areas. Hybrids H6302 and H614, suitable for the highlands, were released in 1977 and 1978, respectively. In November 1983, three OPVs—Kito, Kilima, and Staha—were released. Staha is characterized by its tolerance to maize streak virus (MSV) disease, whereas Kilima was recommended for the intermediate zone. Kito is an early maturing variety adapted to both low and intermediate zones. In 1987 two open-pollinated varieties, TMV1 and TMV2 were released. TMV1 is white flint streak resistant and has intermediate maturity. It is recommended for the lowland and intermediate zones. TMV2 is also white flint, and is recommended for the highlands.

In 1994, the NMRP released versions of Kilima, UCA, Kito, and Katumani that are resistant to MSV diseases. They are Kilima-ST, UCA-ST, Kito-ST, and Katumani-ST. Around the same time two foreign seed companies, Cargill and Pannar, introduced/released seven hybrids for commercial use by the farmers in the country. Since the 1960s no follow-up study has been conducted to assess the adoption process of all these varieties. This paper examines the factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones.

Procedure For Estimation Of Adoption

Feder *et al.* define *adoption* as the degree to which a new technology is used in long-run equilibrium when farmers have complete information about the technology and its potential. Therefore, adoption at the farm level indicates farmers' decisions to use a new

technology in the production process. The commonly used procedure to assess adoption at the farm level is a binary variable (adoption of improved maize seed = 1, non-adoption = 0). The intensity of adoption is analyzed using a continuous dependent variable (e.g., hectares under improved maize varieties).

Most of the technical agricultural innovations are in the form of a technology package. The choice to adopt a technical component entails adoption of one or more of the complementary components. Adoption of several components will require the estimation of two or more adoption equations. The econometric procedure then depends on the assumption about the adoption process. Smale, Just, and Leather indicate that the decision to adopt improved seeds and fertilizer is made simultaneously. In order to correct for the simultaneity bias, the adoption equations have to be solved using the two-stage estimation procedure (Amemiya, Nelson and Olson; Yaron, Dinar and Voet; Kimhi). Due to technical difficulties associated with obtaining consistent estimates of the covariance matrix of a two-stage procedure, Goodwin proposed the use of parametric bootstrapping as illustrated by White. The procedure provides a direct and analytically simplified approach to simultaneous models with censored distributions (Nkonya, Schroeder and Norman). In this approach, a large number of pseudo samples of size N are selected from the original data with replacement. Each pseudo sample is estimated separately as a single equation. The distribution of each estimated coefficient from pseudo samples is then used to calculate the value of the required parameter as the mean of the distribution. As Goodwin shows, the estimated parameters are unbiased, consistent and efficient as compared with maximum likelihood results.

Other studies by Byerlee and Hesse de Polanco; Norman *et al.*; and Kaliba, Featherstone, and Norman have shown that small-scale farmers in low-income countries adopt innovations in a step-wise fashion. Farmers will decide to adopt the major technical innovation from the package (e.g., improved maize seeds) and choose to adopt other com-

plementary components (e.g., fertilizer or pesticides) as they learn by doing. The second adoption equation then constitutes a sub-sample of the major component adopters. Hall identified the first and the second adoption equation as selection and regression equations. When the selection and regression equations are identified by probit and ordinary least square (OLS) models, Green and Saha, Love, Schwart suggest the use of sample selection procedure or the Heckman's two-stage procedure to solve the two equations.

Model Estimated

This paper determined factors affecting allocation of land to improved maize varieties and incidence of fertilizer use for maize production in two agroecological zones. The basic assumption is that a farmer first tests and then adopts improved seeds by allocating part of the land to improved maize, and then decides to use fertilizer. Thus, land allocation to improved maize is independent of fertilizer use, but use of fertilizer is conditional on land allocation to improved maize, which can be specified as follows:

$$\begin{aligned}
 (1) \quad Y_1 &= XB + \mu_1 \\
 Y_1 &> 0 && \text{if } XB + \mu_1 > 0 \\
 Y_1 &= 0 && \text{if } XB + \mu_1 = 0 \\
 Y_2 &= XB + \mu_2 && \text{if } Y_1 > 0 \\
 Y_2 &= \text{unobserved} && \text{if } Y_1 = 0 \\
 \text{var}(\mu_1) &= \sigma^2 && \text{var}(\mu_2) = 1 \\
 \text{Corr}(\mu_1, \mu_2) &= \rho
 \end{aligned}$$

where Y_1 is the proportion of total maize area allocated to improved maize seeds, Y_2 is the incidence of fertilizer use ($Y_2 = 1$ if used fertilizer; 0 otherwise), X 's are exogenous variables affecting adoption, B are parameters to be estimated, σ_1^2 is the standard error of the estimate, μ_1 and μ_2 are random error terms, which are correlated (ρ).

The tobit (Tobin) and probit (McFadden) models were used to test factors influencing adoption of improved maize varieties

(PLAND) and use of inorganic fertilizer (FERT), respectively. The predicted values of PLAND for $Y_1 > 0$, i.e., (PLAND*) were recovered from the procedure and included as an independent variable in the FERT equation. The FERT equation was estimated using bootstrapping technique explained above. In the estimation process, one thousand pseudo-samples of equal observation were drawn from the FERT equation with replacement. Each drawn sample was estimated separately as a probit model. The distributions of estimated coefficients from one thousand equations was used to calculate the value of required parameters as the means of the distributions. The models can further be specified as:

$$\begin{aligned}
 (2) \quad \text{PLAND} &= \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{LAB} + \beta_3 \text{EDVC} \\
 &+ \beta_4 \text{WID} + \beta_5 \text{EXI} + \beta_6 \text{YRATIO} \\
 &+ \beta_7 \text{VA1} + \beta_8 \text{VA2} + \beta_9 \text{AEZ1} \\
 &+ \beta_{10} \text{AEZ2} + \beta_{11} \text{LOW} + \mu_1 \\
 \text{FERT} &= \theta_0 + \theta_1 \text{PLAND*} + \theta_2 \text{AGE} + \theta_3 \text{LAB} \\
 &+ \theta_4 \text{EDVC} + \theta_5 \text{WID} + \theta_6 \text{EXI} \\
 &+ \theta_7 \text{YRATIO} + \theta_8 \text{VA1} + \theta_9 \text{VA2} \\
 &+ \theta_{10} \text{AEZ1} + \theta_{11} \text{AEZ2} + \theta_{12} \text{LOW} + \mu_{21}
 \end{aligned}$$

where:

PLAND = proportion of maize area allocated for improved maize varieties (average of 1992–1994)

FERT = use fertilizer (FERT = 1 if used fertilizer; 0 otherwise) for the same period

β_1 and θ_1 = parameters to be estimated

AGE = household head age in years

LAB = number of adults in the household (15 years and above)

EDVC = education level of household head in years

WID = wealth index

EXI = index of extension services

YRATIO = yield of improved varieties/yield of local varieties (average of 1992–94)

VA1–3 = group of improved maize varieties (VA1 = 1 if the farmer grows the variety in group 1; VA1 = 0 otherwise)

AEZ1–2 = low and medium rainfall areas (AEZ1 = 1 if a farmer is in the low rainfall area, AEZ1 = 0 otherwise)

LOW = lowland zone (LOW = 1 if the farmer is in the lowlands zone, 0 otherwise).

The high rainfall and intermediate zone dummies were not included in the models to avoid multicollinearity (Griffiths *et al.*; Green). From the literature, factors influencing adoption of new agricultural innovation based on profitability of the technology and risk-management strategies of the farmers can be divided into four major categories: (i) farmers' resource endowment-human and physical (Rogers; Feder and Slade; Feder, Just, Zilberman; Rahm and Huffman; Huffman and Lange; Heisey and Mwangi), (ii) external support systems such as marketing systems, infrastructure, credit, and extension; (iii) characteristics of the technology (Ockwell, Adesina and Zinnah, Misra, Carley and Fletcher), and (iv) the geographical characteristics.

Human endowment factors enable potential adopters to understand and evaluate new information, thus affecting both adoption and diffusion of new technologies (Schultz, 1964, 1975). The variable used to capture human endowment is education (Wharton; Huffman; Rahm and Huffman; Goodwin and Schroeder) and experience of the farmer (Feder; Bhattacharyya *et al.*). Exposure to education will increase the ability of farmers to obtain, process, and use information relevant to the adoption of improved maize variety. Hence this exposure will increase farmers' probability to adopt improved maize technologies. In most adoption studies conducted in low-income countries, the age of the farmer is commonly used to reflect experience. Farmers' age can generate or erode confidence; hence they become

more/less risk averse to new technology. It is therefore hypothesised that a farmer's age can increase or decrease the probability of adopting the improved maize technologies. Another factor discussed in literature is the gender of the household head. This affects adoption by influencing the choice of innovation from the recommended technical packages. Female-headed households are usually poor and their choice of innovations to adopt may differ from that of male-headed households. In this study, gender of household head is not included in the analysis because there were few female-headed household in the sample (1 percent). In Tanzania, female-headed households are not very common. To capture them needs a gender specific study with purposeful sampling. Availability of labor is another factor that influences adoption of new technologies. Households with more adults will be able to provide the necessary labor that might be required by improved maize technologies. Thus, labor is expected to increase the probability of adopting the improved maize technologies.

Putler and Zilberman underscored the importance of physical capital endowment in the adoption process. Farm size or cultivated land, livestock and farm implements owned often represent the physical capital endowment (Feder and O'Mara; Feder, Just and Zilberman; Rahm and Huffman; Shapiro; Nkonya, Schroeder and Norman; Kaliba, Featherstone and Norman). Holland suggested establishing a wealth index (WID) to represent the physical capital endowment. The wealth index is calculated by aggregating the average number of livestock units, hand hoes, axes, cutting equipment owned and land cultivated for the past three years. Wealthier farmers may have the means to purchase parts of the improved maize technology; hence it is expected to be positively associated with the decision to adopt improved maize technology package. However, due to differences in risk-management strategies used by relatively poor and rich farmers, the sign on the wealth index may be prior indeterminate. Other studies (see Kaliba, Featherstone and Norman) show that farmers with limited resources use input intensification as a mean of increasing total farm

production and managing risk, while relatively rich farmers with alternative resources use diversification and extensive production to achieve both objectives. When the technologies are input intensive, the wealth index may have negative impact on the adoption of the technologies.

External influences that affect adoption include institutional support systems such as marketing facilities, credit, and research and extension services (Feder). Credit was not included as a factor explaining the adoption of maize technologies because very few farmers in the study area used credit to purchase farm inputs. Holland suggested establishing an extension index (EXT) to represent the flow of information from the extension service to farmers. The number of recommendations the farmer was aware of from the extension technology package consisting of six recommendations—improved seeds, row planting, fertilizer application, ox-ploughing, field pests and disease control—was used to calculate the extension index. The Ministry of Agriculture and Cooperatives (MAC) is the major source of agricultural information in the study area. Hence, it is hypothesized that contacts with extension workers will increase a farmer's likelihood of adopting improved maize technologies.

As stated before, risk and risk management are important factors that affect adoption by small-scale farmers (Saha, Love and Schwart; Kaliba, Featherstone and Norman). The embodied technology characteristics will determine the level of profit and risk to be faced by the farmer and thus a choice between available alternatives. As there is no difference in producer price between IMVs and local varieties of seeds, the difference in yield will determine the marginal gain of adopting IMVs. The yield ratio between IMVs and local varieties can therefore represent profitability of the varieties. A larger value of yield ratio means that the farmer is more likely to get a high profit margin than farmers with a low value-of-yield ratio. The basic assumption is that high yielding varieties will be preferred by farmers over low yielding varieties.

Time to maturity of improved seeds is a

major factor correlated to risk management under subsistence agriculture. Short maturing varieties usually yield less than long maturing varieties but can escape moisture stress easier than long maturing varieties. Therefore, time of maturity can have negative or positive impact on the adoption of improved maize seeds depending on the farmer's attitude toward risk. The IMVs found in the field were therefore grouped according to months to maturity. Group 1 (VA1), were long maturing varieties (6–8 months) and included UCA and Kilima varieties. Group 2 (VA2), were intermediate maturing varieties (4–5 months) and included TMV-1, Staha, Tuxpeno and ICW varieties. The short maturing varieties (3 months) included Kito and Katumaini varieties and were in Group 3 (VA3). Farmers growing Group 3 varieties were assumed to be more risk averse.

Geographical characteristics influence the general performance of many agricultural innovations. Climate, especially rainfall, is a major factor affecting agricultural production of small-scale farmers in low-income countries. High rainfall secures farmers the precipitation needed for improved maize technologies, and thus is expected to have a positive impact on adoption of improved maize technologies. The agroecological zones can positively or negatively influence a farmer's decision to adopt an improved maize technology package.

Source of Data

The results presented in this paper are part of a national study conducted to assess the impact of maize research and development in the seven administrative zones of Tanzania. About 1000 farmers were interviewed nationwide. This paper aggregates the survey results from Central, Eastern, Southern, and Western zones which accounted for 30 percent of the national sample households. At zonal level, districts were purposively selected and clustered by the amount of precipitation and altitude. At district level, villages were purposively selected according to maize production and accessibility. From each village, between 6 to 18 farmers were randomly sampled from the register

Table 1. Summary Statistics of Variables Used in the Tobit and Probit Analysis

Variable	Sample	Adopters		Non-adopters	
		IMVs	Fertilizer	IMVs	Fertilizer
Age of household head (Years)	44.6 (13.0)	44.1 (12.6)	42.8 (12.9)	45.3 (13.4)	45.1 (13.0)
Number of adults in the household	4.9 (4.5)	4.8 (3.7)	4.4 (2.7)	5.1 (4.7)	5.1 (4.9)
Education of household head (years)	4.8 (3.0)	5.3 (2.8)	5.1 (3.1)	4.2 (3.1)	4.8 (3.0)
Wealth index	3.9 (5.9)	3.9 (6.4)	3.5 (2.7)	4.0 (4.6)	4.1 (6.6)
Farmers growing Group 1 varieties (%)	9.21	16.36	10.29	—	—
Farmers growing Group 2 varieties (%)	23.89	42.42	30.88	—	—
Farmers growing Group 3 varieties (%)	32.76	58.18	29.41	—	—
Farmers in agroecological Zone 1 (%)	43.00	27.27	33.82	63.21	45.78
Farmers in agroecological Zone 2 (%)	33.11	45.46	36.77	17.20	32.00

Numbers in brackets are standard deviation

IMVs = improved maize varieties

Agroecological Zone 1 = Low rainfall (<600 mm annually)

Agroecological Zone 2 = intermediate rainfall (600–1000 mm annually)

Agroecological Zone 3 = high rainfall (>1000 mm annually)

of households. To increase data validity and reliability farmers were interviewed by researchers and experienced extension officers using a structured questionnaire developed by a panel of the zonal farming systems' research economists from the Ministry of Agriculture, Sokoine University of Agriculture (SUA), International Maize and Wheat Improvement Center (CIMMYT), and the South African Center for Cooperation in Agricultural Research and Natural Resources (SACCAR), and the national maize breeders and agronomists. The interviews were conducted between June and November 1994. This study does not include varieties released by Cargill and Pannar companies, which released their first varieties when the study was in progress.

Characteristics of sampled households, adopters and non-adopters, used in the analysis of improved maize varieties and fertilizer are presented in Table 1. There were no significant differences between adopters and non-adopters for the household head characteristics, except for the level of education and extension index. The available labor averaged five persons per household and the level of education was five years on average. However, the level of education of adopters was above

the sample mean while that of non-adopters was below the sample mean. Adopters of improved maize varieties and fertilizer knew 60 percent and 50 percent of the technical components of the extension package, respectively. Non-adopters of both technologies were aware of 40 percent and 50 percent of the package components, respectively. About 57 percent and 43 percent of respondents were interviewed from the lowland and intermediate zones, respectively. In the sample, 56 percent of respondents adopted at least one improved maize variety and 23 percent used inorganic fertilizer for maize production. The proportion of land for improved maize varieties relative to the total acreage for maize production averaged 40 percent. Adopters of IMVs allocated 70 percent of the maize field to improved seeds while fertilizer adopters allocated about 50 percent of the field. Most farmers grew varieties in Group 3 (VA3) (33 percent). Nine and 24 percent of the respondents grew Group 1 (VA1) and 2 (VA2) varieties, respectively. About 58, 42 and 16 percent of IMVs adopters grew varieties in group VA3, VA2, and VA1, respectively. IMVs and inorganic fertilizer were adopted by 27 percent and 29 percent of respondents in the high rain-

Table 2. Average Area and Yield of Local and Improved (1992/94)^a

Agroecological Zones	Variety	Area	Yield			
			With Fertilizer		Without Fertilizer	
			Mean	STD	Mean	STD
High rainfall	Local	3.30	—	—	2.48	1.85 (115)
	IMVs	6.85	6.33	7.09 (112)	5.07	4.19 (83)
Intermediate rainfall	Local	3.48	—	—	2.55	2.01 (84)
	IMVs	7.83	5.38	5.89 (109)	5.22	3.28 (63)
Low rainfall	Local	6.85	—	—	3.30	3.34 (101)
	IMVs	16.92	5.68	9.49 (167)	3.67	3.48 (95)

^a Area is estimated in terms of acres and yield in terms of bags. One bag is equivalent to 90 kg

IMVs = improved maize varieties

Local = local varieties

STD = standard deviation

Numbers in brackets are coefficient of variation ((STD/Mean) · 100)

fall areas, respectively; 46 percent and 37 percent in the medium rainfall areas, respectively; 16 percent and 11 percent in the low rainfall areas, respectively.

Area and yield of local and IMVs by agroecological zones are presented in Table 2. The area planted in improved varieties was difficult to establish, because farmers tend to plant more than two improved varieties in one plot. The data collected were therefore total acreage allocated to all IMVs grown by the farmer and their characteristics. The results show that the area allocated to IMVs was more than twice as much as the area allocated to local varieties. Yields of IMVs with and without fertilizer were also more than two times higher than yields of local varieties. However, yield variability increased with the use of IMVs and fertilizer. The coefficient of yield variability for IMVs with fertilizer ranged between 109 to 167 percent for all agroecological zone. For IMVs grown without fertilizer and local varieties, the ranges were 82 to 94 and 83 to 101 percent respectively. The coefficient of variability for IMVs without fertilizer fall within the range of local varieties' coefficient of variability.

Results and Discussion

Land Allocation To Improved Maize Varieties

Table 3 shows the results from the Tobit model explaining the extent of land allocation to

IMVs by respondents. In the Table, $\delta EY/\delta X_i$ shows the effect of a unit change of an explanatory variable on the expected value of the depended variable, $\delta EY^*/\delta X_i$ shows the proportionate change in the extent of adoption among adopters with the unit change of an explanatory variable, and $\delta F(z)/\delta X_i$ shows the change in probability of adoption among non adopters given a unit change in an explanatory variable (McDonald and Moffit; Roncek).

The χ^2 for the log likelihood ratio test of the hypothesis that the exogenous variables included in the model have zero influence on the extent of adoption (i.e. $\beta_i = 0$) was rejected at 0.01 probability level. The estimated proportion of land to be allocated to IMVs at the mean value of all exogenous variables was 43 percent. The results suggest that extension services, yield ratio, variety and geographical characteristics significantly influence the allocation of land to IMVs (Table 3). Farmers' physical and capital endowment has no significant influence on the extent of adoption. Intensity of extension service was the major factor positively influencing the adoption of improved maize seeds. For the whole sample, increase in one unit of extension service intensity increased the average proportion of land allocated to IMVs by 94 percent and the probability of adoption by 66 percent for non-adopters. The same unit increase in the intensity of extension service increased the average proportion of land allocated to IMVs by 66

Table 3. Results of Tobit Estimates on Proportion of Land Allocated to Improved Maize Seeds

Variable	Estimated Coefficient	Asymptotic			
		Standard Errors	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	-0.01294	0.38295	-0.0114	-0.0081	-0.0080
Household head age in years (AGE)	0.00208	0.00478	0.0018	0.0013	0.0013
Adults in a household (LAB)	-0.00614	0.02576	-0.0054	-0.0038	-0.0038
Household head education (EDU)	0.03523	0.02273	0.0312	0.0220	0.0218
Wealth index (WID)	-0.01731	0.01324	0.0153	0.0108	0.0107
Extension index (EXI)	1.06410	0.27623**	0.9409	0.6653	0.6571
Yield Ratio (YRATIO)	0.00334	0.00166**	0.0030	0.0021	0.0021
Varieties in Group 1 (VA1)	0.67947	0.16429**	0.6005	0.4246	0.4193
Varieties in Group 2 (VA2)	0.76908	0.13203**	0.6800	0.4809	0.4749
Agroecological Zone 1 (AEZ1)	-0.83788	0.22988**	-0.7409	-0.5239	-0.5174
Agroecological Zone 2 (AEZ2)	0.02395	0.17971	0.0110	0.0077	0.0077
Low lands (LOW)	0.39752	0.18128**	0.3515	0.2485	0.2455
Sample size					293
Variance of the estimates					0.2096
Probability of adoption (PLAND > 0) at mean of independent variables					0.7946
Observed frequency of adoption (PLAND > 0), F(z)					0.7031
Expected proportion of adoption at mean value of all independent variables					0.4295
z-score					0.5300
Standard normal density function, f(z)					0.3467
Likelihood ratio test statistic					87.538**

Single or double asterisks denote statistical significance at 5% and 1% probability level dEY/dX_i = Marginal effect of explanatory variable on the expected value of the depended variable, dEY^*/dX_i = Marginal effect of explanatory variable on extent of adoption among adopters $dF(z)/dX_i$ = Probability change of adoption given a unit change of explanatory variable among non adopters

percent for adopters. Although the extension intensity indicator used is a crude representation of availability of extension service in the area, it is a good indicator of farmers' knowledge of agricultural information. Since the major source of agricultural information in the study is the extension personnel, the results emphasize the importance of extension services in the adoption of improved maize seeds.

Farmers growing long (VA1) and intermediate (VA2) maturing varieties were more likely to allocate more land to improved maize seeds than farmers growing short maturing varieties (VA3). The probability of growing short and intermediate varieties by non-adopters was higher by 41 percent and 47 percent, respectively, than non-adopters growing short maturing varieties. On average, the proportion of land allocated to improved maize seeds for long and intermediate varieties was higher by 60 and 68 percent respectively as compared to

short maturing varieties. For adopters, the average proportion was higher by 42 and 48 percent for farmers growing long and intermediate maturing varieties, respectively. In low rainfall areas, AEZ1, farmers were less likely to adopt improved seeds than farmers in the high rainfall areas, AEZ3. For the whole sample, the average proportion of area allocated to IMVs in AEZ1 was lower by 74 percent compared to areas in AEZ3. No significant difference was observed on land allocated between intermediate AEZ2 and AEZ3. Improved maize seeds do better than local varieties in high rainfall areas.

Farmers in the lowlands were more likely to adopt improved maize seeds than farmers in the intermediate zone. The average proportion of land allocated to improved maize seeds in the lowland was higher by 35 percent compared with the intermediate zone. The probability of adopting improved maize seeds for

farmers in the lowlands was higher by 25 percent. The lowlands generally receive lower rainfall than the intermediate altitude areas. We would expect higher adoption in the intermediate altitude. These results can be related to the effect of research and extension activities. Most research and extension activities are conducted in the lowlands to reduce the risk of production associated with low rainfall. Ilonga Research Station (Eastern Zone), a lead center for maize research in Tanzania, is in the lowlands and so are the other outreach research stations, i.e., Hombolo in the Central Zone and Mubondo and Tumbi in the Western Zone. The presence of these research stations may affect adoption positively as most of the on-farm evaluation and demonstration trials are conducted within the vicinity of the research stations.

Use Of Inorganic Fertilizer For Maize Production

The probit model results explaining the incidence of inorganic fertilizer use for maize production are presented in Table 4. The χ^2 for the log likelihood ratio test for the hypothesis that the exogenous variables included in the model have zero influence was rejected at 0.01 probability level. The results suggest that extension intensity, yield ratio and variety characteristics significantly and positively influenced the use of inorganic fertilizer. Increase in intensity of extension services and yield ratio by one unit increased the probability of using fertilizer by 96 and 0.26 percent respectively. Farmers growing varieties in Group 1 and 2 were more likely to use fertilizer than farmers growing varieties in Group 3, the probabilities being higher by 28 and 27 percent respectively. Farmers in AEZ1 and AEZ2 were less likely to use fertilizer than farmers in AEZ3, the probability being lower by 63 and 28 percent respectively. The wealth index had a negative impact on adoption of fertilizer. Increasing the wealth index by one unit decreased the probability of using fertilizer by 0.74 percent.

As shown in Table 1, most farmers prefer Group 3 varieties that are low yielding but can

escape moisture stress. Also, Table 2 shows the mean yields of IMVs with fertilizer were relatively higher in all agroecological zones but had higher yield variability compared to yield without the use of fertilizer. Coupled with the fact that only 56 percent of the sample farmers used fertilizer for maize production, the sample farmers can be assumed to be risk averse. However, as mentioned before, relatively poor farmers use input intensification to manage risk whereas relatively rich farmers use extensive production and diversification for the same effect. The negative sign on the wealth index is an indication that risk management factors dominate the purchasing power of farmers in adopting input-intensive technologies. This means that relatively poor farmers are more likely to use inorganic fertilizer to increase total production from the farm as they have no other alternatives. Thus, poor farmers are vulnerable to yield risk. The risk is cushioned by planting Group 3 varieties that can escape moisture stress and minimize the negative effect of fertilizer use.

The human capital variables, i.e. age and labor, marginally increased the probability of using fertilizer by 0.04 and 0.4 percent, respectively. Also, farmers in the lowlands were 23 percent more likely to use fertilizer than farmers in the intermediate zone. These results enforce the Tobit model results in Table 3. Successful use of inorganic fertilizer requires availability of enough moisture, otherwise production can be suppressed. As stated before, it was expected that incidence of fertilizer use will be higher in the intermediate altitude where rainfall is relatively higher than in the lowlands. However, the high concentration of research and extension in the lowlands may have influenced the results.

Land allocated to improved maize seeds has a negative but non-significant influence on fertilizer use. The negative sign on PLAND* variable in the FERT equation is an indication that farmers with more land allocated to improved maize seeds production do not use inorganic fertilizer. This indicates that the adoption of inorganic fertilizer is not significantly influenced by the adoption of improved maize seeds. The results reject the simultaneous

Table 4. Probit Model Estimates on the Incidence of Fertilizer Use (FERT)

Variable	Estimated Coefficient	Asymptotic Standard Error	$\delta EY/\delta X_i$
Constant	-0.84438	0.59648	-0.3242
Land allocated to IMVs (PLAND*)	-0.00073	0.25370	0.0003
Age of household head in years (AGE)	0.00105	0.00698	0.0004
Adults in a household: Age > 18 years (LAB)	0.00949	0.03946	0.0036
Education of household head in years (EDU)	0.02111	0.03314	0.0081
Wealth index (WID)	-0.01937	0.02667	-0.0074
Extension index (EXI)	2.50820	0.45485**	0.9631
Yield Ratio (YRATIO)	0.00677	0.00279**	0.0026
Varieties in Group 1 (VA1)	0.71940	0.27554**	0.2762
Varieties in Group 2 (VA2)	0.70330	0.21167**	0.2701
Agroecological Zone 1 (AEZ1)	-1.63990	0.33217**	-0.6297
Agroecological Zone 2 (AEZ2)	-0.74004	0.26160**	-0.2842
Low lands (LOW)	0.59242	0.27373**	0.2275
Sample size		293	
Percent of right prediction		78.50	
Maddala R ²		40.03%	
Observed frequency of adoption (FERT > 0), F(z)		0.5291	
z-score		0.05	
Standard normal density function, f(z)		0.384	
Likelihood ratio test statistics		69.282**	

Single or double asterisks denote statistical significance at 5% and 1% probability level

IMVs = Improved maize varieties

$dF(z)/dX_i$ = Probability change of adoption given a unit change of explanatory variable among non adopters

adoption of improved maize seeds and inorganic fertilizer. Nkonya *et al.* also observed a step-wise adoption of improved seeds and fertilizer in Northern Tanzania. In their study, adoption of improved seeds by itself appeared to be a likely first step in the adoption process, just as was found in this study.

Conclusion And Policy Implications

This study showed that extension services, yield difference between improved and local varieties, and geographical characteristics significantly influenced the adoption process of improved maize seeds and inorganic fertilizers. The study emphasized the importance of extension services and farmer participation in the research process. Extension service was shown to be an important source of knowledge for farmers that significantly influenced the adoption of improved maize seeds and fertilizer. Currently, there is no short cut for sub-

stantial and dramatic increases in production of maize without improved seeds and use of inorganic fertilizer. Use of organic fertilizer such as manure is limited by many factors. Due to increased demand for land for crop production, coupled with population growth, livestock are pushed away from the villages and arable land to village peripheries and marginal areas. Use of manure for production purposes is highly limited by transportation from livestock kraals to maize fields. Since maize is a staple food and occupies a strategic position in the Tanzanian economy, the need to strengthen extension services in the area cannot be over-emphasized.

Variety characteristics embed risk and risk management factors that suit the socio-economic circumstances and environmental requirements of farmers. The participation of farmers in the research process encourages the flow of information between researchers and farmers. In the process, technologies based on

farmers' needs can be developed and can contribute to achieving the target of food self-sufficiency in Tanzania. As mentioned before, the limitation of this study, as with most cross-sectional analyses limited to a single-visit survey, preclude inclusion of some economic factors likely to influence the adoption process. Factors such as price of input and output, taste and preference of individual households, input distribution and availability may enhance or limit the adoption and diffusion process of the technologies. To develop a realistic maize research and extension program in the area, these factors have to be taken into consideration. Future surveys should collect all economic information that influences the choice of technologies. Such information is important in the adoption studies and in developing comprehensive research and extension programs.

References

- Adesina, A., and M. M. Zinnah. "Adoption, Diffusion, And Economic Impacts Of Modern Mangrove Rice Varieties In Western Africa: Further Results From Guinea And Sierra Leone." In *Towards a New Paradigm for Farming System Research/Extension. Working Paper set for the 12th Annual FSR Symposium 1992*. Michigan State University, 1992:443-466.
- Amemiya, T. "The Estimation Of A Simultaneous Equation Tobit Model." *Int. Econ. Rev.*, 20(1979):169-181.
- Bhattacharyya, A., T. R. Harris, W. G. Kvasnicka, and G. M. Vesperat. "Factors Influencing Rates Of Adoption Of Trichomoniasis Vaccine By Nevada Range Cattle Producers." *J. Agr. Res. Econ.* 22(1997):174-190.
- Byerlee, D., and E. Hesse de Polanco. "Farmers' Stepwise Adoption Of Technological Packages: Evidence from the Mexican Atiplano." *Amer. J. Agr. Econ.* 68(1986):519-527.
- CIMMYT. *From Agronomic Data to Farmer Recommendation. An Economic Training Manual*. Londres, Mexico: International Wheat and Improvement Center, 1988.
- CIMMYT. *The Adoption Of Agricultural Technologies: A Guide For Survey Design*. Londres, Mexico: International Wheat and Improvement Center, 1993.
- Due, J. M. "Summary Of Farming System Bean Research In Tanzania 1982-85." In *Bean Research of the 4th Bean Research Workshop Held at Sokoine University of Agriculture*, eds., A. N. Minjas and M. P. Salema. Interpress of Tanzania LTD, 1986:146-151.
- Feder, G. "Farm Size, Risk Aversion And Adoption Of Technology Under Uncertainty." *Oxford Econ. Papers* 32(July 1980):263-283.
- Feder, G., and G. O'Mara. "Farm Size And The Diffusion Of Green Revolution Technology." *Econ. Dev. Cult. Change* 30(1981):59-76.
- Feder, G., and R. Slade. "The Acquisition Of Information And The Adoption Of New Technology." *Amer. J. Agr. Econ.* 66(August 1984):312-320.
- Feder, G., R. E. Just, and D. Zilberman. "Adoption Of Agricultural Innovations In Developing Countries: A Survey." *Econ. Dev. Cult. Change* 33(1985):255-297.
- Fernandez-Cornejo, J., Douglas Beach, and E. Wen-Yuan Huang. "The Adoption Of IPM Techniques By Vegetable Growers In Florida, Michigan And Texas." *J. Agr. Appl. Econ.* 26(1994):158-172.
- FSD (Food Security Department). *Comprehensive Food Security*. Dar-Es-Salaam: United Republic of Tanzania Ministry of Agriculture and The United Nations Food and Agriculture Organization (FAO), 1992:15-31.
- FSD (Food Security Department). *Tanzania Food Security Bulletin No. 2*. Dar-Es-Salaam: Ministry of Agriculture, April/May 1996:6-7.
- Goodwin, B. K. "Simplified Estimation Of Simultaneous Tobit Model." Unpublished Manuscript, 1993.
- Goodwin, B. K. G., and T. Schroeder. "Human Capital, Producer Education, And Adoption Of Forward-pricing Methods." *Amer. J. Econ.* (November 1994):936-947.
- Green, W. H. *Econometric Analysis*, 2nd ed. New York: MacMillan Publishing Company, 1993: 143-146.
- Griffiths, W. E., R. C. Hill, and G. G. Judge. *Learning and Practicing Econometrics*. John Wiley and Sons, Inc., 1993:417-418.
- Hall, B. H. *Time Series Processor Version 4.3. Reference Manual*. Palo Alto, CA: TSP International, 1994.
- Heisey, P., and W. Mwangi. "An Overview Of Measuring Research Impacts Assessment." In *Impacts of On-Farm Research*, eds., P. Heisey and S. Waddington. CIMMYT Eastern and Southern Africa Farm Research Network Report No. 24, 1993.
- Holland, G. *Ecological Sustainability And Economic Viability Of Smallholder Zero-grazing System In Destocked (Mvumi) Semi-arid Tanzania*. Pa-

- per Presented at Workshop on Sustainable Livestock Based System in Semi-arid Areas. 27-8 September, 1993, Arusha, Tanzania.
- Huffman, W. E. "Allocative Efficiency: The Role of Human Capital." *Quart. J. Econ.* 91(February 1977):59-79.
- Huffman, W. E., and M. D. Lange. "Off-farm Work Decision Of Husbands And Wives: Joint Decision Making." *Rev. Econ. Statist.* 71(August 1989):471-480.
- Just, R. E., and D. Zilberman. "Stochastic Structure, Farm Size And Technology Adoption In Developing Agriculture." *Oxford Econ. Papers.* 35(August 1983):307-328
- Kaliba, A. R. M., A. M. Featherstone, and D. W. Norman. "A Stall-feeding Management System For Improved Cattle In Semi-arid Central Tanzania: Factors Affecting Adoption." *Agricultural Economics.* 17(1997):133-146.
- Kimhi, A. "Quasi Maximum Likelihood Estimation Of Multivariate Models: Farm Couples' Labor Participation." *Amer. J. Agr. Econ.* (November 1994):828-835.
- Mcdonald, J. F., and R. A. Moffit. "The Uses of Tobit Analysis." *Rev. Econ.Statist.* 62(1980): 318-321.
- Mcfadden, D. "Econometric Models of Probabilistic Choice." In *Structural Analysis of Discrete Data with Econometric Application*, eds., C. F. Manski and D. Mcfadden. Cambridge, MA: The MIT Press, 1981:198-272.
- Misra, S. K., D. H. Carley, and S. M. Fletcher. "Factors Influencing Southern Dairy Farmer's Choice Of Milk Handlers." *J. Agr. Appl. Econ.* 25(July 1993):197-207.
- Moshi, A. J., Z. O. Mduruma, N. G. Lyimo, W. F. Marandu, and H. B. Akonaay. "Maize Breeding For Target Environments In Tanzania." In *Maize Research in Tanzania: Proceedings of the First Tanzania National Maize Research Workshop*, eds., A. J. Moshi and J. K. Ransom. Dar-es-Salaam, Tanzania: TARO, 1990:11-16.
- Nelson, F., and L. Olson. "Specification And Estimation Of A Simultaneous Equation Model With Limited Dependent Variables." *Int. Econ. Rev.* 19(1978):695-709.
- Nkonya, E., T. Schroeder, and D. Norman. "Factors Affecting Adoption Of Improved Maize Seeds And Fertilizer In Northern Tanzania." *Amer. J. Agr. Econ.* 48(1997):1-12.
- Norman, D. W., F. D. Worman, J. D. Siebert, and E. Modiakgotla. "The Farming Systems Approach To Development And Appropriate Technology Generation." *FAO Farm System Management Series No. 10. Agricultural Services Division*, Rome: Food and Agricultural Organization of the United Nations, 1995.
- Ockwell, A. P. "Characteristics Of Improved Technologies That Affect Their Adoption In Semi-arid Tropics Of Eastern Kenya." *Journal Of Farming System Research And Extension.* 2(1991):6-18.
- Putler, D. S., and D. Zilberman. "Computer Use In Agriculture: Evidence From Tulare County, California." *Amer. J. Agr. Econ.* 70(1988):790-802.
- Rahm, M. R., and W. E. Huffman. "The Adoption Of Reduced Tillage: The Role Of Human Capital And Other Variables." *Amer. J. Agr. Econ.* 66(1984):405-413.
- Rogers, E. *Diffusion of Innovations*, 3rd ed. New York: The Free Press, 1983.
- Roncek, D. W. "Learning More From Tobit Coefficients: Extending A Comparative Analysis Of Political Protest." *Amer. Soc. Rev.* 57(1992): 503-507.
- Saha, A., H. A. Love, and R. Schwart. "Adoption Of Emerging Technologies Under Output Uncertainty." *Amer. J. Agr. Econ.* 76(November 1994):836-846.
- Shapiro, D. "Farm Size, Household Size And Composition And Men Contribution In Agriculture: Evidence From Zaire." *J. Dev. Studies.* 27(1990):1-21.
- Schultz, T. W. *Transforming Traditional Agriculture*. New Haven: Yale University Press, 1964.
- Schultz, T. W. "The Value of the Ability to Deal With Disequilibria." *J. Econ. Lit.* 13(1975): 827-846.
- Smale, M., R. E. Just, and H. D. Leathers. "Land Allocation In HYV Adoption Models: An Investigation Of Alternative Explanation." *Amer. J. Agr. Econ.* 76(August 1994):535-547.
- Tobin, J. "Estimation of Relationships for Limited Dependent Variables." *Econometrica* 31(1958): 24-36.
- Wharton, C. R., Jr. "The Role Of Farmer Education In Agricultural Growth." New York: The Agricultural Development Council, Inc, 1993.
- White, K. J. *SHAZAM. Econometric Complete Program. User Reference Manual Version 8.0*. The McGraw-Hill Company, 1997:394.
- Yaron, D., A. Dinar, and H. Voet. "Innovation On Family Farms: The Nazareth Region In Israel." *Amer. J. Agr. Econ.* 74(May 1992):361-370.

