Adoption of Maize Production Technologies in **Eastern Tanzania**

Aloyce R.M. Kaliba,

Hugo Verkuijl,

Wilfred Mwangi,

Alfred J. Moshi,

Amos Chilagane,

Joseph S. Kaswende, and

Ponniah Anandajayasekeram

November 1998

Funded by the European Union

CIMMYT
Sustainable Maize and Wheat Systems for the Poor

SACCAR
SOUTHERN AFRICAN CENTRE FOR COOPERATION IN AGRICULTURAL RESEARCH

Adoption of Maize Production Technologies in **Eastern Tanzania**

By

Aloyce R.M. Kaliba,

Hugo Verkuijl,

Wilfred Mwangi,

Alfred J. Moshi,

Amos Chilagane,

Joseph S. Kaswende, and

Ponniah Anandajayasekeram

November1998

* Aloyce Kaliba is with the Livestock Production Research Institute, Mpapwa, Tanzania. Hugo Verkuijl and Wilfred Mwangi are with the Economics Program of the International Maize and Wheat Improvement Center (CIMMYT) and are based in Addis Ababa, Ethiopia. Alfred J. Moshi, Amos Chilagane, and Joseph S. Kaswende are with the Ministry of Agriculture Research and Training Institute, Ilonga, Tanzania. Ponniah Anandajayasekeram is with the Southern Africa Centre for Coordination of Agricultural and Natural Resources Research and Training, Gaborone, Botswana. The views presented in this paper are those of the authors and do not necessarily reflect policies of their respective institutions.

CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 50 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

Financial support for CIMMYT's research agenda currently comes from many sources, including governments and agencies of Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Canada, China, Colombia, Denmark, France, Germany, India, Iran, Italy, Japan, the Republic of Korea, Mexico, the Netherlands, Norway, Pakistan, the Philippines, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, the United Kingdom, Uruguay, and the USA, along with (among others) Cornell University, the European Union, the Ford Foundation, Grains Research and Development Corporation, the Inter-American Development Bank, the International Development Research Centre, International Fund for Agricultural Development, Kellogg Foundation, Leverhulme Trust, Nippon Foundation, OPEC Fund for International Development, Rockefeller Foundation, Sasakawa Africa Association, Stanford University, Tropical Agriculture Research Center (Japan), UNDP, University of Wisconsin, and the World Bank.

Printed in Mexico.

Correct citation: Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A.J. Moshi, A. Chilagane, J.S. Kaswende, and P. Anandajayasekeram. 1998. *Adoption of Maize Production Technologies in Eastern Tanzania*. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), the United Republic of Tanzania, and the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR).

Abstract: This study of the adoption of maize production technologies in Eastern Tanzania forms part of a larger study to evaluate the impact of maize research and extension throughout Tanzania over the past 20 years. Using a structured questionnaire, researchers and extension officers interviewed farmers in June–November 1995. Survey data were classified by agroecological zone (the lowlands and the intermediate zone). The two-stage least squares analysis showed that the availability of labor, extension intensity, and variety characteristics were significant factors affecting how much land a farmer was likely to allocate to improved maize. Short-maturing and medium-maturing varieties increased the probability of allocating land at the means by about 15% and 21%, respectively. Labor and extension increased the probability of allocating land at the means by about 3% and 22%, respectively. Farmers in the lowlands are less likely (by about 3%) to allocate land to improved maize. An increase in the intensity of extension by one unit increased the probability of using fertilizer by 40%. Research needs to develop maize that yields well and can tolerate moisture stress and field pests, especially stalk borers, and should also develop recommendations for fertilizer levels under various weather and soil conditions. Flexible integrated pest management packages that combine a drought-tolerant variety with improved cultural practices can increase yields. An efficient marketing system for inputs and outputs will benefit farmers by providing higher prices for maize and reducing the cost of fertilizer. Research and extension need to be linked and strengthened to increase the flow of information to farmers. Research and extension should also focus on creating off-farm employment that can generate income to meet farmers' short-term needs. In collaboration with the government and other stakeholders, the formal credit system needs to address the credit problems faced by small-scale farmers, especially their lack of knowledge (information) about formal credit systems.

ISBN: 970-648-015-3
AGROVOC descriptors: Tanzania; Maize; Zea mays; Varieties; Plant production; Seed production; Seed industry; Production factors; Production economics; Input output analysis; Socioeconomic environment; Development policies; Marketing policies; Credit policies; Demography; Land resources; Land use; Cultivation; Cropping patterns; Cropping systems; Crop management; Cultural methods; Mechanization; Plant breeding; Shelling; Plant water relations; Drought resistance; Stem eating insects; Pest resistance; Pest control; Inorganic fertilizers; Fertilizer application; Yield increases; Yields; Prices; Diffusion of research; Extension activities; Economic analysis; Economic viability; Technology transfer; Innovation adoption; Small farms; Employment; Environments; Lowland; Highlands; Research projects; Statistical analysis
Additional keywords: Eastern Tanzania; Agroecological zones; CIMMYT; SACCAR; Ministry of Agriculture, Research and Training Institute; Tobit analysis; Probit analysis
AGRIS category codes: E16 Production Economics
E14 Development Economics and Policies
Dewey decimal classification: 338.16

Contents

Tables

Figures

Abbreviations and Acronyms

AEZ	Agroecological zone
CAN	Calcium ammonium nitrate
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DALDO	District Agricultural and Livestock Development Officer
DIVEO	District Village Extension Officer
DRT	Department of Research and Training
FSD	Food Security Department
FSR	Farming systems research
ICW	Ilonga Composite White
Masl	Meters above sea level
MOA	Ministry of Agriculture
MSV	Maize streak virus
NGO	Non-governmental organization
NMRP	National Maize Research Programme
NPK	Nitrogen, phosphorus, and potassium
OPVs	Open pollinated varieties
P-values	Standard normal probability
RALDO	Regional Agricultural and Livestock Development Officer
REDSO/ESA	Regional Economic Development Services Office for East and Southern Africa
REO	Regional Extension Officer
SA	Sulfate of Ammonia
SACCAR	Southern Africa Centre for Coordination of Agricultural Research
SG-2000	Sasakawa-Global 2000
St	Streak resistant
STD	Standard deviation
SUA	Sokoine University of Agriculture
TANSEED	Tanzania Seed Company
TMV	Tanzania maize variety
Tsh	Tanzanian shillings
TSP	Triple super phosphate
UCA	Ukiriguru Composite A
ULVA	Ultra low volume applicators
USAID	United States Agency for International Development
VEO	Village Extension Officer

Acknowledgments

We gratefully acknowledge the support of many individuals and institutions, without which we could not have conducted this study. The financial, institutional, and logistical support provided by the Ministry of Agriculture and Cooperatives (MAC), SACCAR, and CIMMYT are greatly appreciated.

We thank F.M. Shao (former Commissioner for Research and Training, MAC), P. Anandajayasekeram (SACCAR), Joel Ransom (CIMMYT–Nairobi), T.N. Kirway (Assistant Commissioner, FSR, MAC), and D. Maretella (REDSO/ESA), who rendered assistance at various times during the course of the study.

We are also indebted to N. Mdoe (SUE), who helped with survey planning and the first use of the questionnaire in Gairo Division, and to Z.O. Mduruma (National Maize Research Coordinator) for encouragement and support. We thank E. Shayo (REO, Morogoro) for active participation in planning the study, and we also thank the RALDOs, DALDOs, DIVEOs, and VEOs who helped with the surveys. Finally, we are grateful to the many farmers who patiently responded to our questions.

Special thanks are due to Wzo. Aklilewerk Bekele, CIMMYT–Addis Ababa, for typing this survey, and to the Publications and Design staff, CIMMYT–Mexico, for editing and producing the report.

Executive Summary

Maize provides 60% of dietary calories and more than 50% of utilizable protein to the Tanzanian population. The crop is cultivated on an average of two million hectares, which is about 45% of the cultivated area in Tanzania. Recognizing the importance of the maize crop to the lives of Tanzanians, the government has committed human and financial resources to developing the industry. A National Maize Research Program (NMRP) was started in 1974 with the broad objective of developing cultivars suitable for major maize-producing areas. The NMRP and maize extension services have made a considerable impact in increasing food production.

The objective of this study was to evaluate the impact of maize research and extension over the past 20 years. The Department of Research and Training (DRT) conducted the study in collaboration with the Southern Africa Coordination Centre for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement Center (CIMMYT). To increase data validity and reliability, researchers and experienced extension officers used a structured questionnaire for interviewing farmers. Interviews were conducted in all seven agroecological zones of the country between June and November 1995. This report covers survey findings in the Eastern Zone, which includes Tanga, Morogoro, Coast, and Dar-es-Salaam regions. Survey data were classified by agroecological zone (the lowlands and the intermediate zone). These two zones are the most important maize production zones in Eastern Tanzania and therefore the most important categories for analysis. A two-stage least squares procedure was used to analyze factors affecting the allocation of land to improved maize and the use of fertilizer.

Maize research in the Eastern Zone is undertaken at Ilonga Research Institute. The major varieties released and developed include: Ilonga Composite (W) (OPV), Tuxpeño (1976), Staton (ST), Kito, Kilima (1983), TMV2 (1987), CH1, and CH3 (1992). In 1994, streak resistant versions of Kito, Katumani, Kilima, and UCA were released.

The mean age of household heads in the survey sample was 43 years, with an average farming experience of about 20 years. The household head received an average of six years of formal education. Sample households had about seven family members, consisting of at least two male and female adults and three children. Land is a maize production constraint mainly in the lowlands, where average farm size (6.9 acres) was significantly lower than the intermediate zone (9.6 acres). Farmers generally do not own livestock, which are concentrated in the intermediate zone. Hand hoes were the major farm tools used in each zone.

Maize is the major food and cash crop in the study area and is commonly intercropped with legumes or oilseeds. However, monocropping was the maize production strategy preferred by 78% of lowland farmers and 58% of intermediate zone farmers. Land preparation depended on the onset of rain in each zone, and farmers relied on the hand hoe to prepare land for planting maize. Maize was mostly planted in rows with the recommended spacing and weeded at least twice. The first and second weeding depended on the date of sowing and onset of the rains. Use of inorganic fertilizer was reported by 17% of lowland farmers and 8% of intermediate zone farmers, and the use of fertilizer was constrained by its high price and farmers' lack of knowledge about fertilizer. Organic manure was used by only 8% of the farmers in the lowlands, mainly because it was not available.

Stalk borers were the most serious field pests (reported by 54% of lowland farmers and 64% of intermediate zone farmers), but most farmers did not use any control method. Maize streak virus (MSV) was the most important disease, affecting local varieties more than other kinds of maize. Most farmers did not use any method of controlling the disease.

About 39% of the respondents reported that they had recycled improved seed for the past five years, while about 18% had recycled seed for about ten years and 15% for 15 years. About 32% of farmers in the lowlands and 39% in the intermediate zone reported that they purchased seed regularly. Seed selection was based on the size of the maize cob and grain maturity.

Staha was the maize variety preferred by most farmers (38% in the intermediate zone and 55% in the lowlands), largely because of its high yield. In the lowlands, farmers had stopped growing ICW and Katumani because of their relatively lower yields. In the intermediate zone, farmers no longer grew ICW and Kito, because of low yield and also because of susceptibility to diseases.

Of the few farmers who obtained credit, none obtained it from the formal sector. Lack of knowledge and bureaucratic obstacles were the major constraints to obtaining credit from the formal sector.

Most farmers had received information on improved maize practices such as improved seed, weeding, use of fertilizer, planting dates, pest management, and storage. Less information was disseminated about herbicides, ox-drawn implements, and disease control methods. The important sources of information were research and extension.

The two-stage least squares analysis showed that the availability of labor, extension intensity, and variety characteristics were significant factors affecting how much land a farmer was likely to allocate to improved maize. Short-maturing and medium-maturing varieties increased the probability of allocating land at the means by about 15% and 21%, respectively. Labor and extension increased the probability of allocating land at the means by about 3% and 22%, respectively. Farmers in the lowlands are less likely (by about 3%) to allocate land to improved maize. An increase in the intensity of extension by one unit increased the probability of using fertilizer by 40%.

Technical innovation characteristics and external influences, rather than farmers' characteristics, are the major factors in the adoption process. Research needs to develop varieties that fit farmers' tastes and circumstances, and extension should be involved in testing and disseminating these technologies.

A large area of the Eastern Zone is prone to drought, which can destroy the maize crop or chronically reduce yields and increase attack by stalk borers. The development of maize that yields well and can tolerate moisture stress and field pests, especially stalk borers, should be given priority.

Flexible integrated pest management packages that combine a drought-tolerant variety with improved cultural practices can increase yields. Thus, low-cost technologies for controlling stalk borers and MSV, using environmentally friendly industrial chemicals, should be developed.

Most improved varieties are responsive to fertilizer, and economic yields are usually obtained after fertilizer application. But use of fertilizer is constrained by high prices and lack of availability. An efficient marketing system for inputs and outputs will benefit farmers by providing higher prices for maize and reducing the cost of fertilizer. Such a system would require supporting policies from the government. Studies of the economics of seed and fertilizer use should be undertaken, especially now that input and output markets have been liberalized. However, researchers should develop recommendations for fertilizer levels under various weather and soil conditions.

Extension increases the adoption of improved maize varieties and fertilizer. Research and extension efforts need to be linked and strengthened to increase the flow of information to farmers. Research and the extension systems should not only find ways of increasing productivity of the farming systems, but should also focus on creating off-farm employment that can generate income to meet farmers' short-term needs, such the need to purchase fertilizer. In collaboration with the government and other stakeholders, the formal credit system needs to address the credit problems faced by small-scale farmers, especially their lack of knowledge (information) about formal credit systems. Cumbersome bureaucratic procedures for obtaining credit should be amended. The formation of farmer credit groups should be encouraged, because lending to groups tends to reduce transactions costs and improves the rate of loan recovery.

Adoption of Maize Production Technologies in Eastern Tanzania

Aloyce R.M. Kaliba, Hugo Verkuijl, Wilfred Mwangi, Alfred J. Moshi, Amos Chilagane, Joseph S. Kaswende, and Ponniah Anandajayasekeram

1.0 Introduction

1.1 Motivation and Objectives for This Study

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% of dietary calories to Tanzanian consumers (FSD 1992, 1996). The cereal also contributes more than 50% of utilizable protein, while beans contribute only 38% (Due 1986). Maize is grown in all 20 regions of Tanzania. The crop is grown on an average of two million hectares or about 45% of the cultivated area in Tanzania. However, most of the maize is produced in the Southern Highlands (46%), the Lake zone, and the Northern zone. Dar-es-Salaam, Lindi, Singida, Coast, and Kigoma are maize-deficit regions. Dodoma is a surplus region during good growing years, and in years following a plentiful rainfall the region is the number one supplier of maize to Dar-es-Salaam (FSD 1992; Mdadila 1995).

Maize is not only a staple crop in surplus regions but a cash crop as well. For instance, in the Lake Zone, maize competes aggressively with cotton for land, labor, and farmers' cash. Realizing the importance of the maize crop to lives of Tanzanians, 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 because of drought and the "villagization" campaign, which displaced farmers (Maliyamkono and Bagachwa 1990). The food crisis prompted the nation to launch several campaigns with the objective of food self-sufficiency, including "agriculture for survival" (*kilimo cha kufa na kupona*). The country also initiated a maize project in 1974 with assistance of the U.S. Agency for International Development (USAID). The project's objective was to promote maize production in pursuit of food self-sufficiency. On the research frontier, the National Maize Research Programme (NMRP) was launched, with the broad objective of developing cultivars suitable for major maize-producing areas.

The NMRP and maize extension have made considerable a impact in increasing food production. This study was conducted to evaluate the impact of maize research and extension during the past 20 years. Conducted by the Department of Research and Training (DRT) in collaboration with the Southern Africa Coordination Centre for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement Centre (CIMMYT), the study included the nation's seven agroecological zones. The study was conducted between June and November 1995. This report covers the survey findings in the Eastern Zone. The objectives of the study were to describe the maize farming systems of the zone, evaluate the adoption of improved maize production technologies, and identify future issues for research.

1.2 The Study Area

The location of the Eastern Zone is shown in Figure 1. The area lies between 0 and 1,500 meters above sea level (masl), covering the low and midaltitude zones, with low to moderate rainfall. The zone is administratively divided into four regions (Tanga, Morogoro, Coast, and Dar-es-Salaam) and 18 districts. It occupies an area of 13.1 million hectares and has a population of about 4.5 million people (National Population Census 1988). Both livestock (dairy cattle, beef cattle, goats, sheep, pigs, and poultry) and crops are important for the zone. Most of the area consists of lowlands (0-1,000 masl), although some areas around the Usambara, Uluguru, and Ukaguru mountain ranges are midaltitude areas (1,000-1,500 masl). Rainfall in most areas is unimodal (December-May), although a few bimodal rainfall areas benefit from the short rains occurring in October-November.

Cash crops include sisal, sugarcane, tea, cashews, and cotton. The first three crops are mainly grown in plantations, while the others are smallholder crops. Food crops include maize, rice, sorghum, millet, grain legumes, roots and tubers, horticultural crops, and coconuts, all largely produced by smallholders.

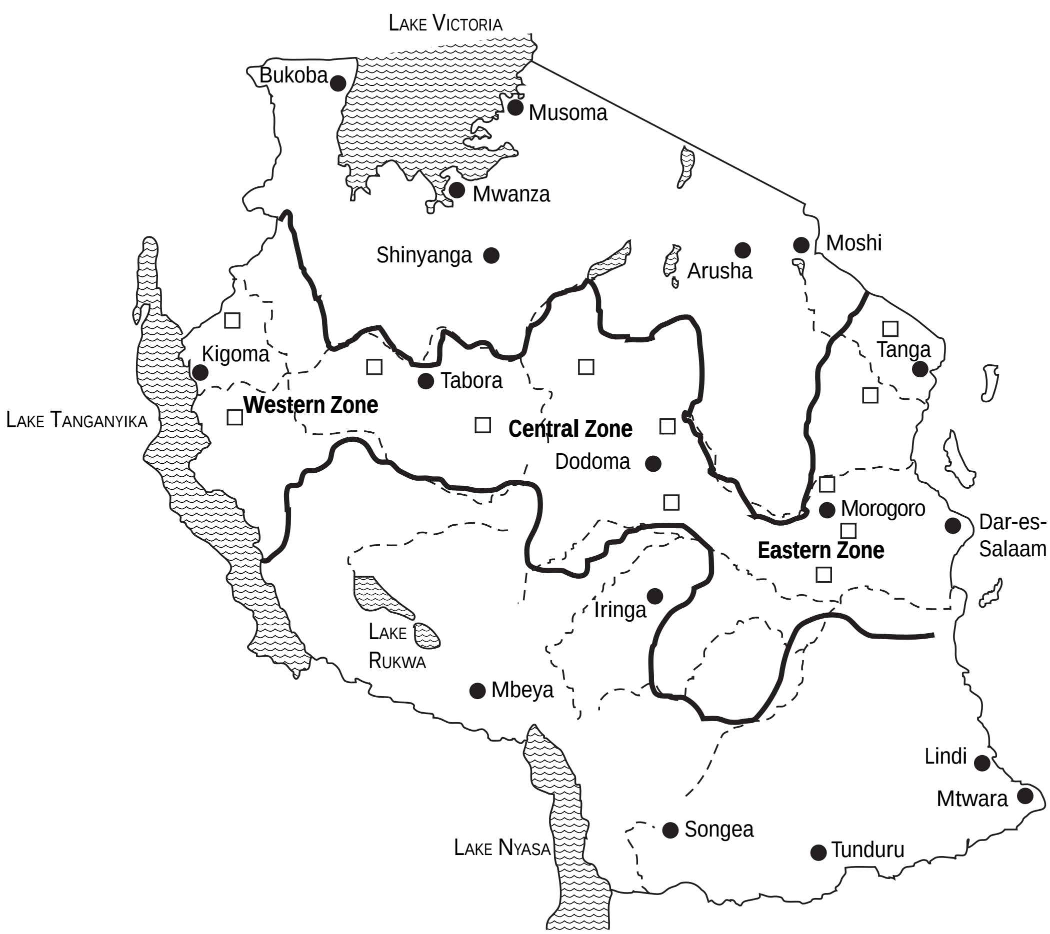


Figure 1. Eastern Tanzania.

Maize is an important food and cash crop in the Eastern Zone and accounts for 9% of total national maize production and 14.5% of national maize area. Most of the maize is produced in Tanga (40%) and Morogoro (55%), and the remainder is grown in the Coast and Dar-es-Salaam regions (5%). Average yields remain low at about 1.5 t/ha. Of the improved maize seed distributed countrywide, about 13% is used in the Eastern Zone, mostly in Tanga and Morogoro regions.

The two major agroecological zones in the Eastern Zone can be subdivided into the lowlands and the intermediate zone, each of which encompasses smaller divisions.

Lowlands (0-900 masl)

- Ulaya division: This division, which covers the central part of southern Kilosa District, has an altitude of <900 masl. It is characterized by bimodal rainfall and off-season crop production is possible in the valley bottoms. Rainfall ranges from 800 to 1,000 mm per annum. Major crops include maize, rice, cassava, sorghum, and cotton. Horticultural crops include citrus, bananas, coconuts, and mangoes.
- Turiani division: This division, located in the northern part of Morogoro Rural District, has an altitude of <900 masl. It is characterized by bimodal rainfall and off-season crop production is possible in the valley bottoms. Rainfall ranges from 800 mm to 1,000 mm per annum. Major crops include maize, rice, cassava, grain legumes, and horticultural crops (bananas and citrus). Sugarcane is grown on large plantations (Mtibwa) and on small-scale farms. Monocropping and intercropping of cereals and legumes are practiced, as well as relay cropping.
- Maramba division: The division covers the northern part of Muheza District, in Tanga Region. It lies at <500 masl and has a coastal climate, characterized by bimodal rainfall totaling about 1,000 mm per annum. It is hot all year round. The major crops are cassava, maize, rice, citrus, oranges, and coconuts. Monocropping and some intercropping of fruit trees with cereals is widely practiced.

Intermediate zone (900-1,500 masl)

- Gairo division: This division covers the northern part of Kilosa District and is in the intermediate dry altitude between 900 masl and 1,500 masl. It is characterized by unimodal rainfall totaling 500-800 mm per annum. The major farming system is a crop/livestock system, in which the major crops include maize, sorghum, grain legumes, sweet potatoes, oilseeds (groundnuts and sunflower), cassava, millet, and (in some areas) cotton. Monocropping and intercropping of cereals with legumes is widely practiced. Most livestock are indigenous breeds, including cattle, goats, sheep, and some donkeys.
- Korogwe division: This division lies around and east of Korogwe town, at an altitude of 900-1,500 masl. It is a dry, intermediate altitude area with bimodal rainfall totaling 700-800 mm per annum. The major crops are maize, cassava, grain legumes, some horticultural crops (bananas and citrus), and some rice. Livestock (cattle and goats) are also found in the farming systems in the division. Citrus trees and sisal plantations are common. Monocropping and intercropping of cereals and legumes is practiced.

1.3 Methodology

1.3.1 Sampling procedure

The number of farmers interviewed in the nationwide survey was determined by the importance of maize production. About 1,000 maize farmers were interviewed nationwide. Eastern Zone was allocated 114 farmers, approximately 11% of the national sample.

At the zonal level, three divisions were allocated to Morogoro region and two to Tanga region, based on maize area and total production. At the division level, three villages were purposively selected according to maize production and accessibility criteria. In each village, six farmers were randomly sampled from the register 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, CIMMYT and SACCAR economists, and national maize breeders and agronomists. The interviews were conducted between June and November 1995. To maintain uniformity, data from all zones were compiled at Selian Agricultural Research Institute (SARI) and then sent back to the respective zones for analysis and completion of the reports.

1.3.2 Analytical framework

Factors influencing the adoption of new agricultural technologies can be divided into three major categories: farm and farmers' associated attributes; attributes associated with the technology (Adesina et al. 1992; Misra et al. 1993); and the farming objective (CIMMYT 1988). Factors in the first category include a farmer's education, age, or family and farm size. The second category depends on the type of technology (e.g., the kind of characteristics a farmer likes in an improved maize variety). The third category assesses how different strategies used by the farmer, such as commercial versus subsistence farming, influence the adoption of technologies. In this study a two-stage least square analysis is used to test factors affecting allocation of land to improved maize varieties (intensity of adoption) and adoption of inorganic fertilizer (incidence of adoption). The basic assumption is that a farmer first tests and adopts improved seed by planting it on part of his or her land designated for maize production, and then decides to use fertilizer. The tobit (Tobin 1958) and probit (McFadden 1981) models, which test the factors affecting intensity and incidence of adoption, can be specified as:

$$Y_{ij} = \beta_{ij} X_{ij} + \varepsilon_i$$

i = 1 if farmer grows improved maize variety; j = 0 otherwise

$$Y_{ij} = \beta_{ij} X_{ij} + \alpha_i$$

i = 1 if farmer uses fertilizer; j = 0 otherwise

where:

Y_{ij} = the proportion of maize area allocated to improved maize varieties or adoption of inorganic fertilizer;

β_{ij} = the parameter to be estimated; and

ε_i and α_i = error terms.

The models were further specified as:

$$PLAND = A+EXP+EDVC+WID+EXI+LAB+VA1+VA2+VA3+AEZ1+AEZ2+\varepsilon_i$$
$$FERT = A+EXP+EDVC+WID+EXI+LAB+IMR+VA1+VA2+VA3+AEZ1+AEZ2+\alpha_i$$

where:

PLAND	=	proportion of maize area allocated to improved maize varieties (average for 1992-94).
FERT	=	use fertilizer (FERT=1 if used fertilizer; 0 otherwise) for the same period.
A	=	constant.
EXP	=	household head experience of farming (years).
EDVC	=	education level of household head (years).
WID	=	wealth index.
EXI	=	intensity of extension index.
LAB	=	number of adults in the household (15 and above years).
IMR	=	Inverse Mills' ratio of equation PLAND.
VA1-3	=	group of improved maize varieties (VA1=1 if farmer grows the variety in group 1, VA1 = 0 otherwise). The varieties were grouped according to months to maturity. Group one (VA1) consists of Katumani and Kito (3 months); group two (VA2), of TMV1, Staha, Tuxpeño, and ICW (3.5-4 months); group three (VA3), of UCA and Kilima (4.5-5 months).
AEZ1-2	=	lowlands and intermediate zone (AEZ1=1 if the farmer is in the lowlands, AEZ1=0 otherwise). The intermediate zone (AEZ2) was not included in the models to avoid multicollinearity (Griffiths et al. 1993; Greene 1993).
ε_i and α_i	=	error terms.

Formation of the model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to adopt or reject a new technology at any time is influenced by the combined (simultaneous) effects of a number of factors related to the farmer's objectives and constraints. The following variables were hypothesized to influence the adoption of improved maize technologies:

Farmer's experience: An experienced farmer is hypothesized to be more likely to adopt an improved maize technology package.

Household head received education: Exposure to education will increase a farmer's ability to obtain, process, and use information relevant to the adoption of an improved maize variety. Hence education will increase the probability that a farmer will adopt an improved maize technology package.

Labor: Large households will be able to provide the labor that might be required by improved maize technologies. Thus, household size would be expected to increase the probability that a farmer will adopt an improved maize technology package.

Wealth index: Wealthier farmers may have the means of buying improved maize technology, so wealth is expected to be positively associated with the decision to adopt an improved maize technology package.

Extension intensity: Agricultural extension services provided by the Ministry were the major source of agricultural information in the study area. Hence, it is hypothesized that contact with extension workers will increase the likelihood that a farmer will adopt improved maize technologies.

Inverse Mills ratio: Adoption of improved seed enhances the use of inorganic fertilizer.

Agroecology: The agroecological zones can influence a farmer's decision to adopt an improved maize technology package both positively and negatively.

Hotland (1993) has suggested establishing a wealth index by aggregating the major wealth indicators in a study area. Numbers of livestock and farm implements owned, as well as the average amount of cultivated land, are major wealth indicators in the Eastern Zone. These indicators were aggregated by calculating the wealth index (WID) as follows:

$$WID = \sum_{j=1}^{n} \frac{Yi}{Yij} \quad (i=1,\ldots,5;\ j=1,2,\ldots,N)$$

where:

Y_i = the average number of livestock units, farm implements (hand hoes, axes, cutting equipment) and cultivated land for the past three years;

Y_{ij} = the sample mean for each item; and

N = the sample size.

Extension services were the major source of information in the study area for improved agricultural practices. The number of recommendations with which a farmer is familiar can be used as an index of the transfer of information from extensionists to farmers. The extension index (EXT) was calculated as follows:

$$EXT = \frac{n}{6}$$

where:

n = the number of recommendations that a farmers knows from the improved technology package, such as improved seed, row planting, fertilizer application, ox-plowing, and field pest and disease control.

The PLAND equation was estimated using the tobit model (Tobin 1958). The inverse Mills ratio for equation PLAND was calculated and included as a regressor in equation FERT to correct for correlation between PLAND and FERT equation errors. Quasi-maximum likelihood was not used because of the problem of convergence (Saha and Love 1992; Hill 1994). Both models were estimated using TSP, Version 4.3.

2.0 Maize Research and Development in Tanzania

2.1 Maize Research in Tanzania

About 85% of the maize produced in Tanzania is grown by peasants whose farms are less than 10 ha. Ten percent of maize production occurs on medium-scale commercial farms (10-100 ha), and the remaining 5% occurs on large-scale commercial farms (>100 ha). Between 1961-65 and 1985-95, national maize production is estimated to have grown by 4.6%, of which 2.4% can be attributed to growth in area and 2.2% to growth in yield. Despite this yield growth, average yields are less than 1.5 t/ha, although grain yields tend to be higher in high-potential areas such as the Southern Highlands (Moshi et al. 1990).

Maize breeding and agronomy trials have been conducted in Tanzania for more than 20 years. The improved open pollinated varieties (OPVs) ICW and UCA were developed, tested, and released in the 1960s and are still widely used. During the same period, a few research stations undertook agronomy research, which later formed the basis for recommendations that were applied to the entire country.

In 1974, the NMRP was launched to coordinate maize research and encourage the better utilization of some resources. The program is responsible for coordinating all phases of maize research, from varietal development and maize management research on station to verification on farmers' fields. The NMRP has divided the country into three major agroecological zones for varietal recommendations:

- The highlands (elevations above 1,500 masl), with a growing period of 6-8 months.
- The intermediate (or midaltitude) zone (900-1,500 masl), which is further subdivided into "wet" (>1,100 mm rainfall, with a 4-5 month growing period) and "dry" subzones (<1,100 mm rainfall, with a 3-4 month growing period).
- The lowlands (0-900 masl), with a 3-4 month growing period.

To date, several breeding populations have been developed and are being improved through recurrent selection for specific traits. Since 1974, two hybrids and six OPVs have been released. In 1976, Tuxpeño 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 were released: Kito, Kilima, and Staha. Staha is characterized by its tolerance to maize streak virus (MSV), whereas Kilima was recommended for the midaltitude zone. Kito is an early maturing variety adapted to both lowland and midaltitude zones. In 1987 two OPVs, TMV1 and TMV2, were released. TMV1 has white, flinty grain, is streak resistant, and has intermediate maturity. It is recommended for the lowland and midaltitude zones. MV2 is also a white flint maize and is recommended for the high-altitude and high-potential maize-producing areas.

In 1994, the NMRP released versions of Kilima, UCA, Kito, and Katumani that are resistant to MSV: Kilima-St, UCA-St, Kito-St, and Katumani-St. Around the same time, two foreign seed companies, Cargill and Pannar, introduced or released seven hybrids for commercial use. For improvement of husbandry practices, the NMRP conducted off-station agronomy trials that in 1980 resulted in maize production recommendations specific to 11 regions. The recommendations related to choice of variety, plant spacing, plant density, fertilizer rate, weeding regime, and pesticide use.

2.2 The Maize Seed Industry in Tanzania

The hybrid CG4141 is multiplied and distributed by Cargill Hybrid Seed Ltd., which is based in Arusha. The locally bred hybrids H622 and H632 are grown mainly by farmers in the intermediate zones. Only a few farmers in the lowlands grow the locally bred hybrids because they mature late. Locally bred cultivars have flint grain, good pounding and storage qualities, and yield as well as CG4141. They are marketed mainly by the Tanzania Seed Company (TANSEED), which has not been doing very well in the newly competitive seed industry. This has contributed to reduced adoption of locally bred hybrids. Before the input market was liberalized in 1990, locally bred varieties were almost the only improved maize seed planted in Tanzania.

After market liberalization, private companies not only engaged in seed multiplication but conducted trials to evaluate the adaptability of imported varieties to the local environment. The varieties deemed suitable are subsequently released to farmers. CG4141 is competing aggressively with the locally bred cultivars multiplied and sold by TANSEED. Pannar started producing and marketing maize seed in 1995. The new companies have recruited chains of stockists who sell their seed in villages and towns, and TANSEED has followed suit. Farmers have reported that seed sold by private companies is purer, more uniform, and higher yielding than seed from TANSEED, which has reduced demand for TANSEED products.

The drawbacks of the new varieties sold by Cargill and Pannar are their high price, poor storability, poor pounding quality, and unsatisfactory taste. Pounded maize is used to make a local dish prepared from grains from which the seed coat has been removed (*kande*). Some farmers also pound their maize before milling to make a whiter and softer dough (*ugali*). When pounded, maize seed with a soft seed coat breaks, and flour losses before milling are greater. This underscores the importance of the flint trait in farmers' varietal preferences.

The latest development in the maize seed industry is the resumed importation of a once-famous hybrid, H511, from Kenya, by the Tanganyika Farmers' Association (TFA). H511 yields as well and matures as early as CG4141; its advantage over CG4141 is its flinty grain. The 1994/95 price for Cargill maize seed (CG4141) and Pannar seed (PAN 6481) was Tanzanian shillings (Tsh) 650/kg, while Kilima, a composite, sold at Tsh 450/kg. The high prices of maize seed have forced many farmers to recycle hybrid seed.

Before market liberalization, quasi-governmental institutions and cooperative unions monopolized input marketing. These institutions were inefficient in delivering inputs to farmers. They suffered from chronic liquidity problems, because they depended on borrowing money for buying inputs. This led to delayed input supply and chronic shortages that served as a disincentive to farmers (Mbiha 1993; Nkonya 1994). Market liberalization caused a rapid increase in the number of private businesses that engage in input marketing. Farmers could obtain inputs from village stockists who are located much closer to them than prior to 1990. Inputs have also become readily available on time in villages. As expected, the price of inputs has increased sharply, wiping out the shortages that existed before.

2.3 Maize Research in Eastern Tanzania

Maize research in the Eastern Zone started at Ilonga in the early 1950s, with research on agronomic practices. Breeding research started in 1963 and an OPV, Ilonga Composite (W), was released for the lowlands. Research at Muheza to develop a variety specifically for areas below 300m altitude were not successful. Some work was conducted at Amani on obtaining resistance to MSV. Katumani, an OPV developed in Kenya, was recommended for situations where early maturing maize was important.

Following the start of the nationally coordinated maize research program in 1974, several maize breeding populations targeted to the lowlands were developed. Experimental varieties extracted from these varieties were evaluated at Ilonga, Katrin (Ifakara), Morogoro (SUA), Mlingano, Kibaha, and Chambezi. This work resulted in the release of Tuxpeño in 1976 and Staha (a streak tolerant version) in 1983. Both are full-season varieties and were recommended for the lowland zone. Kito, an early maturing variety, was released in 1983 for the lowlands and intermediate zone. Kilima was also released in 1983 for the intermediate zone. TMV1, a medium maturity, streak resistant variety, was released in 1987. Many on-farm trials and demonstrations were conducted during 1975-80.

In 1983, maize research was started at the Chollima Agro-Scientific Research Center. The main objective was to develop hybrids for the lowlands and technologies for growing maize under irrigation. This resulted in the release in 1992 of hybrids CH1 and CH3 for the lowland zone. In early 1994, researchers at Ilonga released streak tolerant versions of Kito, Katumani, Kilima, and UCA. In addition to breeding research, agronomy research was conducted and recommendations were released (discussed in the next section).

2.4 Maize Production Recommendations

2.4.1 Varieties

Maize production recommendations were developed to fit the three agroecological zones described earlier. Recommended varieties for the lowland areas of Eastern Zone consisted of early maturing materials (Kito, Kito-St, Katumani, Katumani-St); medium maturing materials (TMV1); and full-season materials (Staha, ICW, CH1, CH3). The recommended full-season maize materials for the intermediate zone were Kilima, Kilima-St, TMV1, UCA, UCA-St, and H632. Table 1 shows the major attributes of some of the materials recommended for the Eastern Zone.

2.4.2 Planting time, planting method, and spacing

Because the onset of rains can fluctuate, planting time should be timed correctly to ensure that seed set occurs when there is sufficient moisture. Recommended planting dates for some locations in the Eastern Zone are shown in Table 2. Recommended planting depth for maize is 5-7 cm. In clay soils that crust easily, it is 2-3 cm.

Plant spacing options for maize in the Eastern Zone are shown in Table 3. The recommended spacing for maize the Eastern Zone is 75 x 30 cm or 90 x 25 cm, for tall-statured varieties. For small-statured varieties such as Kito or Katumani, the recommended spacing is 75 x 20 cm, with one plant per hill. Research has shown that in Eastern Tanzania maize yields from two plants per hill spaced at 60 cm intervals are similar to yields from one plant per hill spaced at 30 cm intervals. Alternatively, for a 90 cm inter-row spacing, the intra-row spacing may be 50 cm with two plants per hill.

2.4.3 Fertilizer type, timing, and method of application

Organic and inorganic sources of nutrients are used in maize production. Because the nutrient content of organic fertilizer is low, high rates are required (e.g., 10-15 t/ha of farm yard manure). Recommended rates of chemical fertilizer depend on the fertility status of the soil. Recommended fertilizers include sulfate of ammonia (SA), calcium ammonium nitrate (CAN), urea, triple super phosphate (TSP), di-ammonium phosphate (DAP), and nitrogen-phosphorus-potassium formulations.

Table 1. Recommended maize varieties and their characteristics, Eastern Tanzania

Area	Variety	Year released	Type	Kernel type	Months to maturity	Yield (t/ha) On station	Yield (t/ha) On farm	Major attributes
0-900 m	Kito	1983	OPV	F	3.0	3.5	2.5	Early maturing
Morogoro	Kito-St	1994	OPV	F	3.0	4.4	3.0	Early maturing, streak tolerant
Ifakara	Katumani	1967	OPV	F	3.0	3.4	2.0	Early maturing
Turiani	Katumani-St	1994	OPV	F	3.0	4.3	3.0	Early maturing, streak tolerant
Malinyi	Staja	1983	OPV	F/D	4.0	5.0	3.5	Streak tolerant
Tanga	Tuxpeño	1976	OPV	D	4.0	4.0	3.2	Good standability
Muheza	ICW	1963	OPV	F	4.0	4.0	3.2	Long cobs
Kibaha	TMV1	1987	OPV	F	3.5	4.5	3.5	Streak resistant
Korogwe	CH1	1992	H	F/D	4.0	5.2	4.0	Streak resistant
Handeni	CH2	1992	H	F/D	4.0	5.3	4.1	Streak tolerant
900-1,500 m	UCA	1966	OPV	DF	4.5	5.0	3.5	Large cobs
Mgeta	UCA-St	1994	OPV	DF	4.5	6.0	4.5	Streak tolerant
Mahenge	Kilima	1993	OPV	FD	4.5	5.0	3.6	Good standability
Matombo	Kilima-St	1994	OPV	FD	4.5	5.7	4.5	Streak tolerant
	TMV1	1987	OPV	PF	4.0	4.5	4.0	Streak resistant

Note: OPV = open pollinated variety; H = hybrid; F = flint; D = dent; P = partially.

Table 2. Estimated maize planting dates, Eastern Tanzania

Location	Short rains	Long rains
Gairo	–	Dec–Jan
Kilosa	Oct–Nov	Jan–Feb
Ifakara	–	Jan–Feb
Mgeta	Nov–Dec	March
Matombo	–	Nov–Dec
Morogoro	–	Feb–Mar
Wami	–	Jan–Feb
Korogwe	Oct–Nov	Mar–Apr
Muheza	Oct–Nov	Mar–Apr
Pangani	Oct–Nov	Mar–Apr

Table 3. Maize planting recommendations, Eastern Tanzania

Row width (cm)	Space between rows (cm)	Number of plants per hill	Plant density
75	60	2	44,444
90	25	1	44,444
90	50	2	44,444
75	20	1	66,666
75	40	2	66,666

Sulfate of ammonia is recommended for neutral or only alkaline soils, whereas CAN is recommended for acidic soils. Fertilizer recommendations for specific locations in Eastern Tanzania are shown in Table 4.

The nitrogen (N) application may be split by applying about 50% of the total amount at planting and the remainder just before tasselling. Fertilizer is normally placed 5 cm below the seed and about 5-8 cm to the side. This is accomplished by digging a single hole beside each seed, placing fertilizer in the hole, and covering it with soil. Alternatively, a continuous furrow is made along the length of the planting row. Fertilizer is then placed in the furrow and covered with soil. The seed is planted on top of this soil and covered properly. For off-season maize planted under residual moisture, fertilizer (SA or urea) should be buried deeply in the soil to be taken up easily by the plants.

2.4.4 Weed control

Two weedings are recommended in Eastern Tanzania. The first weeding should be done two weeks after germination and the second should be done two weeks later. Weeding is normally done by hand hoe, although herbicides can also be used. Commonly used herbicides include Gesaprim 500FW and Premagram 500FW, both at 5 L/ha, applied pre-emergence, and 2,4-D at 1.5 L/ha, applied post-emergence.

2.4.5 Pest and disease control

The most important maize diseases in the Eastern Zone are lowland rust (*Puccinia polysora*), blight (*D. maydis*), MSV, and stem rots. The best control for these diseases is varieties that are resistant or tolerant to them. Early planting may reduce the incidence of MSV.

The most important field pests of maize are stalk borers and armyworms. The most common borers are the spotted stalk borer (*Chilo partellus*) and the pink stalk borer (*Sesamia calamistis*). These are controlled by applying a pinch of dust or granules of an insecticide such as Endosulphan 4% dust, at 5 kg/ha; Cymbush dust 1% at 2.5 kg/ha, or Sumicombi 1.8% at 5 kg/ha. Once the damage is assessed to be economic, insecticide should be applied to all plants in the field.

Armyworm (*Spodoptera exempta*) occurs in major outbreaks. These pests are controlled at the national level through aerial spraying of insecticide. Hand sprayers and ultra low volume applicators (ULVA) may also be used for local control. Chemicals such as Fenvalerate 7EC at 2 L/ha, Malathion 50EC at 1.25 L/ha, and Cypermethrin 25EC at 0.5 L/ha may be used.

2.4.6 Harvesting and storage

Maize should be harvested when it has reached physiological maturity and the “black layer” has been formed. Harvested maize should be dried

Table 4. Fertilizer recommendations (50 kg bags/ha) for specific locations, Eastern Tanzania

Location	Triple super phosphate	Sulfate of ammonia	Calcium ammonium nitrate	Urea
Ilonga	1.0	2.0	1.5	1.0
Gairo	1.0	2.0	1.5	1.0
Ifakara	1.0	4.5	3.5	2.0
Mikese/Ubena	1.0	2.5	2.0	1.0
Mgeta	1.0	3.0	2.5	1.5
Mlingano	1.0	2.5	2.0	1.0
Kange	0.5	2.5	2.0	1.0
Kabuku	1.0	2.0	2.0	1.0
Bumbuli	0.5	3.0	2.5	1.5
Coast Region	0.5	2.0	2.0	1.0
Dar-es-Salaam	0.5	2.0	2.0	1.0

on the cob and shelled and winnowed before it is stored. Cleaning may done manually or by hand-held maize shellers. To be stored, maize should have a moisture content of less than 15% and should be treated with chemicals before being placed in bags or other containers.

Common storage pests in the Eastern zone are the larger grain borer (*Prostephanus truncatus*), the maize weevil (*Sitophilus zeamais*), and the angoumois moth (*Sitotroga cerealella*). Chemicals available for controlling these pests include Pirimiphos methyl (Actellic 25EC or 50EC), Permethrin (50EC), and Actellic Super (Pirimiphos methyl 1.6% and Permethrin 0.3%).

Rodents can cause considerable damage to the maize crop in the field and in storage. A combination of rodent control methods (use of cats, rodenticides, rat guards, and so on) may be used.

3.0 Demographic and Socioeconomic Characteristics

3.1 Demographic Characteristics

Table 5 summarizes the characteristics of sample households in Eastern Tanzania. The mean age of the household head was 45 years, with about 20 years of farming experience. The level of formal education was about six years in both zones. No significant differences were found for these characteristics between zones.

Sample households had about seven family members, consisting of at least two male adults, two female adults, and three children. The number of male adults in the lowlands was significantly larger than the intermediate zone (p=0.1). About 32% of lowland farmers and 18% of intermediate zone farmers had off-farm income, which they used to purchase seed (56%), pesticide (16.5%), fertilizer (8.8%), and other household requirements (18.7%) such as soap and fuel.

Table 5. Demographic characteristics of sample households, Eastern Tanzania

	Lowlands		Intermediate zone		
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**t-statistic**
Household head					
Age (yr)	44.9	13.5	45.6	15.4	0.22 (NS)
Education (yr)	5.6	2.2	6.2	2.2	1.29 (NS)
Years lived in the village	25.8	16.1	27.6	16.8	0.5 (NS)
Farming experience (yr)	20.2	12.5	19.0	11.0	0.45 (NS)
Labor availability (number)					
Male adults	2.1	1.4	1.7	1.0	1.6*
Female adults	2.1	1.4	1.9	1.3	0.79 (NS)
Children	3.0	2.2	3.4	2.5	0.78 (NS)
Off-farm employment					
Male adults	1.4	0.7	0.7	0.6	1.47 (NS)
Female adults	1.0	—	0.7	—	1.00 (NS)
	Number of farmers	**Percent of farmers**	**Number of Farmers**	**Percent of farmers**	χ^2
Off-farm income					
Yes	17	31.5	5	14.3	3.4*
No	37	68.5	30	85.7	

Note: NS = not significant; * = significant at 10% level.

3.2 Land Resources and Allocation

Land is a limiting factor in the lowlands. Land shortages are acute for villages around sisal estates, and the problem is also prominent in Kilosa and Korogwe Districts. Figures 2 and 3 show trends in farm size and maize area in the lowlands and intermediate zone. More land was available in the intermediate zone, and farm size and maize area were significantly larger than in the lowlands (significant at the 1% and 5% levels, respectively). Farmers in the intermediate zone had 2.7 plots, whereas lowland farmers had 2.3, and this was significantly different ($p=0.05$). Farmers in both zones rented in an average of about 2.7 acres. Farmers in the lowlands rented out a significantly larger portion of their land (6.8 acres) than farmers in the intermediate zone (2.6 acres) (significant at $p=0.1$).

About 78% of lowland farmers and 67% of intermediate zone farmers had increased their farm size because of higher demand for food. Other reasons for enlarging the farm included the need to earn more money or the initiation of a new agricultural enterprise. Farmers gave similar reasons for changes in maize area. About 64% of the farmers in the lowlands and intermediate zone reported that a higher demand for maize had led them to change their maize area; other reasons included declining soil fertility and the initiation of a new enterprise.

As indicated earlier, maize was the major cash and staple food crop in both zones. More than 75% of the respondents indicated that they intended to increase both their total cultivated area and the area they planted to improved maize. Although respondents in Muheza District indicated that they would not change their total area cultivated (50%), they all indicated that they would increase the area under improved maize to meet the increased demand for food.

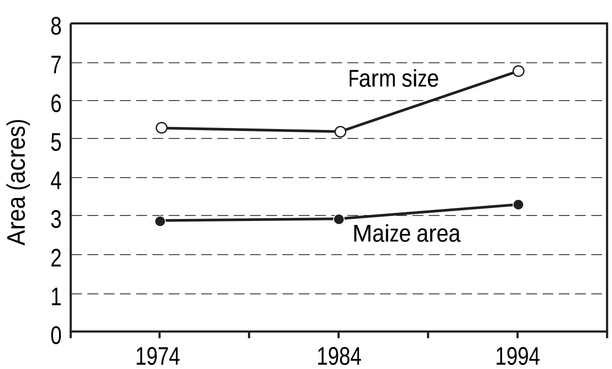


Figure 2. Trends in farm size and maize area in the lowlands, Eastern Tanzania.

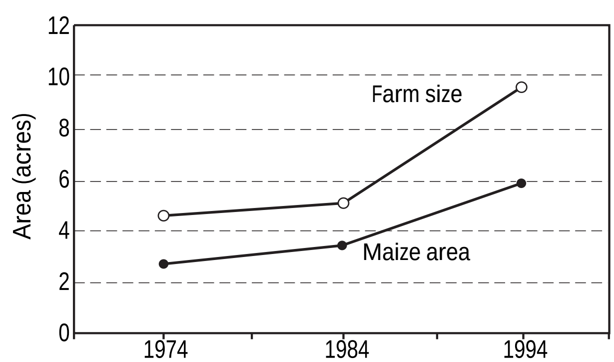


Figure 3. Trends in farm size and maize area in the intermediate zone, Eastern Tanzania.

3.3 Livestock Ownership and Farm Mechanization

Table 6 shows numbers of livestock and farm implements owned by sampled farmers. It was not common for farmers in either zone to raise livestock; nor did livestock ownership vary much between zones. Most livestock was concentrated in the intermediate zone. Chickens were owned by more than 75% of sample households.

In both agroecological zones, farmers owned an average of four hand hoes and three cutting implements per household. Farmers did not own tractors, ox-plows, or carts. About 30% of the farmers hired tractors, which were mainly used for land cultivation.

Table 6. Numbers of livestock and farm implements, Eastern Tanzania

	Lowlands		Intermediate zone		
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**t-statistic**
Number of livestock					
Goats	14.2	16.7	12.6	10.9	0.26 (NS)
Sheep[a]	0.0	—	5.0	—	—
Cattle	3.0	1.4	8.4	14.2	0.52 (NS)
Farm implements					
Hand hoe	4.2	2.1	4.3	2.5	0.08 (NS)
Cutting equipment	3.1	1.4	2.9	1.4	0.71 (NS)

Note: NS = not significant.
[a] One farmer owned sheep.

4.0 Maize Production and Crop Management

4.1 Crops and Cropping Systems

Maize was commonly intercropped with legumes or oilseeds in both zones, although lowland farmers preferred to monocrop maize (Table 7). About 78% of lowland farmers and 58% of intermediate zone farmers monocropped their maize, and the difference was significant ($p=0.05$). Farmers in both zones intercropped mainly because they wanted to spread risk, because land was scarce, or because they needed to save on labor. In both zones, maize was grown on the same plot for about 11 years.

4.2 Maize Crop Management Practices

4.2.1 Land preparation

In the lowlands, land preparation started in August and ended in January to take advantage of the short rains; in the intermediate zone, where farmers depended on the long rains to produce maize, land preparation was done between November and March (Table 8). The hand hoe was the major tool used to prepare land, although about 17% of lowland farmers and 6% of intermediate zone

Table 7. Maize cropping systems, Eastern Tanzania

	Lowlands		Intermediate zone		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Intercropping					
Monocrop	42	77.8	21	58.3	3.88**
Intercrop	12	22.2	15	41.7	–
Reasons for intercropping					–[a]
Saves labor	2	20.0	2	14.3	–
Land is scarce	3	30.0	5	35.7	–
Spreads risk	4	40.0	7	50.0	–
Provides more food	1	10.0	–	–	–

Note: ** = significant at 5% level.
[a] χ^2 not calculated because of empty cells.

Table 8. Time and methods of land preparation, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of land preparation				
August-October	23	42.7	8	22.3
November December	6	11.2	14	38.9
January-March	25	46.4	14	38.9
Method of land preparation				
Hand hoe	43	81.1	30	83.3
Tractor	9	17.0	2	5.6
Zero-tillage	1	1.9	4	11.1

farmers hired tractors to prepare land. Zero tillage was practiced by 11% and 2% of the farmers in the intermediate zone and lowlands, respectively. Only one farmer in the lowlands used oxen for land preparation.

4.2.2 Seedbed type, planting pattern, and weed control

Table 9 shows farmers' major agronomic practices. All farmers planted maize on flat seedbeds. Lowland farmers generally planted maize between November and January, whereas intermediate zone farmers planted between February and March. The time of planting was later in the intermediate zone than in the lowlands because intermediate zone farmers depended on the long rains.

Most farmers planted in rows because this practice made it easier to manage the field. Other farmers said they planted in rows to obtain higher yields or because extension had advised them to do so. Respondents had about ten years of experience in planting maize in rows, and most farmers used the recommended spacing.

Table 9. Farmers' major agronomic practices, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of planting (1994/95)				
August–October	35.2	19	2.8	1
November–December	29.6	9	27.7	10
January–March	33.4	18	66.7	24
April–May	20.4	11	2.8	1
Planting method				
Row	92.6	50	100.0	36
Random	7.4	4	0.0	0
Reasons for row planting				
Ease of field management	94.4	51	83.3	30
Other	5.6	3	16.7	6
Spacing between rows				
Use recommended spacing	82.0	41	68.6	24
Use other spacing	18.0	9	31.4	11
Time of first weeding				
October–December	37.1	20	19.5	7
January–March	22.2	12	55.5	20
April–May	40.8	22	25.0	9
Time of second weeding				
November–December	14.3	7	2.9	1
January–March	36.7	18	48.6	17
April–June	49.0	24	48.6	17
	Mean		**Mean**	
Number of seeds per hill	1.3		1.5	
Weeding frequency	2.1		2.2	

Farmers in both zones generally weeded at least twice. The time of weeding depended on the date of planting and the presence of weeds in the field. In the lowlands, the first weeding was done between October and January and the second was done between February and March. In the intermediate zone, the first weeding was done in February and March while the second took place mainly in April.

4.2.3 Type of fertilizer, method of application, and quantity

About 17% of the farmers in the lowlands and 8% in the intermediate zone used inorganic fertilizer (urea, SA, TSP, and NPK) (Table 10). Farmers who did not use fertilizer said they did not use it because of its high price or because they had no need for it. Only 8% of the sample farmers in the lowlands and none in the intermediate zone used organic manure because of its unavailability.

4.2.4 Fallowing and crop rotation

About 44% of lowland farmers and 37% of intermediate zone farmers fallowed their land (Table 11), mainly to replenish soil fertility. Fallows lasted 1.9 years in the lowlands and 1.2 years in the intermediate zone, and this difference was significant ($t=4.15$, $p=0.01$). Most farmers grew maize immediately after fallow because maize was the main crop and provided more income. The main reason for not fallowing in both zones was land scarcity.

Table 10. Fertilizer use by sample households, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Use inorganic fertilizers (IF)				
Yes	9	16.7	3	8.3
No	45	83.3	33	91.7
Use organic fertilizer				
Yes	4	7.4	0	0.0
No	50	92.6	36	100.0
Reasons for not using IF				
Expensive	4	80.0	4	100.0
Do not need	1	20.0	0	0.0

Table 11. Fallowing and crop rotation, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Fallow maize	20	44.4	11	36.7
Reasons for fallowing				
Replenish soil fertility	20	100.0	7	87.5
No fertilizer	0	0.0	1	12.5
Rotate crops	13	24.1	14	38.9
Reasons for crop rotation				
Uses previous fertilizer residues	0	0.0	5	71.4
Breaks disease cycles	1	100.0	2	28.6

About 24% of lowland farmers and 39% of intermediate zone farmers rotated their crops. The common crop rotations were maize–cassava, maize–tobacco–legumes, maize–cassava–legumes, and maize–oilseeds. One lowland farmer rotated crops to break the disease and pest cycles. In the intermediate zone, farmers rotated crops to take advantage of fertilizer residues (71.4%) or to break disease/pest cycles (28.6%). The main reason that farmers in both zones gave for not rotating crops was a shortage of land

4.2.5. Crop residue management

Farmers who do not apply fertilizer or who use only a small amount are recommended to plow crop residues back into the soil to avoid mining. About 95% of lowland farmers and 74% of intermediate zone farmers followed this recommendation (Table 12). About 20% of the farmers in the intermediate zone grazed cattle on maize residues in the field.

4.2.6 Pest and disease control

Field pests, diseases, and their control methods are summarized in Table 13. About 54% and 64% of the sample farmers in the lowlands and intermediate zone, respectively, reported that stalk borers

Table 12. Farmers' management of crop residues, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Plow residues under	50	94.3	25	73.5
Burn residues	2	3.8	1	2.9
Feed residues to cattle	1	1.9	7	20.6
Other	–	–	1	2.9

Table 13. Major pests and diseases and their control, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Field pests				
None	15	27.8	8	22.2
Stalk borers	29	53.7	23	63.9
Cutworms and termites	1	1.9	1	2.8
Vermin	9	16.7	4	11.1
Method of control				
Thiodan	3	5.6	3	8.3
DDT	3	5.6	5	13.9
Marshal	1	1.9	–	–
Guard	8	14.8	–	–
None	38	70.4	28	77.8
Field diseases				
None	31	57.4	26	72.2
MSV	22	40.7	7	19.4
Cob-rot	–	–	3	8.3
Smut	1	1.9	–	–
Most affected maize varieties				
Local varieties	48	88.9	33	91.7
Hybrids	1	1.9	2	5.6
Composites	5	9.2	1	2.7

were the most serious field pest. Other field pests included cutworms, termites, and vermin. Most respondents used no method for controlling maize field pests; those who did used DDT, Marshal, and guards.

The most important maize disease in both zones was MSV, which was reported by 41% and 19% of farmers in the lowlands and intermediate zone, respectively. About 92% of lowland farmers and 97% of intermediate zone farmers reported that they did nothing to control diseases. Local varieties were most affected by maize field pests and diseases.

4.2.7 Harvesting, transportation, and storage of maize

The maize harvest depends on the time of sowing and the end of the rainy season, but most maize was harvested between May and July (Table 14). Harvested maize was transported to the homestead by headload, bicycle, and ox-cart. About 58% of lowland farmers and 40% of intermediate zone farmers stored their maize on cribs; other methods included gunny bags and the traditional storage structure (*kihenge*). The majority of farmers in the intermediate zone (60%) treated their maize before storage, compared to 40% of farmers in the lowlands. Storage losses without treatment can be substantial. Treatment with Actellic Super was the most common control method in the intermediate zone (89.5%); farmers in the lowlands generally used of ash or other local materials (57% of farmers). Lowland farmers had started treating stored maize significantly earlier (11 years ago) than farmers in the intermediate zone (5 years ago) ($t=1.71$, $p=0.10$).

4.2.8 Seed selection and recycling

About 32% of lowland farmers and 39% of intermediate zone farmers reported that they purchased seed regularly, but most respondents reported recycling their hybrid and composite seed. About 39% of the respondents had recycled improved seed for the past five years, whereas 18% had recycled seed for ten years and 15% had recycled seed for 15 years. In both zones, the most important

Table 14. Maize harvesting, transportation, and storage, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Months of harvest				
March–April	11	21.5	9	–
May	12	23.5	9	31.0
June	7	13.7	5	17.2
July	17	33.3	13	44.8
August	4	7.8	2	6.9
Method of transportation				
Headload	26	55.3	12	41.4
Bicycle	14	29.8	8	27.6
Cart	5	10.6	9	31.0
Other	2	4.3	—	0.0
Maize storage				
Shell and store in *kihenge*	7	14.0	9	25.7
On cribs	29	58.0	14	40.0
Gunny bags	14	28.0	12	34.3

criterion for selecting seed was the size of the cob (Table 15). Seed was selected when farmers were harvesting maize or shelling it for storage. Selected maize was either stored on cribs (44%) or shelled and stored in gunny bags with chemicals.

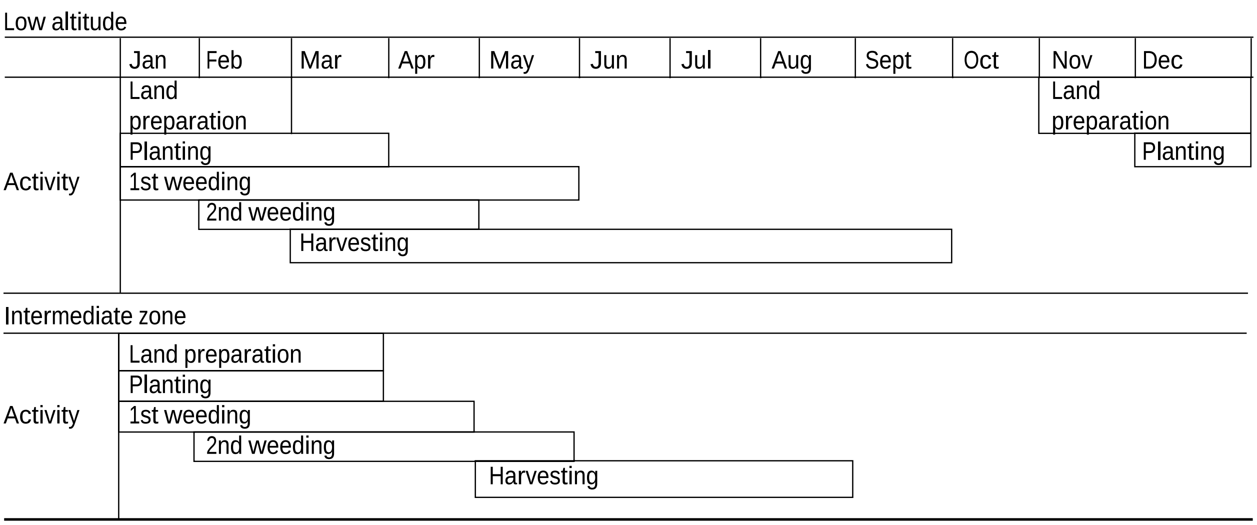
4.2.9 Maize cropping calendar for Eastern Tanzania

Table 16 presents the maize cropping calendar for Eastern Tanzania. In both zones, the peak labor demand occurred between January and April, while the remainder of the year was relatively slack.

Table 15. Farmers' seed selection criteria, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Big cob	45	100.0	31	93.9
Mature grain	0	0.0	2	6.1

Table 16. Maize cropping calendar, Eastern Tanzania



5.0 Adoption/Disadoption of Improved Maize in the Study Area

5.1 Varieties Currently Grown

Table 17 shows maize varieties grown by sample farmers in the 1994/95 farming season. The first four varieties grown in both zones were Staha, TMV1, Katumani, and Tuxpeño. Other varieties that farmers grew included CG4141 and ICW in the lowlands and Kito, ICW, CG4141, and Kilima in the intermediate zone. Staha was mostly planted in the lowlands (44.7%).

5.2 Preferred Improved Maize Varieties and Reasons for Farmers' Preferences

The most preferred maize varieties are shown in Table 18. Differences in farmers' preferences for improved maize varieties across zones can be attributed to variation in pests and diseases, soil fertility, and climate.

Table 17. Maize varieties planted in the 1994/95 season, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Local variety	10	21.3	4	16.7
Staha	21	44.7	7	29.2
TMV1	6	12.8	3	12.5
Katumani	4	8.5	3	12.5
Tuxpeño	3	6.4	2	8.3
Kito	0	0.0	1	4.2
ICW	3	6.4	4	16.7

Table 18. Preferred maize varieties, Eastern Tanzania

	Lowlands		Intermediate zone	
Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Staha	23	54.8	12	37.5
TMV1	9	21.4	8	25.0
Tuxpeño	4	9.5	2	6.3
Katumani	3	7.1	2	6.3
Kilima	0	–	1	3.1
ICW	2	4.8	6	18.8
Local	1	2.4	1	3.1

Staha and TMV1 are the most preferred improved maize varieties in both zones. About 55% of lowland farmers and 38% of intermediate zone farmers preferred Staha. In the lowlands, Staha and TMV1 were preferred for their high yield and tolerance to drought stress (Table 19). Tuxpeño was valued for its tolerance to drought stress. In the intermediate zone, Staha and TMV1 were preferred for the same characteristics. It is not surprising that tolerance to drought stress was emphasized in both zones, given that maize production is rainfed.

5.3 Disadoption of Improved Maize

In the lowlands, about 32% of the respondents said they no longer grew ICW, and 23% no longer grew Katumani. Other disadopted varieties included TMV1, Staha, and Kito. In the intermediate zone, about 46% of farmers had disadopted ICW and 23% no longer grew Kito. Other disadopted varieties included Katumani, Kilima, Staha, and CG4142. Farmers' major reasons for disadopting a variety were low yield, susceptibility to pests and diseases, and unavailability of seed (Table 20).

Table 19. Reasons for farmers' preferences for certain maize varieties, Eastern Tanzania

		High yield		Drought resistant		Good grain		Pest/disease resistance	
Altitude	Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Lowlands	Staha	15	75.0	5	25.0	–	–	–	–
	TMV1	4	44.4	4	44.4	–	–	1	11.1
	Tuxpeño	–	–	3	100.0	–	–	–	–
Intermediate zone	Staha	4	44.4	4	44.4	1	11.1	–	–
	TMV1	–	–	7	100.0	–	–	–	–
	ICW	2	50.0	1	25.0	–	–	1	25.0

Table 20. Maize varieties/hybrids no longer grown by farmers, Eastern Tanzania

		Low yield		Susceptible to diseases/pests		Not available	
Altitude	Varieties	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Lowlands	ICW	1	33.3	1	33.3	1	33.3
	Katumani	1	50.0	–	–	1	50.0
Intermediate zone	ICW	2	40.0	–	–	2	40.0
	Kito	1	50.0	1	50.0	–	–

6.0 Credit and Extension Services

6.1 Credit Availability

About 6% of lowland farmers and 14% of intermediate zone farmers had used credit to produce maize. All of them indicated that they received credit from informal moneylenders to purchase agricultural inputs. The average loan amounted to Tsh 20,600, with a maximum of Tsh 60,000. Credit was mainly used to purchase fertilizer (25%) and farm tools (75%), which had higher returns in the short and long term. Lack of knowledge and bureaucracy were the major constraints to obtaining loans. Table 21 summarizes the sources and use of credit by zone.

6.2 Extension Services

All districts represented in the Eastern Zone survey are covered by the National Agriculture and Livestock Extension Project (NALEP), which is sponsored by the World Bank and Government of Tanzania (GOT), and which encouraged use of the training and visit (T&V) extension system. About 93% of respondents said they had received recommendations on improved varieties, while 66% of respondents had received recommendations on fertilizer use. Farmers' sources of information on improved maize technology are shown in Table 22. The most important source of information was research/extension. Most farmers received information on agronomic management practices, but information on the use of herbicides, ox-drawn implements, and disease control methods was relatively limited in both zones.

Table 21. Farmers' sources and use of credit, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Access to credit	3	5.6	5	13.9
Source of credit				
Informal sector	2	100.0	4	100.0
Availability of credit				
Difficult to obtain	53	98.1	36	100.0
Not difficult to obtain	1	1.9		0.0
Constraints to obtaining credit				
Lack of knowledge	52	96.3	30	83.3
Bureaucracy	2	3.7	6	16.7

Table 22. Farmers' sources of information about maize production, Eastern Tanzania

	Lowlands		Intermediate zone	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Improved maize varieties				
Received information	49	90.7	34	94.4
Source of information				
Research/extension	38	95.0	21	91.3
Other farmers	0	0.0	1	4.3
Other sources	2	5.0	1	4.3
Planting method				
Received information	51	94.4	33	91.7
Source of information				
Research/extension	24	70.6	15	71.4
Other farmers	2	5.9	1	4.6
Other sources	8	23.5	5	23.8
Fertilizer				
Received information	35	64.8	24	66.7
Source of information				
Research/extension	19	86.4	17	89.5
Other farmers	0	0.0	1	5.3
Other sources	3	13.6	1	5.3
Weed management				
Received information	49	90.7	33	91.7
Source of information				
Research/extension	35	87.5	23	92.0
Other farmers	2	5.0	1	4.0
Other sources	3	7.5	1	4.0
Herbicide				
Received information	27	50.0	16	44.4
Source of information				
Research/extension	16	72.7	12	85.7
Other farmers	1	4.5	—	0.0
Other sources	5	22.8	2	14.3
Ox-drawn tools				
Received information	21	38.9	20	55.6
Source of information				
Research/extension	14	73.7	12	70.6
Other farmers	1	5.3	2	11.8
Other sources	4	21.0	3	17.6
Pest management				
Received information	38	70.4	29	80.6
Source of information				
Research/extension	31	93.9	25	96.2
Other farmers	1	3.0	1	3.8
Other sources	1	3.0	0	0.0
Disease control				
Received information	28	51.9	20	55.6
Source of information				
Research/extension	22	88.0	16	94.1
Other farmers	1	4.0	1	5.9
Other sources	2	8.0	0	0.0
Storage practices				
Received information	43	79.6	29	80.6
Source of information				
Research/extension	32	84.2	22	88.0
Other farmers	3	7.9	1	4.0
Other sources	3	7.9	2	8.0

7.0 Factors Affecting Adoption

7.1 Definitions

Feder et al. (1985) defined adoption as the degree of use of a new technology in a long run equilibrium when a farmer has full information about the new technology and its potential. Therefore, adoption at the farm level describes the realization of farmers' decision to apply a new technology in the production process. On the other hand, aggregate adoption is the process of spread or diffusion of a new technology within a region. Therefore a distinction exists between adoption at the individual farm level and aggregate adoption within a targeted region. If an innovation is modified periodically, however, the equilibrium level of adoption will not be achieved. This situation requires the use of econometric procedures that can capture both the rate and the process of adoption. The rate of adoption is defined as the proportion of farmers who have adopted a new technology over time. The incidence of adoption is defined as the percentage of farmers using a technology at a specific point in time (for example, the percentage of farmers using fertilizer). The intensity of adoption is defined as the level of adoption of a given technology (for instance, the number of hectares planted with improved seed or the amount of fertilizer applied per hectare).

7.2 Rate of Adoption of Improved Maize in the Eastern Zone

The common procedure for assessing the rate of adoption is the use of a logistic curve, which captures the historical trend of adoption over a given time and can be used to assess the effectiveness of agricultural institutions that have served the farming system over time. The logistic curve is constructed using data on the proportion of farmers who have adopted an improved technical innovation over a given period. The basic assumption is that adoption increases slowly at first but then increases rapidly to approach a maximum level (CIMMYT 1993). Mathematically, the logistic curve is given by the following formula:

$$Y_t = \frac{K}{1 + e^{-a-bt}}$$

where:

Y_t = the cumulative percentage of adopters at a time t;
K = the upper bound of adoption;
b = a constant, related to the rate of adoption; and
a = a constant, related to the time when adoption begins.

Figure 4 shows the adoption of improved maize varieties in the lowlands and intermediate zone. By 1994, about 85% of lowland farmers and 92% of intermediate zone farmers had adopted improved maize varieties. The rate of adoption for 1974-94 was 0.22 for the lowlands and 0.52 for the intermediate zone. Improved maize varieties gained popularity in the mid-1980s, when farmers allocated more land to improved maize than local maize. Between 1992 and 1994, however, the

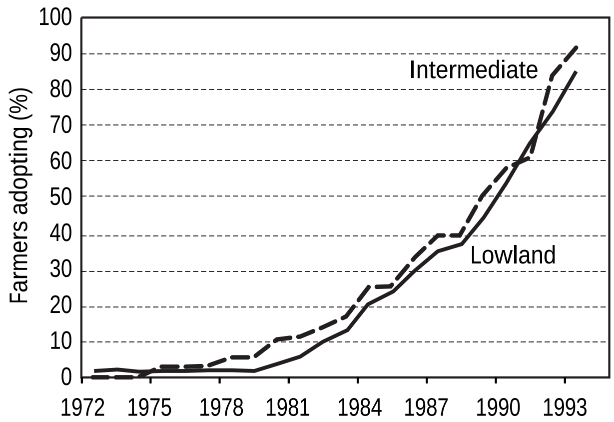


Figure 4. Adoption of improved maize in the lowland and intermediate zones, Eastern Tanzania.

land allocated to improved maize declined, especially in the intermediate zone. The declined probably occurred because improved seed was hard to obtain during that period, when the seed market was liberalized. Formal seed marketing channels were disturbed and the informal sector could not respond quickly enough to take over the market of improved seed. The consequence was a reduction in maize seed supply and higher seed prices. At the same time, maize prices fell, causing farmers to allocate less land to maize.

7.3 Tobit Analysis of Land Allocated to Improved Maize

The tobit model results on the proportion of land allocated to improved maize varieties are presented in Table 23. The tobit model was used because the proportion of land allocated to improved maize seed is continuous but truncated between zero and one. The use of ordinary least squares will result in biased estimates (McDonald 1980). In Table 23, $\delta EY/\delta X_i$ shows the marginal effect of an explanatory variable on the expected value (mean proportion) of the dependent variable, $\delta EY^*/\delta X_i$ shows changes in the intensity of adoption with respect to a unit change of an independent variable among adopters, and $\delta F(z)/\delta X_i$ is the probability of change among

Table 23. Tobit model estimates for allocation of land to improved maize

Parameter	Coefficient	t-statistic	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	-0.0366	-0.1415	0.000293	-0.0248613	-0.0152745
EXPF	-0.0081	-1.4785	0	-0.0055	-0.00338
LAB	0.0676	2.4454**	0.0010007	0.04591862	0.02821188
EDVC	-0.0006	-0.02822	0	-0.00041	0.028512
WID	-0.0328	-0.7669	0.000236	-0.02228	-0.0136886
EXI	0.5345	2.1423**	0.06256064	0.36306956	0.223065864
VA1	0.3619	2.9126**	0.02868025	0.24582764	0.151033744
VA2	0.4959	3.9896*	0.05385103	0.336849756	0.206956711
AEZ1	-0.0683	-0.6142	0.0010215	-0.0463941	-0.028504
SIGMA	0.5024	12.2847*			
Number of samples			90		
Number of positive observations			79		
Proportion of positive observations			87.78		
Z-score			1.17		
f(z)			0.20121		
Log likelihood function			-61.171		
Restricted log of likelihood function (b=0)			33.9*		
χ^2 (8)			21.995		

Note: ** = significant at 5% level; * = significant at 1% level.

nonadopters (e.g., the probability of adopting improved maize varieties) with a unit change of independent variable δX_i. The log-likelihood ratio test was significant at the 1% level.

The significant variables were availability of labor, extension, and type of variety grown. The marginal effect of labor on the mean proportion of land allocated to improved maize varieties was 0.001, and labor increased the probability of adoption by 2.8%. A variety's characteristics had a positive and significant influence on the proportion of land allocated to improved maize. Farmers growing short-maturing varieties (Katumani and Kito) (VA1) and medium-maturing varieties (VA2) were more likely to allocate more land to improved maize varieties than farmers growing long-maturing varieties (VA3). The marginal effect of the short-maturing and medium-maturing varieties on the mean proportion of land allocated to improved maize varieties was 3% and 5%, respectively. The short-maturing and medium-maturing varieties increased the probability of adoption by about 15% and 21%, respectively. A unit increase in available labor among adopters increased the proportion of land allocated to improved maize by 5% and increased the probability of adoption by 3%. The marginal effect of extension on the mean proportion of land allocated to improved maize was 6%, and extension increased the probability of adoption by about 22%. Farmers in the intermediate zone were more likely to allocate land to improved maize varieties than farmers in the lowlands. The marginal effect of the lowlands zone on the mean proportion of land allocated to improved varieties was less by 0.1%. The probability that farmers would allocate land to improved maize was less by 2.8%. This result may be attributed to lowland farmers' reluctance to plant improved maize varieties that perform badly under drought stress.

7.4 Probit Analysis of the Use of Fertilizer

The probit model results on factors affecting the use of fertilizer are summarized in Table 24. The probit model was used because the responses on the use of inorganic fertilizer was binary (1 = if farmer used inorganic fertilizer for the past three years, 0 = otherwise). Establishing the quantity of fertilizer used per hectare was difficult because data were not available (McDonald 1980). In Table 24, the change in probability ($\delta Y/\delta X_i$) shows a change in the probability of using fertilizer given a unit change in the independent variable. The likelihood ratio test was significant at 0.001. The factor for correct prediction was 0.9. The inverse Mills ratio was not significant, indicating that the use of fertilizer was not directly related to use of improved seed alone. Although the inverse Mills ratio was not significant, the calculated probability that farmers who used improved seed would also use fertilizer was high. The use of improved seed increased the probability of using fertilizer by about 13%. The significant variable was the intensity of extension. An increase in extension intensity by one unit increased the probability of using fertilizer by 40%. Extension services were an important factor influencing farmers to use fertilizer for maize production.

Farmers in the intermediate zone were more likely to use fertilizer than farmers in the lowlands. Labor availability had a negative influence on fertilizer use. Farmers with more labor or wealth increased maize production through extensification, whereas farmers with less labor and wealth maximized output per unit area by intensification, including the use of fertilizer. The negative sign on group one and two varieties indicates that farmers growing short- and medium-maturing varieties were less likely to use fertilizer than farmers growing long-maturing varieties. The probability that farmers growing short- and medium-maturing varieties would use fertilizer was less by 21% and 29%, respectively.

Table 24. Probit model estimates for use of fertilizer

Parameter	Coefficient	t-statistic	$\delta Y/\delta X_i$
Constant	-6.7004	-2.8884**	-0.8388
EXPF	0.0304	1.111	0.0038
LAB	-0.2796	-1.5762***	-0.0351
EDVC	0.1271	0.9309	0.0159
WID	0.1442	0.8596	0.01806
EXI	11.1886	3.7374*	0.4007
IMR	1.0201	0.8015	0.1277
VA1	-1.6649	-1.5485***	-0.2084
VA2	-2.3381	-1.6004***	-0.2927
AEZ1	-3.3151	-0.5508	-0.00394
Number of samples	90		
Number of positive observations	59		
Proportion of positive observations	65.56		
R-squared	0.66		
Factor of correct prediction	0.9		
Log of likelihood function	-20.4558*		
Restricted log of likelihood function (b=0)	74.98		
χ^2 (9)	23.59		

Note: *** = significant at 10% level; ** = significant at 5% level; * = significant at 1% level.

8.0 Conclusions and Recommendations

8.1 Conclusions

This study has provided information on maize production in Eastern Tanzania, including varieties grown and preferred by farmers, maize management practices, and factors that can enhance adoption of improved maize. The information has some implications for priority setting and future research themes within maize research programs.

The mean age of farmers in the study areas was 45 years, with about 20 years of farming experience. The level of formal education averaged about six years in both zones. The sample households had about seven family members, including at least two male adults, two female adults, and three children. The number of male adults in lowland households was significantly higher.

Most farmers grew maize as a major cash and staple food crop. Many of the varieties currently grown were developed within the region. TMV1 and Staha are the most popular varieties, followed by Tuxpeño and Katumani. These varieties were preferred for their yield, tolerance to drought stress, and pest resistance (stalk borers were the most important field pests).

Land preparation and planting depended on rainfall. In areas with bimodal rainfall, maize planting extended from late September to January, whereas in areas with unimodal rainfall planting started in late February. Maize was planted in rows and most farmers used the recommended spacing. Maize fields were weeded at least twice, with the time of both weedings dependent on rainfall and the time of planting. However, most farmers weeded three weeks after planting (between January and March) and weeded a second time after the emergence of weeds (in April and mid-May). Maize was harvested mainly in June and July. In the bimodal rainfall areas, some maize was harvested in March.

The use of fertilizer for maize production was limited by high prices and marketing problems. The farmers who used fertilizer applied it only once, at planting or when the maize was knee-high. To increase soil fertility, some farmers plowed crop residues back into the soil or fallowed their land. Crop rotation was limited by land scarcity and farmers' lack of knowledge about the potential benefits of the practice.

Most farmers recycled their seed for up to five years, but others had recycled seed for 10-15 years. During the harvest, or when maize was being shelled, seed was selected for the next cycle on the basis of the size of the cob and maturity of the grain. Seed maize was stored separately food maize, mainly on cribs. Food maize was shelled and stored in gunny bags, on cribs, or in the *kihenge*. Most farmers treated stored maize with industrial chemicals to control storage pests.

Few farmers obtained credit to purchase agricultural inputs. Credit was used mainly to purchase fertilizer and farm implements, which have higher returns in the short and long term. Credit was not available from the formal sector and was difficult to obtain even in the informal sector, as suggested by most respondents. Lack of knowledge and bureaucratic procedures were the major constraints to obtaining credit.

Most farmers had received information on improved maize practices, which included improved seed, weeding, use of fertilizer, planting dates, pest management, and storage practices. Research and extension were important sources of information about improved production practices.

The two-stage least squares analysis showed that the availability of labor, extension intensity, and variety characteristics were significant factors affecting the proportion of land allocated to improved maize. Short-maturing and medium-maturing varieties increased the probability of allocating land at the means by about 15% and 21%, respectively. Labor and extension increased the probability of allocating land at the means by about 3% and 22%, respectively. Farmers in the lowlands have a 3% lower probability of allocating land to improved maize. An increase in the intensity of extension by one unit increased the probability of using fertilizer by 40%.

8.2 Recommendations

Both research and extension are important for the adoption of improved maize production practices, and farmers' characteristics have a more limited influence on adoption. Research needs to develop varieties and production practices that fit farmers' tastes and circumstances, and extension should be involved in testing and disseminating these technologies.

Research should focus on developing or screening varieties that yield well and tolerate drought stress and field pests, especially stalk borers. Flexible integrated pest management packages, which combine a drought tolerant variety with improved cultural practices, can increase yields. Low-cost technologies for controlling stalk borer and maize streak virus using cultural practices or environmentally friendly industrial chemicals should be developed.

Most improved varieties are responsive to fertilizer, and farmers usually obtain economic yields with fertilizer. Researchers should develop recommendations for fertilizer levels under various weather and soil conditions. Given that fertilizer use is constrained by high prices, an efficient marketing system for inputs and outputs will benefit farmers by paying higher prices for maize and reducing the cost of fertilizer. Such a system cannot be established without policy support from the government. Studies on the economics of seed and fertilizer use should also be undertaken, especially now that input and output markets have been liberalized.

Extension increases the adoption of improved maize varieties and fertilizer. Research and extension efforts need to be linked and strengthened to increase the flow of information to farmers. Along with finding ways to increase the productivity of farming systems, research and extension should focus on creating off-farm employment. Such employment could generate income to meet short-term demands for cash (to purchase fertilizer, for example).

In collaboration with the government and other stakeholders, the formal credit system needs to address the credit problems faced by small-scale farmers, especially their lack of knowledge (information) about formal credit and the bureaucratic procedures for obtaining credit. The formation of farmer groups should be encouraged, because lending to groups tends to reduce transactions costs and improve the rate of loan recovery.

References

Adesina, A., and M. Zinnah. 1992. 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 for the 12th Annual Farming System Symposium. East Lansing: Michigan State University. Pp. 443-466.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Mexico, D.F.: CIMMYT.

CIMMYT. 1993. The Adoption of Agricultural Technology: A Guide for Survey Design. Mexico, D.F.: CIMMYT.

Due, J.M. 1986. Summary of farming systems bean research in Tanzania, 1982-85. In: A.N. Minjas and M.P. Salema (eds.), Bean Research. Proceedings of the 4th Bean Research Workshop held at Sokoine University of Agriculture. Interpress of Tanzania Ltd. Pp. 146-151.

Feder, G., R.E. Just, and D. Zilberman. 1985. Adoption of agricultural Innovations in developing countries: A survey. Economic Development and Cultural Change 33(2):255-297.

FSD (Food Security Department). 1992. Comprehensive Food Security. Dar-Es-Salaam, Tanzania: Government of the United Republic of Tanzania and The United Nations Food and Agriculture Organisation (FAO).

FSD (Food Security Department). 1996. Tanzania Food Security Bulletin No. 2, April/May 1996. Dar-Es-Salaam, Tanzania: Ministry of Agriculture. Pp. 6-7.

Greene, W.H. 1993. Econometric Analysis. 2nd Edition. New York: MacMillan.

Griffiths, W.E., R. Carter-Hill, and G. Judge. 1993. Learning and Practicing Econometrics. New York: John Wiley.

Hotland, G. 1993. Ecological sustainability and economic viability of smallholder zero-grazing system in de-stocked (mvumi) semi-arid Tanzania. Paper presented at the Workshop on Sustainable Livestock Based Systems in Semi-Arid Areas, 27-28 September 1993, Arusha, Tanzania.

Kimhi, A. 1994. Quasi maximum likelihood estimation of multivariate models: Farm couplesí labor participation. American Journal of Agricultural Economics: 828-835.

Mbiha, E.R. 1993. Effects of government intervention in maize production and marketing: Implications for agricultural marketing and price liberalization in Tanzania. Agricultural Economics Analysis and Rural Development 3(2).

McDonald, J.F, and R.A. Moffit. 1980. The uses of tobit analysis. The Review Of Economics and Statistics 62:318-321.

McFadden, D. 1981. Econometric models of probabilistic choice. In C.F. Manski and D. McFadden (eds.), Structural Analysis of Discrete Data with Econometric Applications. Cambridge, Massachusetts: MIT Press. Pp. 198-272.

Mdadila, J.M. 1995. Industry Review of Maize, Rice and Wheat, 1993/94. Dar Es Salaam: Marketing Development Bureau (MDB), Ministry of Agriculture, Tanzania. Pp. 23-32.

Misra, S.K., D.H. Carley and S.M. Fletcher. 1993. Factors influencing southern dairy farmers' choice of milk handlers. Journal of Agricultural and Applied Economics, July 1993:197-207.

Moshi, A.J., Z.O. Mduruma, N.G. Lyimo, W.F. Marandu, and H.B. Akonnay. 1990. Maize breeding for target environments in Tanzania. In A.J. Moshi and J.K. Ransom (eds.), Maize Research in Tanzania: Proceedings of the First Tanzania National Maize Research Workshop. Dar-Es-Salaam, Tanzania: TARO. Pp. 11-16.

Nkonya, E.M. 1994. Adoption of the Sasakawa-Global 2000 Maize Production Package in the Marginal Areas of Northern Tanzania. MSc thesis, Kansas State University, College of Agriculture, Department of Agricultural Economics, Manhattan, Kansas.

Saha, A., H.A. Love, and R. Schwart. 1994. Adoption of emerging technologies under output uncertainty. American Journal of Agricultural Economics, November 1994:836-846.

Tobin, J. 1958. Estimation of relationships for limited dependent variables. Econometrica 31: 24-36.