Adoption of Maize Production Technologies in Central Tanzania

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Abstract: This study of the adoption of maize production technologies in Central 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 grouped by agroecological zone: the lowlands, intermediate zone, and highlands. A two-stage least squares procedure was used to analyze factors affecting farmers' allocation of land to improved maize varieties and use of inorganic fertilizer across zones. Germplasm characteristics, production potential of the area, and extension were the most important factors affecting the amount of land allocated to improved maize and use of inorganic fertilizer. Later maturity in a variety increased the probability that a farmer would plant improved maize by about 22%. Extension increased the probability of allocating land to improved maize by about 14% and increased the probability of using fertilizer by 115%. Several issues require closer attention from research, extension, and policy makers. Research and extension efforts need to be linked and strengthened to increase the flow of information to farmers. In developing improved maize varieties, researchers must consider yield as well as other important traits: drought resistance/tolerance, resistance to storage pests, shelling quality, and taste. For this to occur, farmers must participate in the research process. The formal credit system needs to be altered to address the credit problems faced by small-scale farmers. A more efficient marketing system for inputs and outputs would benefit farmers by providing higher maize prices and reducing fertilizer costs. 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.

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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)
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
P-values	Standard normal probability
SA	Sulfate of ammonia
SACCAR	Southern Africa Centre for Coordination of Agricultural Research
SG-2000	Sasakawa-Global 2000
St	Streak resistant
STD	Standard deviation
TANSEED	Tanzania Seed Company
TMV	Tanzania Maize Variety
Tsh	Tanzanian shillings
TSP	Triple super phosphate
UCA	Ukiriguru Composite A

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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 Programme (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.

This report forms part of a larger study to evaluate the impact of maize research and extension in Tanzania 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 Central Zone. Survey data were grouped into three agroecological zones: the lowlands, intermediate zone, and highlands, representing Kondoa, Singida, and Mpwapwa, respectively. These are the most important maize production zones and therefore the most important categories for the analysis. A two-stage least squares procedure was used to analyze factors affecting farmers' allocation of land to improved maize varieties and use of inorganic fertilizer.

Most maize research in the Central Zone is undertaken at Ilonga Research Institute. The zone usually receives verification and on-farm demonstration trials supervised by extension agents. The major varieties found in the area were open pollinated materials, such as Staha, UCA, TMV1, Kilima, ICW, and Tuxpeño. Few farmers grew hybrids such as H622, CG4141, and CG4142.

The mean age of the household head was 43 years, with an average farming experience of about 19 years. Farmers' levels of formal education were low, averaging about five years. Households averaged about ten persons, with at least three permanent workers. Most farmers kept livestock, generally cattle, sheep, and goats. The hand hoe was the major farm tool used in the study area. Animal power was used by about 30% of the farmers, concentrated in the intermediate zone and highlands. Hiring of tractors was relatively common in the lowlands, where extensive maize production was practiced. Land was not a limiting factor in the farming system.

Farmers in the lowlands and intermediate zone recycled maize seed for five to eight years; those in the highlands recycled seed for eight to ten years. Seed was selected during the harvest or when maize was shelled for storage, and selection was based on the size of the cob. Most of the selected cobs were shelled, and the seed was treated with chemicals and/or ash and stored in gunny bags. Maize was shelled and stored in a local container called a *kihenge*. The majority of farmers in the three zones treated their maize before storage.

The few farmers who obtained credit from the informal sector used it to purchase farm inputs such as fertilizer. No farmers obtained credit from the formal sector because they lacked knowledge (information) about formal credit and found the procedures long, cumbersome, and bureaucratic.

The Training and Visit (T&V) extension system was used in all villages covered by this study. Research and extension were farmers' major sources of information on agricultural production. Most farmers had received information on improved maize varieties, planting methods, and weed management. Very few farmers had received information on disease control measures and pest management.

Maize remains an important crop in the farming system. The expansion of cultivated area has gone hand-in-hand with a greater allocation of land to maize production. However, the entry of improved maize varieties into the farming system has been slow, especially in Kondoa District where extensive maize production was practiced. Some farmers have tested and rejected some improved maize varieties. Kilima, Katumani, CG4142, and Tuxpeño were rejected by some farmers in Singida, Kondoa, and Mpwapwa Districts, respectively, because of the materials' low yields, susceptibility to storage pests and diseases, and poor shelling quality.

The most popular maize varieties were Kilima, TMV1, and Staha in the intermediate zone, Staha and TMV1 in the lowlands, and Staha, TMV1, and Kilima in the highlands. The reasons for these preferences were (in order of importance) high yield, drought resistance, and resistance to storage pests. However, most farmers grew CG4142 hybrid because seed was available.

The adoption of recommended management practices depended on the cost of the practice. Most farmers adopted row planting, the cheapest technology, while they did not adopt control of field pests and diseases because of the high cost.

The two-stage least squares analysis showed that variety characteristics, production potential of the area, and extension were the most important factors affecting the amount of land allocated to improved maize varieties and the use of inorganic fertilizer. Later maturity in a variety increased the probability that a farmer would plant improved maize by about 22%, while early and intermediate maturity varieties increased the likelihood of adoption by about 17% and 13%, respectively. Extension increased the probability of allocating land to improved maize by about 14% and increased the probability of using fertilizer by 115%. Farmers in the lowlands were less likely to use fertilizer, probably because maize varieties responded less to fertilizer in low rainfall areas.

Both research and extension are important for adoption of improved maize practices. Farmers' characteristics have a limited influence on the adoption process. Technical innovation characteristics and external influence are the major factors affecting adoption. Research needs to develop varieties that fit farmers' tastes and circumstances, and extension should be involved in testing and disseminating these technologies. 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 maize streak virus, 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 farmers' lack of knowledge. 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.

In developing improved maize varieties, apart from increasing yields, other factors should be taken into consideration. These factors include drought resistance/tolerance, resistance to storage pests, shelling quality, and taste. For this to occur, farmers must participate in the research process. Research and extension efforts need to be linked and strengthened to increase the flow of information to farmers. 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) of 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 improve the rate of loan recovery.

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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. 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. 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. 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 a considerable impact in increasing food production. This study was conducted to evaluate that impact 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 Center (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 from the Central 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

Figure 1 shows the location of the Central zone in Tanzania. The Central Zone comprises Dodoma and Singida administrative regions, which are part of the semi-arid zone. Rainfall in the area is erratic. About 85% of the rain falls between January and March. Rains generally fall in short intervals and average 600 mm per annum.

The vegetation of the Central Zone can be categorized into four groups: bushland, woodland, wooded grassland, and grassland. Topographically, the zone is characterized by plains with scattered inselbergs, ridges, or rows of hills. The region's economy depends entirely on crop production and livestock. Agriculture is still characterized by low productivity. Although livestock production is still largely a subsistence enterprise, the Central Zone is one of the principal livestock-producing areas in the country.

It is difficult to classify the zone into distinct, contiguous agroecological areas using altitude and rainfall as criteria because of the undulating topography and varying rainfall. However, four major farming systems can be identified: the maize and groundnut system; the sorghum, pearl millet, and groundnut system; the rice farming system; and the peri-urban livestock production system.

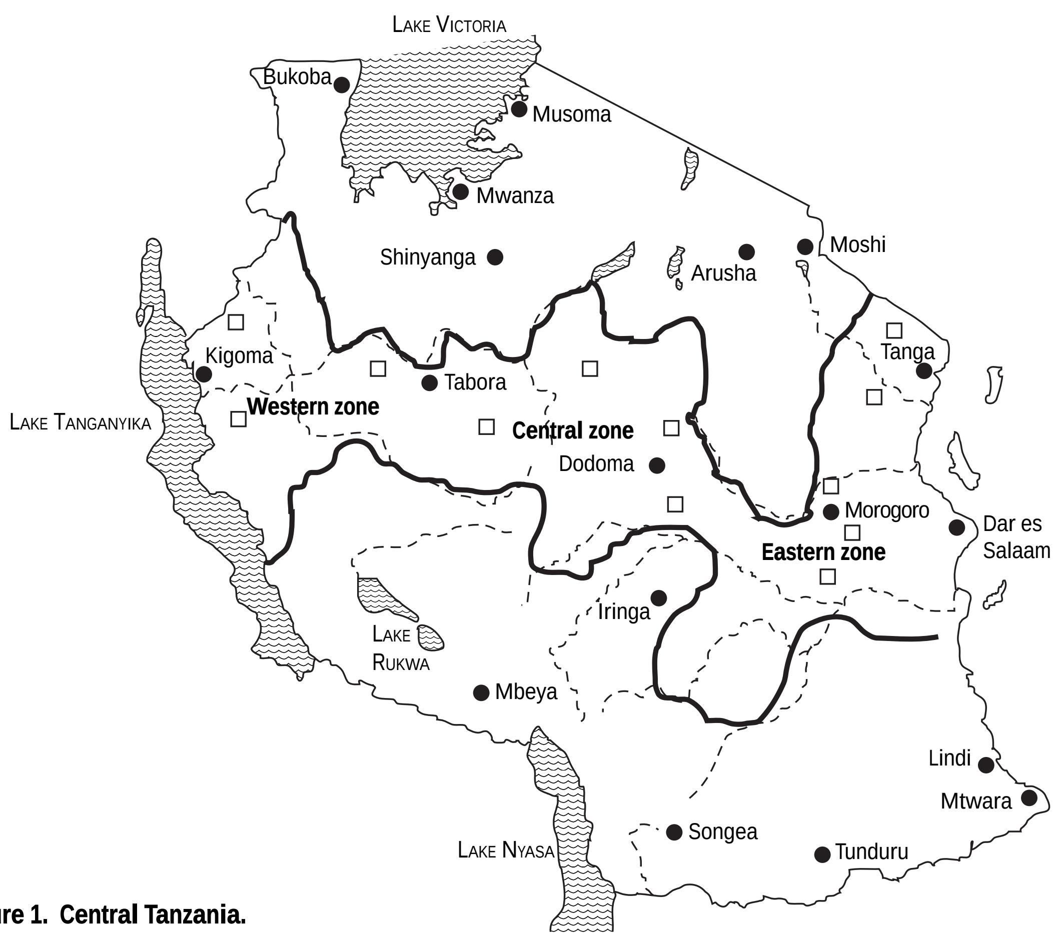

Figure 1. Central Tanzania.

Maize and groundnut farming is found in the northern and northwestern part of the zone and covers most of Iramba District, the Kondoa lowlands, and northeastern Mpwapwa District. Annual rainfall surpasses 750 mm. Major crops, in order of importance, are sorghum, pearl millet, maize, and natural pastures and forages. Minor crops, in order of importance, include oilseeds (sunflower and *simsim*), cassava, sweet potatoes, finger millet, and horticultural crops (mainly onions and tomatoes).

The **sorghum, pearl millet, and groundnut farming system** covers most of the central and western part of the Central Zone. Elevation ranges from 500 masl to 1,000 masl, and annual rainfall is between 400 mm and 600 mm. Major crops, in order of importance, are maize, grain legumes, tubers (cassava and sweet potatoes), finger millet, and natural pastures and forages.

Irrigated rice production is found inside the west lift valley, in some valley bottoms with black cotton soils, and along permanent rivers. Rainfall is between 500 mm and 800 mm per year. The major crops, in order of importance, are sorghum and pearl millet. Minor crops, in order of importance, are maize, grain legumes, roots, tubers (cassava and sweet potatoes), and horticultural crops (onion).

Peri-urban livestock production systems are found in all peri-urban areas (around Dodoma, Singida, Kondoa, Mpwapwa, and Manyoni townships). Major crops, in order of importance, are improved pastures and forages for zero-grazing, maize, and grapes (specialty crops for Dodoma). Minor crops, in order of importance, include grain legumes, watermelons, and sunflowers.

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 in a given zone. About 1,000 maize farmers were interviewed nationwide. Central Zone was allocated 54 farmers, approximately 5% of the national sample.

Central Zone farmers were sampled from districts that are important for maize production. Production figures from the statistical unit of the Ministry of Agriculture (MOA) were used to establish the relative importance of each district for maize production. Three districts were purposively selected for the Central Zone survey, and three villages were randomly selected from these districts. The selected sites were:

- Ihanda Village, located in Mpwapwa District, which is characterized by relatively high rainfall and elevation, and has high potential for maize production
- Mudida Village, located in Singida Rural District, which is characterized by medium rainfall and medium elevation and has a medium potential for maize production
- Mwailanje Village, located in Kondoa District, which is characterized by low rainfall and low elevation and has low potential for maize production

From each village, 18 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 structural 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 squares analysis is used to test factors affecting the 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 = the proportion of maize area allocated to improved maize varieties or adoption of inorganic fertilizer;

β = the parameters 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+AEZ3+ε_i

FERT = A+EXP+EDVC+WID+EXI+LAB+IMR+VA1+VA2+VA3+AEZ1+AEZ2+AEZ3+α_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).
AEZ1-3	=	lowland, intermediate, and highland zones (AEZ1=1 if the farmer is in the lowlands, AEZ1=0 otherwise). The highland zone (AEZ3) 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 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 Central Zone. These indicators were aggregated by calculating the wealth index (WID) as follows:

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

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 farmer knows from the improved technology package (i.e., improved seed, row planting, fertilizer application, ox-plowing, 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). Both models were estimated using TSP, Version 4.3.

2.0 Maize Research and Development in Tanzania and the Study Area

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 midalatitude) 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) disease, 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. TMV2 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 hybrids CG4141 and CG4142 are multiplied and distributed by Cargill Hybrid Seed Ltd., which is based in Arusha. About 72% of the farmers in the lowland and intermediate zones grew CG4142, whereas only 22% of the farmers in the highlands grew CG4142. The locally bred hybrids H622 and H632 are not grown by farmers in Central Tanzania, even though they have flint grain and good pounding and storage qualities, and yield as well as CG4141 and CG4142. Locally bred hybrids are marketed mainly by the Tanzania Seed Company (TANSEED), which has not done well in the newly competitive seed industry. This has contributed to the lack of adoption of locally bred hybrids in Central Tanzania. Before input markets were 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 grain 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 has led to 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 Production Technology Recommendations

2.3.1 Varieties

Maize production recommendations were developed to fit the three agroecological zones described earlier. Several OPVs developed in Tanzania and Kenya have been introduced in the midaltitude and low altitude zones of central Tanzania: Staha, UCA, Katumani, TMV I, Kito, Kilima, ICW, and Tuxpeño. Three hybrids have been introduced for these zones: H522, CG4141, and CG4142. Table 1 shows the yield potential and attributes of some of the materials recommended for the Central Zone.

2.3.2 Planting time, planting method, and spacing

The recommended planting time in Central Zone is after the rains begin, which usually occurs in November and December. It is recommended that maize flowering should occur when there is less moisture. Row planting is recommended to achieve the desirable plant population. Spacing depends on the maturity of the variety. Medium maturity and full-season varieties should have a spacing of 90 cm x 50 cm and two plants per hill, or 75 cm x 60 cm and two plants per hill, for a population of 44,444 plants/ha. Spacing also depends on the time to maturity of the variety grown. Early maturing varieties, such as Katumani, should be spaced like the medium maturity varieties, but farmers should have three plants per hill for a population of 66,666 plants/ha.

2.3.3 Fertilizer type, timing, and method of application

To provide nitrogen (N) one can either use urea, calcium ammonium nitrate (CAN), or sulfate of ammonia (SA). Nitrogen may be split into two applications, with 30-50% of the total amount being applied at planting and the remainder when maize is about one meter high.

Table 1. Commercial maize varieties and their yield potential, Central Tanzania

Variety	Major attributes	Target zone	Potential yield (t/ha)
TMV-1	Streak resistant, medium maturity, yield	Low, medium	4.25
Staha	Streak tolerant, yield	Lowlands	4.00
Tuxpeno	Good standability	Lowlands	3.75
Kito	Early maturity	Lowlands	2.50
Kilima	Good standability, yield	Medium	4.5–6.25
CG4141	High yielding, resistant to leaf and cob disease	Low, medium	4.5–6.25
H614	High yielding, takes 120–180 days to mature	High, intermediate	5.0–7.0
H6302	High yielding takes 180 days to mature	Low, intermediate	6.0–8.0

Table 2 summarizes the fertilizer recommendations for maize by agroecological zone. For low altitude areas, 40 kg N/ha is recommended. For areas receiving more than 800 mm of rainfall per annum, a rate of 80-112 kg N/ha is recommended. Phosphorus (P) is deficient throughout the zone, and triple super phosphate (TSP) is recommended as basal fertilizer. The amount recommended is up to 40 kg P_2O_5/ha. Fertilizer is normally placed 5 cm below the depth of the seed and about 5 cm to the side. This is accomplished by digging a single hole beside each seed and 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 then planted on top of this soil and covered properly.

Table 2. Fertilizer recommendations for maize by altitude, Central Tanzania

		Optimum fertilizer rate (kg/ha)	
Altitude (masl)	**Rainfall**	**N**	**P_2O_5**
0–900	Low	0–20	0–20
900–1,500	Medium	20–100	20–40
>1,500	High	20–50	20–40

2.3.4 Weed control

In all agroecological areas of the Central Zone, two weedings are recommended. The first weeding should be done two weeks after germination and the second weeding at three to four weeks after the first weeding. Weeding is usually done with a hand hoe.

2.3.5 Pest and disease control

Important maize pests in the Central Zone include armyworms and stalk borers. Armyworms are serious when an outbreak occurs, but stalk borers are a serious problem for off-season maize production. Thiodan can be applied against all pests.

The breeding programs have been releasing varieties that are resistant or tolerant to the most important maize diseases, so there is no recommendation for chemical control against maize diseases. Maize streak virus is not yet important in the Central Zone.

2.3.6 Harvesting and storage

Maize is harvested by hand immediately after it is mature and dry. Most maize is stored in gunny bags as well as the traditional storage structure (*vilindo*). The important storage pests are maize weevils, and Actellic Super is the recommended for controlling them.

3.0 Demographic and Socioeconomic Characteristics in the Study Area

3.1 Demographic Characteristics

Table 3 summarizes the household characteristics of sample farmers in the Central Zone. The mean age of household heads in the study area was 43 years. Farmers in the lowlands tended to be younger than those in the other two zones, although the age difference was not significant ($p = 0.05$). On average farmers have lived in the sampled villages for about 23 years, and their farming experience was about 19 years. The level of education for household heads was about five years and no significant difference was found among the agroecological zones.

The average size of the households was about 10 members, including three male adults, two female adults, and five children. The number of female adults in the lowlands was significantly lower ($p = 0.05$) than in the other two zones. At least three male adults and two female adults worked on the farm permanently, although a few respondents indicated that some household members worked off of the farm. Those who worked off of the farm were temporarily or permanently employed by the government or non-governmental organizations (NGOs). The minimal number of part-time workers and off-farm activities is an indication of the limited off-farm opportunities in the study area.

Farmers who did have some off-farm income used the money to purchase farm inputs and capital goods such as hand hoes and plows (75%) and to meet other family needs (25%).

3.2 Land Resources and Allocation

The average farm size in the lowlands was about 62 acres, while the intermediate zone and highlands had an average farm size of about 20 and 25 acres, respectively. Shifting cultivation was widely practiced in the lowlands, since the population density was still low. There was a significant difference ($p = 0.05$) between the lowland zone and the intermediate and highland zones, respectively. Cultivated area was about 41 acres in the lowlands, 18.9 acres in the intermediate zone,

Table 3. Demographic characteristics of sample households, Central Tanzania

	Lowlands		Intermediate zone		Highlands		P-values		
Mean of	**Mean**	**STD**	**Mean**	**STD**	**Mean**	**STD**	**L/M**	**L/H**	**M/H**
Age of household head (yr)	41.8	12.7	44.8	14.4	43.7	13.0	NS	NS	NS
Number of male adults	2.2	1.4	3.2	1.3	3.3	2.8	NS	NS	NS
Number of female adults	1.5	0.8	2.9	1.9	3.3	1.7	0.05	0.05	NS
Number of children	2.7	1.6	5.4	3.5	4.2	4.6	NS	NS	NS
Education of household head (yr)	4.7	3.2	5.3	2.4	5.1	3.1	NS	NS	NS
Farming experience (yr)	17.3	6.2	19.2	12.6	22.6	11.6	NS	NS	NS

Note: NS = not significant; L/M = lowlands/intermediate zone; L/H = lowlands/highlands; M/H = intermediate zone/highlands; STD = standard deviation.

and 21.2 acres in the highlands. Farmers had 2.0 plots in the lowlands, 3.4 in the intermediate zone, and 3.3 in the highlands. A significant difference ($p = 0.05$) was found between the number of plots in the lowlands and in the intermediate and highland zones, respectively. Across all three zones, only small portions of land were rented in (2 acres) and rented out (0.8 acres). Rented land was found in valley bottoms that were wetter and suitable for growing vegetables.

In all zones, more than 60% of cultivated land was allocated to maize production. Figures 2–4 show trends in total farm size and maize area over the past 20 years. In all zones, the importance of maize in the farming system has remained stable. Maize area increases have been proportional to increases in total farm size. Because of changes in tastes and preferences, maize replaced the traditional sorghum and millet crops as a major food and cash crop. In the intermediate zone, sample farmers started growing improved maize varieties in the mid-1980s. Lowland and highland zone farmers started doing so earlier, in the mid-1970s.

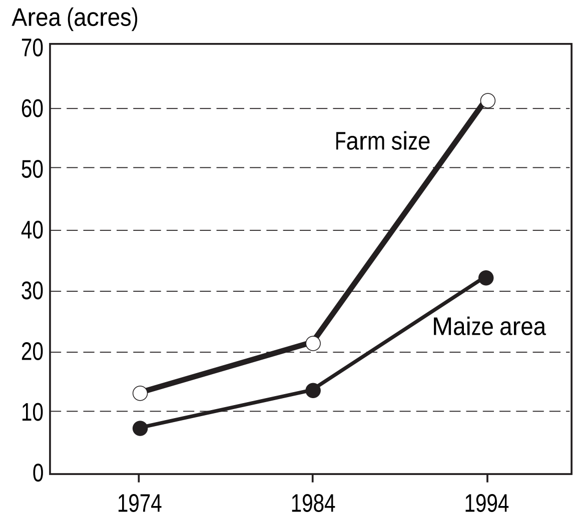

Figure 2. Trends in farm size and maize area, lowlands, Central Tanzania.

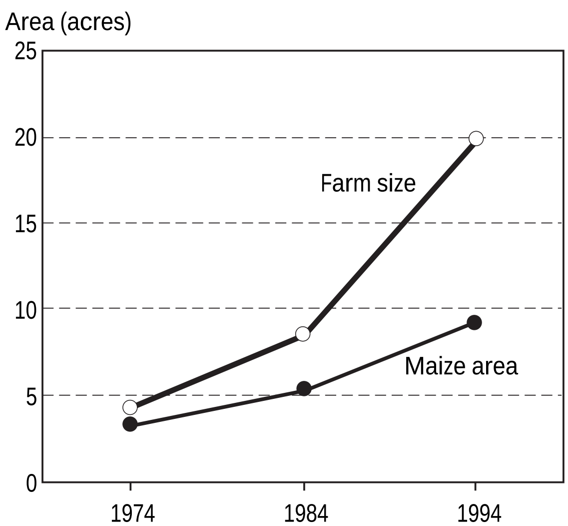

Figure 3. Trends in farm size and maize area, intermediate zone, Central Tanzania.

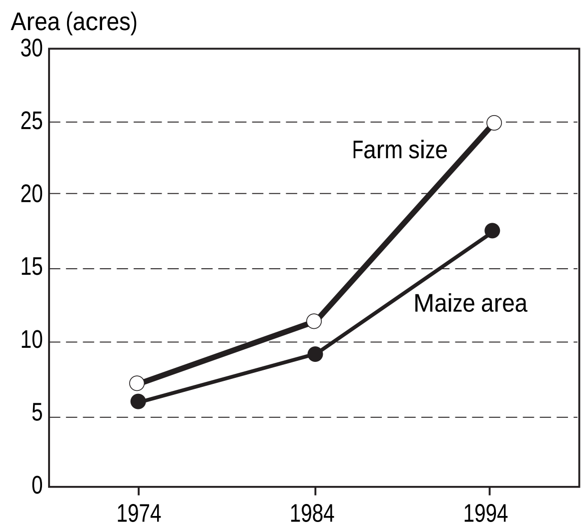

Figure 4. Trends in farm size and maize area, highlands, Central Tanzania.

Drought has affected maize production trends, prices, and incentives to produce the crop. The drought that occurred in the late 1970s caused maize prices to increase sharply, and more land was allocated to maize production. Farmers reduced the land allocated to maize during the mid- and late 1980s, mainly because of low maize prices and the inability of the Dodoma Region Cooperation Union to buy maize from the farmers. In the early 1990s, maize production increased sharply, perhaps as a result of trade liberalization, which occurred at that time, and as a result of the increase in the price of maize.

3.3 Livestock Ownership

Farmers in the intermediate zone had the highest livestock population in the Central Zone. The mean number of livestock for the sample households was 13 head of cattle, two sheep, and seven goats. Table 4 shows numbers of livestock by zone. The farmers in the intermediate zone had a significantly higher number of sheep ($p = 0.05$) than farmers in the lowland zone.

3.4 Farm Mechanization

Table 4 shows the number of farm tools owned by farmers. The number of hand hoes was highest in the highland zone. Other farm equipment, such as machetes, axes, and knives, averaged at least one per household. In all zones, few respondents owned tractors or carts, but tractor hire was reported by 5.6% of respondents in the intermediate zone and 22.2% in the lowlands. Eleven percent of the respondents in the lowlands and highlands reported hiring plows. Animal traction was more common in the intermediate zone than in the lowlands and highlands. Tractors and plows were hired mainly for land cultivation.

Table 4. Numbers of livestock and farm tools owned by sample households in Central Tanzania

	Lowlands		Intermediate		Highlands		P-values		
	Mean	STD	Mean	STD	Mean	STD	L/M	L/H	M/H
Animals									
Goats	7.5	7.1	10.6	9.4	7.0	9.8	NS	NS	NS
Sheep	0.3	0.8	4.7	5.1	1.4	2.9	0.05	NS	NS
Cattle	10.6	13.6	16.9	11.8	17.7	22.6	NS	NS	NS
Farm tools									
Hand hoe	3.9	1.8	4.8	3.4	8.5	7.6	NS	NS	NS
Ox-plow	1.7	0.6	2.0	0.8	2.0	1.1	NS	NS	NS
Cutting equipment	1.0	0.0	1.7	0.6	2.25	0.5	NS	0.05	NS
Cart	1.0	1.4	1.1	0.3	1.0	0.0	NS	NS	NS
Tractor	1.0	1.0	1.0	—	1.0	0.7	NS	NS	NS

Note: NS = not significant; STD = standard deviation.

4.0 Maize Production, Crop Management, and Marketing in the Study Area

4.1 Crops and Cropping System

Maize was planted mainly as a monocrop in the lowlands (78% of farmers), intermediate zone (58%), and highlands (76%). In the lowlands, maize was intercropped with beans, cowpeas, and pigeonpeas or mixed with bulrush millet to spread risk. A maize/pigeonpea cropping system was more common in this zone. In the intermediate zone, maize was mainly intercropped with cowpeas or mixed with sunflowers (the maize/sunflower cropping system was more common). In the highlands, maize was intercropped with groundnuts and cowpeas. Intercropping was practiced mainly to save labor (constrained by land scarcity) and to spread risk. Table 5 shows the various cropping systems in the three zones.

4.2 Maize Crop Management Practices

4.2.1 Land preparation methods

In the highlands, land preparation starts in November and ends in January to take advantage of the November-January short rains. However, in the intermediate zone and the lowlands, 90% and 67% of the respondents, respectively, reported that they began land preparation in September-October and ended it in November.

Table 6 shows the different methods of land preparation for all zones. Lowland and highland farmers most often used hand hoes to prepare land. Intermediate zone farmers generally relied on ox-plows to prepare their land.

4.2.2 Seedbed type, planting pattern, and weeding

All farmers used flat seedbeds, a practice attributed to the type of tools used in land cultivation and farming. The use of the hand hoe and shifting cultivation does not encourage ridging because of the high labor requirements.

Table 7 shows farmer's major agronomic practices. In the 1994 maize season, the majority of lowland and intermediate zone farmers planted maize in December, and the majority of highland

Table 5. Maize cropping systems in the three major agroecological zones of Central Tanzania

	Lowlands		Intermediate zone		Highlands	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Monocropped maize	14	82.4	10	58.8	13	81.3
Intercropped maize	3	17.6	7	41.2	3	18.8
Reasons for intercropping						
Save labor	1	25.0	2	40.0	4	57.1
Land scarcity	2	50.0	–	–	2	28.6
Spread risk	1	25.0	3	60.0	1	14.3

Table 6. Timing and method of land preparation for maize, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Timing of land preparation						
August–October	8	47.1	12	66.9	4	25.1
November	4	23.6	4	22.3	9	56.4
December	4	23.6	1	5.6	3	18.8
January	1	5.9	1	5.6	–	–
Method of land preparation						
Hand hoe	8	50.0	5	31.3	7	41.2
Ox-plow	2	12.5	7	43.8	1	5.9
Tractor	2	12.5	–	0.0	2	11.8
Hand hoe and oxen	2	12.5	3	18.8	6	35.3
Zero tillage	2	12.5	–	0.0	–	0.0

Table 7. Farmers' major agronomic practices for maize, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Planting time						
November	3	16.8	5	27.8	–	–
December	8	44.6	9	50.1	5	27.9
January	7	38.9	3	16.8	12	66.7
February	–	–	1	5.6	1	5.6
Planting method						
Row	18	100.0	18	100.0	15	88.2
Random	0	0.0	0	0.0	2	11.8
Reasons for row planting						
Ease of field management	15	93.8	11	73.3	8	47.0
Increase yields	–	–	2	13.3	4	23.5
Advised by extension	–	–	2	13.3	5	29.4
Spacing between rows						
Use recommended spacing	11	68.8	9	64.3	5	35.7
Use other spacing	5	31.2	5	35.7	9	64.3
Spacing between hills						
Use recommended spacing	13	81.3	10	71.5	9	64.3
Use other spacing	3	18.7	4	18.5	5	35.7
Time of first weeding						
November	–	–	1	6.3	–	–
December	3	16.7	8	50.0	1	5.6
January	8	44.4	4	25.0	14	77.8
February	7	38.9	2	12.5	2	11.1
March	–	–	1	6.3	1	5.6
Time of second weeding						
January/December	–	–	1	15.4	–	–
February	7	77.8	8	61.5	11	73.3
March	2	22.2	3	23.1	3	20.0
April	–	–	–	–	1	6.7
	Number of farmers	**Mean**	**Number of farmers**	**Mean**	**Number of farmers**	**Mean**
Number of seeds/hill	18	2.2	17	2.2	16	2.1
Frequency of weeding	18	2.0	18	2.0	18	2.2

farmers planted later, in January. Most farmers planted maize in rows, although 12% of the farmers in the highlands did not. The major reason for row planting was to ease the management of maize fields.

Most farmers in the intermediate zone and lowlands used the recommended spacing between rows and hills, although only 36% of farmers in the highlands did so. On average, all households planted the recommended number of two seeds per hill. Most farmers in all zones weeded twice, as recommended. The time of weeding depended on the onset of the rains and the presence of weeds in the field. The first weeding was mostly done between January and February, while the second weeding was done between February and March.

4.2.3 Type of fertilizer, method of application, and quantity

Inorganic fertilizer was used by 16.7% of lowland farmers, 76.5% of intermediate zone farmers, and 16.7% of highland farmers. Most farmers used urea or CAN. The use of inorganic fertilizer was constrained by cost and lack of knowledge. No farmer used fertilizers regularly, and fertilizer was applied only to parts of the field where maize had symptoms of N deficiency (Table 8).

4.2.4 Fallowing and crop rotation

In the lowlands about 39% of farmers fallowed their land, while only 18.9% of intermediate zone farmers and 5.9% of highland farmers practiced fallowing (Table 9). This result is not surprising, given that farmers in the lowlands have larger farms. The major reason for leaving land fallow was to replenish soil fertility, and land shortages were the major constraint on fallowing. Maize and wheat were grown immediately after the fallow cycle because farmers felt that those crops needed more fertile soils and generated higher returns.

Table 8. Use of fertilizer by sample households, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Use inorganic fertilizer (IF)	3	16.7	13	76.5	3	16.7
Use organic fertilizer	3	16.7	13	72.2	4	22.2
Reason for not using IF						
Expensive	2	10.0	7	35.0	1	5.0
Destroys soil	0	0.0	1	5.0	1	5.0
Lack of knowledge	1	5.0	2	10.0	2	10.0
Soil fertile enough	1	5.0	0	0.0	2	10.0

Table 9. Fallowing and crop rotation by sample households, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Fallow	7	38.9	3	18.8	1	5.9
Crop rotation	10	58.8	14	82.4	6	33.3

About 59% of the farmers in the lowlands, 82.4% in the intermediate zone, and 33.3% in the highlands rotated crops to add fertility to the soil and break disease and pest cycles (Table 9). The major reason for not practicing crop rotations was farmers' lack of awareness of the potential benefits.

4.2.5 Crop residue management

Farmers who did not apply fertilizer or used only a small amount were advised to avoid soil mining by plowing crop residues back into the soil. About 67% of the farmers in the lowlands followed this recommendation, compared to 17.6% and 12.5% in the intermediate zone and highlands (Table 10). About 82% and 87% of farmers in the intermediate zone and highlands reported grazing their cattle on maize stover left in the field.

4.2.6 Pest and disease control

Field pests, diseases, and control methods are summarized in Table 11. Stalk borers were the most important pest. The lowlands and intermediate zone were the most affected by stalk borer (78% of respondents, compared to 22% of highland respondents). Other pests mentioned by farmers in the

Table 10. Management of crop residue by sample households, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Plow residues under	10	66.7	3	17.6	2	12.5
Feed residues to cattle	5	33.3	14	82.4	14	87.5

Table 11. Major maize pests and diseases and their control, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Pest						
Stalk borers	14	77.8	14	77.8	4	22.2
Cutworms and termites	0	0.0	1	5.6	1	5.6
Vermin	1	5.6	0	0.0	1	5.6
None	3	16.7	3	16.7	12	66.7
Pest control method						
Thiodan	0	0.0	1	5.6	0	0.0
DDT	3	16.7	2	11.1	1	5.6
Local method	0	0.0	1	5.6	0	0.0
None	15	83.3	14	77.8	17	94.4
Disease						
Maize streak virus	1	5.6	0	0.0	3	16.7
Cob rot	3	16.7	2	11.1	0	0.0
Smut	0	0.0	0	0.0	1	5.6
None	14	77.8	16	88.9	14	77.8
Disease control method						
Chemicals	0	0.0	1	5.6	0	0.0
None	18	100.0	17	94.4	18	100.0

highlands were vermin, cutworms, and termites. DDT was used to control field pests in all districts of the lowlands and highlands. Thiodan and local control methods were used by only a few respondents from the intermediate zone.

Maize streak virus was reported in the lowlands and highlands by 5.6% and 16.7% of respondents, respectively. Cob rot was reported by about 17% and 11% of the respondents from the lowlands and intermediate zones, respectively. Only one farmer in the intermediate zone used chemicals to control diseases.

4.3 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 crops were harvested in June and July (Table 12). Most farmers used ox-carts to transport maize to the homestead (other methods included bicycles and pick-up trucks). About 94% of the farmers in the lowlands stored their maize in gunny bags, while the majority of farmers in the other zones (66.7% in the intermediate zone, 91.7% in the highlands) shelled the maize and stored the grain in a local container (*kihenge*). The majority of farmers in the three zones treated their maize before storing it. Storage losses without treatment could be substantial. Treatment with Actellic Super was the most common method of controlling storage pests (94% of lowland farmers and 88% of highland farmers). The most common control method in the intermediate zone was the use of ash or other local materials (56% of farmers).

4.4 Seed Selection and Recycling

About 90% of farmers in the intermediate zone and highlands selected seed at home, while 44.4% of lowland farmers selected seed in the field (Table 13). The most important criterion for selecting seed for the next season was the size of the maize cob. Most selected seed was shelled, treated, and stored

Table 12. Maize harvesting, transport, and storage, Central Tanzania

Practice	Lowlands		Intermediate zone		Highlands	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Harvesting time						
May	1	5.6	0	0.0	0	0.0
June	9	50.0	5	27.8	4	22.2
July	8	44.4	12	66.7	12	66.7
August	0	0.0	1	5.6	1	11.1
Transportation method						
Bicycle	0	0.0	1	5.6	0	0.0
Ox-cart	15	93.8	17	94.4	18	100.0
Pick-up truck	1	6.3	0	0.0	0	0.0
Maize storage						
Shell and store in *kihenge*	1	6.3	8	66.7	11	91.7
Cribs	0	0.0	1	8.3	0	0.0
Gunny bags	15	93.8	3	25.0	1	8.3

in gunny bags. Farmers said that commercial seed was also readily available, and they bought it from wither stockists or other farmers.

Varying numbers of farmers in each zone said they purchased improved maize seed regularly (23% in the lowlands, 14% in the intermediate zone, and 57% in the highlands). Farmers in the lowlands reported that they recycled seed for five to eight years; intermediate zone and highland farmers said they recycled seed for eight to ten years.

4.5 Maize Cropping Calendar for the Central Zone

Table 14 presents the maize cropping calendar for the Central Zone. Labor demand peaks twice during the year, first between January and March and then between June and August. Planting and weeding were the major activities in the first period, and harvesting and postharvest processing were the major activities in the second period.

Table 13. Farmers' seed selection criteria, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Big cob	18	52.9	18	50.0	14	58.3
Mature grain	12	35.3	11	30.6	7	19.2
Other	4	11.1	7	19.4	3	12.5

Table 14. Maize cropping calendar by agroecological zone, Central Tanzania

Zone	Activity	Months (JAN–DEC)
Lowlands	Land preparation	AUG–DEC
	Sowing	JAN
	Sowing	DEC
	1st weeding	JAN–FEB
	2nd weeding	FEB–APR
	Harvesting	MAY–JUL
Inter-mediate zone	Land preparation	AUG–NOV
	Sowing	FEB
	Sowing	NOV
	1st weeding	JAN–MAR
	2nd weeding	FEB–APR
	Harvesting	MAY–AUG
Highlands	Land preparation	AUG–DEC
	Sowing	JAN–FEB
	Sowing	DEC
	1st weeding	JAN–MAR
	2nd weeding	FEB–APR
	Harvesting	MAY–JUL

5.0 Farmers' Adoption/Disadoption of Improved Maize

5.1 Current Varieties Grown

Table 15 shows maize varieties grown by the sample farmers in the 1994/95 farming season. Most farmers in the lowlands and intermediate zone grew CG4142, released in 1992 by Cargill. This level of adoption could be attributed to efficient marketing strategies by Cargill, which is well established in northern Tanzania and facilitated dissemination of Cargill seed from Arusha into the lowland and intermediate zones of the Central Zone. In the highlands, other maize materials were popular (e.g., Staha, UCA, and Tuxpeño).

5.2 Preferred Improved Maize Varieties and Reasons for Farmers' Preferences

Farmers' varying preferences for improved maize across zones may be attributed to zonal differences in pest populations, disease incidence, soil fertility, and climate. The most preferred maize in the lowland and intermediate zones was CG4142, whereas it was Staha in the highlands (Table 16). The main reason for these preferences was drought resistance (Table 17).

Table 15. Maize varieties and hybrids planted in 1994/95, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Local	5	27.8	2	11.1	11	61.1
CG4142*	13	72.2	13	72.2	4	22.3
UCA	0	0.0	0	0.0	1	5.6
Staha	0	0.0	0	0.0	1	5.6
Kilima	0	0.0	3	16.7	—	0.0
Tuxpeño	0	0.0	0	0.0	1	5.6

Note: * = or other improved maize variety.

Table 16. Maize varieties/hybrids preferred by farmers, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Practice	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Kilima	0	0.0	3	30.0	0	0.0
Staha	0	0.0	0	0.0	8	66.7
TMV-1	1	12.5	0	0.0	0	—
Tuxpeño	0	0.0	0	0.0	2	16.7
CG4142	6	75.0	6	60.0	1	8.3
Other*	1	12.5	1	10.0	1	8.3

Note: * = or other improved maize variety.

5.3 Disadoption of Improved Maize

About 17% of farmers had discontinued growing improved maize materials, including ICW, H6302, H614, Tuxpeño, and CG4142, largely because of low yields and susceptibility to pests and diseases (Table 18).

Table 17. Reasons for farmers' preferences for certain maize varieties/hybrids

		Lowlands		Intermediate zone		Highlands	
Zone	Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Lowlands	TMV 1	0	0.0	1	100.0	0	0.0
	CG4142	0	0.0	4	100.0	0	0.0
Intermediate	Kilima	1	33.3	1	33.3	1	33.3
	CG4142	1	33.3	5	83.3	0	0.0
Highlands	Staha	1	0.0	5	100.0	0	0.0

Table 18. Maize varieties/hybrids no longer grown by farmers, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
ICW	0	0.0	0	0.0	1	50.0
H6302/H614	2	100.0	1	20.0	0	0.0
Tuxpeño	0	0.0	0	0.0	1	50.0
CG4141	0	0.0	4	80.0	0	0.0

6.0 Credit and Extension Services

6.1 Credit Availability

About 12% of highland respondents and 7% of lowland respondents reported that they had access to credit. All farmers who used credit received it from the informal sector. The average loan was for 1,452.32 Tanzanian shillings (Tsh); the maximum amounts were Tsh 35,000.00 in the highlands and Tsh 13,340.00 in the lowlands. This credit was used mainly to purchase fertilizer. More than half of the respondents in the lowlands and intermediate zone said that credit was difficult to obtain from the formal sector because of the bureaucratic application process, but the main constraint to formal credit for highland farmers was their lack of knowledge of how the credit system worked (Table 19).

6.2 Extension Services

Farmers' sources of information on improved maize technology are shown in Table 20. The three most important sources information were extension agents, other farmers, and NGOs. In all zones, extension led in disseminating knowledge to farmers for all technologies. The Training and Visit (T&V) extension system is used the study area, and most components of the technology package had been introduced to participating farmers. NGOs were the second most important source of knowledge about new technology. Most farmers received information on improved varieties, planting method, fertilizer, weeding, ox-drawn implements, and pesticide use. Information on herbicide use and disease control measures was low, however. Also, farmers in the lowlands received less information than other farmers about ox-drawn implements.

Table 19. Sources and use of credit, Central Tanzania

	Lowlands		Intermediate zone		Highlands	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Access to credit						
Yes	1	6.7	0	0.0	2	12.5
No	14	93.3	15	100.0	14	87.5
Sources of credit						
Informal sector	1	100.0	—	—	2	100.0
Availability of credit						
Difficult to obtain	12.2	85.7	11	84.6	12	100.0
Not difficult to obtain	2	14.3	2	15.4	0	0.0
Constraint to obtaining credit						
Lack of knowledge	0	0.0	0	0.0	2	25.0
Bureaucracy	7	58.3	5	62.5	2	25.0
No collateral	2	16.7	0	0.0	1	12.5
Other	3	25.0	3	37.5	3	37.5

Table 20. Farmers' sources of information about maize production technologies, Central Tanzania

Technology	Lowlands		Intermediate zone		Highlands	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Improved maize						
Received information	16	100.0	10	90.9	17	100.0
Source of information						
Research/extension	8	61.5	5	83.3	8	66.7
Other farmers	0	0.0	0	0.0	3	25.0
NGOs	4	30.8	1	16.7	1	8.3
Traders	1	7.7	0	0.0	0	0.0
Planting method						
Received information	14	87.5	10	90.9	16	100.0
Source of information						
Research/extension	8	72.7	8	100.0	12	92.3
Other farmers	0	0.0	0	0.0	1	7.7
NGOs	3	27.3	0	0.0	0	0.0
Fertilizer						
Received information	9	64.3	6	60.0	15	93.8
Source of information						
Research/extension	10	83.3	3	75.0	11	91.7
NGOs	2	16.7	1	25.0	1	8.3
Weed management						
Received information	8	53.3	8	72.7	13	76.5
Source of information						
Research/extension	6	66.7	6	100.0	7	77.8
Other farmers	0	0.0	0	0.0	2	22.2
NGOs	3	33.3	0	0.0	0	0.0
Herbicide						
Received information	1	9.1	2	22.2	2	16.7
Source of information						
Research/extension	1	100.0	2	100.0	2	100.0
Ox-drawn tool						
Received information	5	33.3	8	72.7	13	76.5
Source of information						
Research/extension	2	66.7	3	42.9	5	50.0
Other farmers	0	0.0	1	14.3	2	20.0
NGOs	1	33.3	3	42.9	3	30.0
Pest management						
Received information	6	46.2	7	63.6	7	53.8
Source of information						
Research/extension	5	83.3	6	100.0	5	83.3
Other farmers	1	16.7	0	0.0	0	0.0
NGOs	0	0.0	0	0.0	1	16.7
Disease control measures						
Received information	3	23.1	2	28.6	5	41.7
Source of information						
Research/extension	2	100.0	2	100.0	6	100.0
Storage practice						
Received information	12	80.0	8	88.9	14	82.4
Source of information						
Research/extension	8	80.0	5	100.0	8	80.0
Other farmers	0	0.0	0	0.0	1	10.0
NGOs	2	20.0	0	0.0	1	10.0

7.0 Factors Affecting Adoption of Agricultural Technologies in the Study Area

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 Varieties in Central Tanzania

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 5 shows the rate of adoption of improved maize varieties for the Central Zone. In 1994 about 78% of farmers were planting improved maize varieties, but the rate of adoption for improved maize over 1974-94 was 0.13, which is rather low. In recent years, the adoption rate has increased dramatically, probably because of improvements in input delivery under liberalized markets and because of increased extension efforts, such as those of Sasakawa-Global 2000.

7.3 Tobit Analysis of Land Allocated to Improved Maize Varieties

Results of the tobit model for the proportion of land allocated to improved maize are presented in Table 21. The tobit model was used because the proportion of land allocated to improved maize is a continuous variable but truncated between zero and one. The use of ordinary least squares will result in biased estimates (McDonald 1980). In Table 21, $\delta EY/\delta x_i$ 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 nonadopters (e.g., the probability of adopting improved maize varieties) with a unit change of independent variable x_i. The log-likelihood ratio test was significant at the 1% level. The socioeconomic household characteristics were not significant. The significant variables included the type of variety grown by the farmer, agroecological zone, and extension.

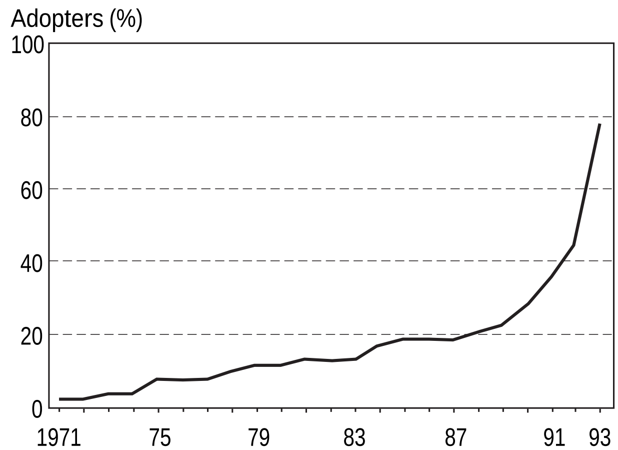

Figure 5. Rate of adoption of improved maize, Central Tanzania.

A variety's characteristics had a positive and significant influence on the proportion of land allocated to improve maize. Farmers growing the long-maturing varieties UCA and Kilima were more likely to allocate more land to maize than

Table 21. Tobit model estimates for land allocated to improved maize varieties, Central Tanzania

Parameter	Coefficient	t-statistic	$\delta EY/\delta x_i$	$\delta EY^*/\delta x_i$	$\delta F(Z)/\delta x_i$
Constant	0.0854	0.3584	0.0016	0.05801	0.03564
EXPF	-0.0038	-0.7604	0	-0.0026	-0.0016
LAB	-0.01197	-0.7351	0	-0.0081	-0.005
EDVC	-0.0118	-0.6847	0	-0.008	-0.0049
WID	0.0074	0.8916	0	0.00503	0.00309
EXI	0.3379	1.5828***	0.025002	0.2295252	0.1410177
VA1	0.4072	3.2111*	0.03631	0.2765986	0.169939
VA2	0.3058	3.3113*	0.020478	0.2077206	0.1276212
VA3	0.5238	3.8682*	0.060081	0.3558014	0.2186004
AEZ1	-0.8211	-4.0217*	-0.1476379	-0.557748	-0.342674
AEZ2	-0.1417	-1.0394	-0.0044	-0.09625	-0.05914
SIGMA	0.2972	7.5782	0.019342	0.2018789	0.1240321
Sample size			54		
Number of positive observations			31		
Proportion of positive observations			57.4		
Z-score			0.19		
f(z)			0.39181		
Log of likelihood function			-13.1798*		
Log of restricted likelihood function			66.98		

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

farmers growing materials that matured earlier. The marginal effect of the long-maturing varieties on the mean proportion of land allocated to improved maize varieties was 6%, while the marginal effect was 3% and 2% for group one and two varieties, respectively. The long-maturing varieties increased the probability adopting improved maize by about 22%, while group one and two varieties increased the probability of adoption by about 17% and 13%, respectively. The marginal effect of extension on the mean proportion of land allocated to improved maize varieties was 3%, and extension increased the probability of adoption by 14%.

Farmers in the highlands were more likely to allocate land to improved maize varieties than farmers in the lowlands and the intermediate zone. The marginal effect of the lowlands and intermediate zone on the mean proportion of land allocated to improved maize varieties was less by 15% and 0.4%, respectively, compared with the highlands. The probability that farmers would allocate land to improved maize was less by 34% for the lowlands and 6% for the intermediate zone. In the lowlands, allocation of land to improved maize remained low compared to the other two zones. One reason for this might be the low rainfall in the lowlands; farmers may be unwilling to plant improved maize that performs badly under moisture stress.

7.4 Probit Analysis of the Use of Fertilizer

Results of the probit model for the use of inorganic fertilizer are presented in Table 22. The probit model was used because the response on inorganic fertilizer use was binary (= 1 if the farmer used inorganic fertilizer for the past three years and = 0 otherwise). Establishing the quantity of fertilizer used per hectare was difficult because of the lack of data. In Table 22, the change in probability ($\delta Y/\delta x_i$) shows the change in probability that a farmer will use fertilizer, given a unit change in the independent variable. The likelihood ratio test was significant at the 1% level. The inverse Mills ratio was not significant and negative; thus fertilizer use was not influenced by adoption of improved varieties alone. The significant variable influencing the adoption of fertilizer was extension services. An increase in the intensity of extension services increased the probability of fertilizer use by 115%. The negative signs on the agroecological zones showed that farmers were less likely to use fertilizer for maize production, especially in the low rainfall areas. This could be explained by the lower response of maize varieties to fertilizer in low rainfall areas.

Table 22. Probit model estimates for use of fertilizer, Central Tanzania

Parameter	Coefficient	t-statistic	$\delta Y/\delta x_i$
Constant	-9.328	-1.4772	-0.6134
EXPF	0.1136	1.3461	0.0075
LAB	0.1493	0.5485	0.0098
EDVC	0.8173	1.5229	0.0603
WID	0.0269	0.2636	0.0018
EXI	17.4586	2.1362**	1.1481
IMR	2.2658	1.1529	0.1491
VA1	-0.4029	-0.1716	-0.0265
VA2	-6.2756	-1.7209	-0.4127
VA3	-3.8855	-1.5964	-0.2555
AEZ1	-7.0066	-1.6317	-0.4608
AEZ2	-8.5556	-1.7411	-0.5626
Sample size	54		
Number of positive observations	30		
Proportion of positive observations	0.56		
R-squared	0.86		
The factor of correct prediction	0.96		
Log likelihood function	-37.1*		
Restricted log likelihood function (β=0)	61.64		
$\chi^2_{(10)}$	25.18		

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

8.0 Conclusions and Recommendations

8.1 Conclusions

Among the farmers sampled for the survey, the mean age of the household head was 43 years, with 19 years of farming experience. Farmers' level of education was low, averaging about four years of formal schooling. Households averaged about ten persons, with at least three permanent workers. Most farmers kept livestock and the hand hoe was their major farm tool. Animal power was used by about 30% of farmers, mainly in the intermediate zone and highlands. Hiring of tractors was relatively common in the lowlands, where farmers practiced extensive maize production. Land was not a limiting factor in the farming system.

Farmers in the lowlands and intermediate zone recycled maize seed for five to eight years, while highland farmers recycled seed for a longer period (eight to ten years). Seed was selected during harvest and shelling for storage, based on the size of the cob. Most selected seed was shelled, treated against insects, and stored in gunny bags. Maize for food was shelled and stored in the *kihenge*. The majority of farmers in the three zones treated their maize before storage.

The few farmers who obtained credit did so through the informal sector and used the money mainly to purchase farm inputs such as fertilizer. Farmers' inability to obtain credit from the formal sector was attributed to lack of knowledge about the formal credit system and the bureaucratic process for obtaining loans.

Farmers' chief source of information on agriculture was the research and extension system; the T&V (Training and Visit) extension system was used throughout the study area. Most farmers had received information on improved maize varieties, planting methods, and weed management, but few knew about disease control measures and pest management.

The most popular maize varieties were Kilima, TMV1, and Staha in the intermediate zone; Staha and TMV1 in the lowlands; and Staha, TMV1, and Kilima in the highlands. The reasons for farmers' preference of these varieties were, in order of importance, their high yield, drought resistance, and resistance to storage pests. Despite these stated preferences, most farmers actually planted the hybrid CG4142 because it was available.

Farmers' adoption of maize crop management practices depended on their cost. Most farmers planted maize in rows (the cheapest technology), but fewer farmers used chemical pest and disease control methods because of their high cost.

The two-stage least squares analysis showed that variety characteristics, production potential of the area, and extension were the most important factors affecting the amount of land allocated to improved maize and use of inorganic fertilizer. Farmers who grew long-maturing maize were about 22% more likely to allocate land to improved maize, while the use of group one and two varieties increased the likelihood of adoption by about 17% and 13%, respectively. Extension increased the probability of allocating land to improved maize at the means by about 14%, and it increased the probability of using fertilizer by 115%. Lowland farmers were less likely to use fertilizer, probably because of the lower response of maize to fertilizer in low rainfall areas.

8.2 Recommendations

Technical innovation characteristics and external influences are the major factors affecting the adoption of improved maize practices. Research needs to develop varieties that fit farmers' tastes and circumstances, and extension should be involved in testing and disseminating these technologies. 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. But use of fertilizer is constrained by high price and lack of knowledge. 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, however. Studies on the economics of seed and fertilizer use should also be undertaken, especially now that input and output markets have been liberalized.

In developing improved maize varieties, factors other than yield should be taken into consideration, including drought resistance/tolerance, resistance to storage pests, shelling quality, and taste. This requires farmer participation in the research process. Research and extension efforts need to be linked and strengthened to increase the flow of information to farmers. 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.

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