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Abstract: This study of the adoption of maize production technologies in Western 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 into the high rainfall zone and low rainfall zone. 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. The analysis showed that extension, short-maturing varieties, and rainfall were significant factors affecting the proportion of land allocated to improved maize. Extension increased the probability of allocating land at the means by about 30%. Short-maturing maize varieties increased the probability of allocating land at the means by about 24%. Farmers in the high rainfall zone are 14% less likely to allocate land to improved maize. An increase in the wealth index by one unit increased the probability of using fertilizer by 13%. Research should give priority to developing or screening varieties that yield well and tolerate drought stress and field pests, especially stalk borers. Flexible integrated management packages that combine a drought-tolerant variety with improved cultural practices such as timely planting and weeding can increase yields. More research should be directed to strategies for improving soil fertility and soil conservation, because the use of chemical fertilizer is likely to remain low in the foreseeable future. Extension should direct more effort toward appropriate soil fertility recommendations. An efficient marketing system for inputs and outputs will benefit farmers by paying higher prices for maize and reducing the cost of fertilizer. Studies on the economics of seed and fertilizer use should also be undertaken, especially now that input and output markets have been liberalized. In collaboration with the government and other stakeholders, the formal credit system needs to address the credit problems faced by small-scale farmers.

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Acronyms and Abbreviations

AEZ	Agroecological zone
ARTI	Agricultural Research and Training Institute
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
EAAFRO	East Africa Agriculture and Forest Research Organization
FSD	Food Security Department
FSR	Farming systems research
GOT	Government of Tanzania
ICW	Ilonga Composite White
masl	Meters above sea level
MOA	Ministry of Agriculture
MSV	Maize streak virus
NALEP	National Agriculture and Livestock Extension Project
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	Souteher Africa Centre for Coordination of Agricultural Research
SARI	Selian Agricultural Research Institute
SG-2000	Sasakawa-Global 2000
ST	Streak resistant
STD	Standard deviation
SUA	Sokoine University of Agriculture
T&V	Training and Visit
TANSEED	Tanzanias Seed Company
TFA	Tanganyka Farmers' Association
TMV	Tanzania maize variety
Tsh	Tanzanian Shillings
TSP	Triple super phosphate
UCA	Ukiruguru Composite A
ULVA	Ultra low volume applicators
USAID	United States Agency for International Development
VEO	Villege Extension Officer

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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 Western Zone, which includes Tabora and Kigoma regions.

Data collected in the survey were grouped into two agroecological zones: the high and low rainfall zones. 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.

Maize research in the Western Zone is undertaken in collaboration with Ilonga Research Institute. Recommended maize varieties and hybrids include Kilima, Katumani, TMV1, CG4141, UCA, H622, and H632.

The mean age of farmers was about 46 years in the high rainfall zone and 49 years in the low rainfall zones. For both zones, mean farming experience was about 18 years and the level of formal education was about four years. Farmers in the high and low rainfall zones had about nine and eight family members, respectively. The number of female adults and children was significantly higher in the high rainfall zone.

The time for land preparation, planting, and harvesting depends on rainfall. Land preparation for maize usually starts in August-September, planting starts in October-December, and harvesting occurs mainly between May and June. The maize plot was weeded twice at most. The time of these weedings depended on rainfall and planting date, but most farmers weeded after the first three weeks of planting and weeded a second time depending on weed re-emergence. Most farmers in the high rainfall zone weed in November-December, while farmers in the low rainfall zone weed in December-January. More farmers in the high rainfall zone weed twice compared to farmers in the low rainfall zone.

The use of fertilizer on maize was constrained by high fertilizer prices. Farmers mainly used urea, and the average fertilizer application was higher in the low rainfall zone (57.2 kg/ha) compared to the high rainfall zone (54.2 kg/ha). To increase soil fertility, farmers plowed crop residues back into the soil (mainly in the low rainfall zone). More farmers in the low rainfall zone practiced a crop rotation (66.7%) compared to farmers in the high rainfall zone (44.6%). The important field pests and diseases in both zones were stalk borers and maize streak virus (MSV).

Most farmers recycled seed for five years in a row, but others recycled seed for as much as 10-15 years. Seed was selected during the harvest or when maize was shelled for storage, and selection was based on the size of the cob and grain maturity. Maize for seed was stored separately from the main crop, mainly on cribs. Maize for food was shelled and stored in gunny bags, on cribs, or in the traditional storage structure (*kihenge*). Most farmers treated stored maize with industrial chemicals to control pests.

The main maize varieties grown during the 1994/95 farming season in the high rainfall zone were local varieties, H614, Tuxpeño, and ICW. In the low rainfall zone, the main varieties were local varieties, H614, Tuxpeño, and UCA-St. The improved maize varieties preferred by farmers in the high rainfall zone included H6302/H614 and Tuxpeño. Tuxpeño and UCA-St varieties were preferred by farmers in the low rainfall zone. Varieties were preferred for their yield, resistance to drought, and resistance to field pests. About 14% of the farmers in the high rainfall zone and 33% in the low rainfall zone had stopped growing an improved maize variety. Farmers in the high rainfall zone mainly disadopted H6302/H614, whereas farmers in the low rainfall zone mainly disadopted H614 and UCA.

About 44% of the farmers in the high rainfall zone and 32% in the low rainfall zone used credit. The important credit institutions were cooperative unions, non-governmental organizations (NGOs), and agro-companies providing credit in kind. More farmers in the low rainfall zone (90.4%) reported that credit was difficult to obtain compared to farmers in the high rainfall zone (42.6%). Lack of knowledge (information) and bureaucracy were the main constraints to obtaining credit in the high rainfall zone. Farmers in the low rainfall zone reported that those who were not growing cash crops had no access to credit. Most farmers had received information on improved maize varieties, use of fertilizer, weed and pest control, and storage practices. The most important sources of information were research and extension.

The two-stage least squares analysis showed that extension, short-maturing varieties, and rainfall zone were significant factors affecting the proportion of land allocated to improved maize varieties. Extension increased the probability of allocating land at the means by about 30%. Short-maturing maize varieties increased the probability of allocating land at the means by about 24%. Farmers in the high rainfall zone were about 14% less likely to allocate land to improved maize. An increase in the wealth index by one unit increased the probability of using fertilizer by 13%.

Large parts of Western Tanzania are prone to frequent drought that can destroy maize or chronically reduce yields and increase stalk borer attack. Research should give priority to developing or screening varieties that are high yielding and that tolerate moisture stress and field pests, especially stalk borers. Flexible integrated pest management packages, which combine drought tolerant varieties with improved cultural practices such as timely planting and weeding, could increase yields. Low-cost techniques for controlling stalk borer and MSV using cultural practices or environmentally friendly industrial chemicals should be developed.

Extension efforts need to be strengthened to increase the flow of information to farmers. More effort should be directed toward soil fertility technologies, as a majority of farmers use inefficient fertilizer practices. Advice to farmers to use organic manure to supplement chemical fertilizer should be increased.

Most improved varieties are fertilizer responsive and economic yields are usually obtained after fertilizer application, but the use of fertilizer is constrained by its high price and unavailability. Policy makers should support the promotion of an efficient marketing system for outputs and inputs, which would offer higher maize prices to farmers and reduce the cost of fertilizers. More research should be directed to soil mining, supplementation of chemical fertilizer with different sources of organic manure, crop residue management, and soil conservation. Additional soil fertility research will be particularly relevant because the use of chemical fertilizer is likely to remain low in the foreseeable future because of its rising price. Also, studies on the economics of fertilizer use should be undertaken, especially now that input and output markets have been liberalized.

With rising input prices, providing credit to farmers becomes increasingly important. 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 (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. 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 Center for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement Centre (CIMMYT), the study included the nationís seven agroecological zones. The study was conducted between June and November 1995. This report covers survey findings from the Western Zone of Tanzania. The objectives of the study were to describe the maize farming systems in the

Western Zone, evaluate the adoption of improved maize production technologies, and, in light of the findings, identify future themes for research.

1.2 The Study Area

The Western Zone of Tanzania is administratively divided into Tabora and Kigoma regions (Figure 1). Tabora region occupies about 73,500 km in west-central Tanzania. It lies between 4° and 7° south of the equator and between 31° and 34° east of Greenwich. Variations in elevation are not great and range from less than 1,100 masl to more than 1,500 masl. The climate is warm. Rainfall is markedly seasonal and ranges from an annual average of 1,000 mm in the west to 600 mm in the northeast. More than half of the region is under natural forests, consisting of *miombo* woodland. In the northeast, the dominant species are *Acacia, Commiphora,* and *Combetrum*.

Kigoma region is characterized by variable land forms ranging in elevation from 770 masl along Lake Tanganyika to 2,399 masl in some parts of Kasulu. Most of the region is part of the Central plateau (around 1,000 masl), an immense, gently undulating plain with gentle slopes, shallow valleys, and a large area of swamps bordering the main watercourses. The region occupies about 36,600 km^2. The climate is characterized by a single rainy season (November to early May) followed by a prolonged dry season. Annual rainfall ranges between 900 mm and 1,000 mm and the mean annual temperature is 12–28°C. The climate is modified by Malagarasi swamp, Lake Tanganyika, and the highlands, resulting in lower annual mean temperatures and higher rainfall than might be expected.

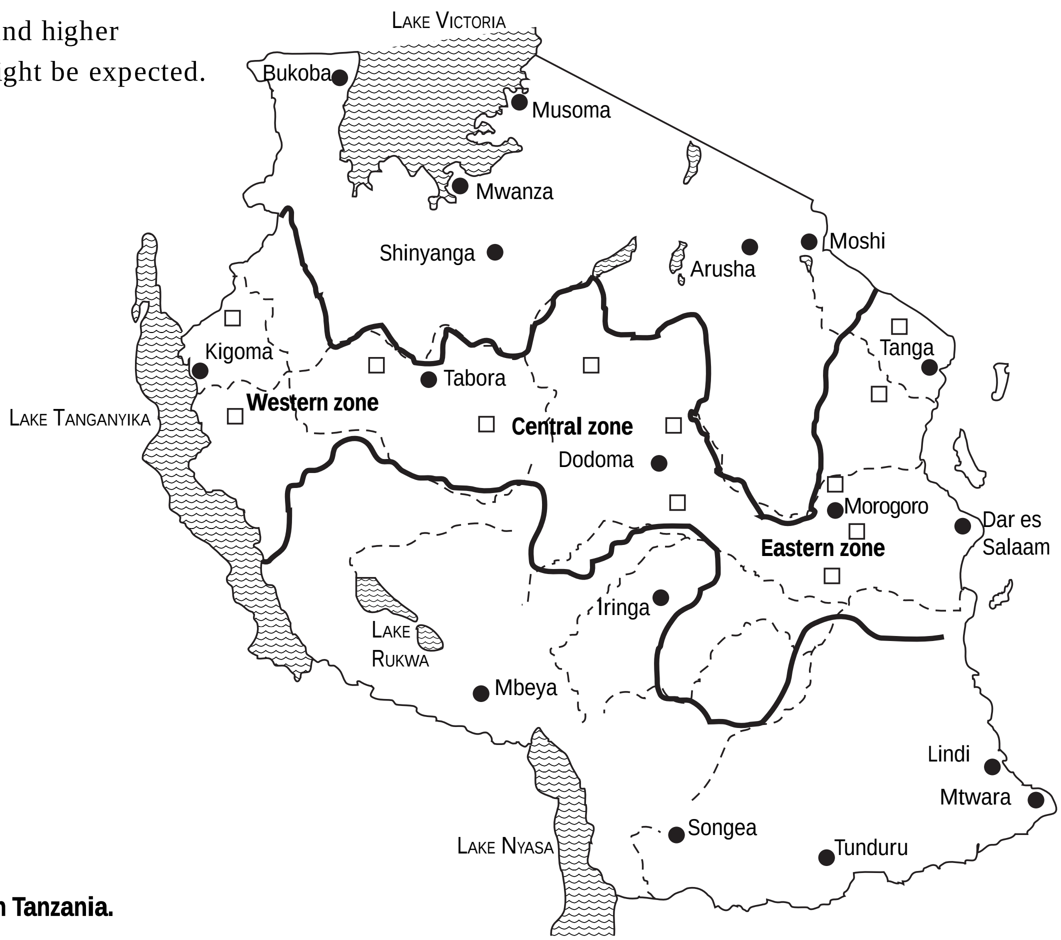


Figure 1. Western Tanzania.

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. The Western Zone was allocated 114 farmers or approximately 11% of the national sample. At the zonal level, two districts were purposively selected for each zone. Both zones are in the intermediate altitude, and they are disaggregated by the amount of precipitation they receive. Urambo and Kasulu Districts are part of the high rainfall areas (>1,000 mm annually) and Tabora and Nzega Districts are part of the low rainfall areas (<1,000 mm annually). At the district level, three villages were purposively selected according to maize production and accessibility. From each village, about 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 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 squares 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 grow improved maize variety; j = 0 otherwise

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

i = 1 if use fertilizer; j = 0 otherwise

Where:

Y = the proportion of maize area allocated to improved maize varieties (IMV) or adoption of inorganic fertilizer;

β_{ij} = parameters to be estimated; and

ε_i and α_i = error terms.

The models were further specified as:

$$PLAND = A+EXP+EDVC+WID+EXI+LAB+VA1+VA2+VA3+AEZ1+AEZ2+\varepsilon i$$
$$FERT = A+EXP+EDVC+WID+EXI+LAB+IMR+VA1+VA2+VA3+\alpha I$$

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 in 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 years and above).
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, Kilima, Tuxpeño, and ICW (3.5-4 months); group three (VA3), of UCA and hybrids (4.5-5 months).
AEZ1-2 = high and low rainfall zone (AEZ1=1 if the farmer is in the low rainfall zone, AEZ1=0 otherwise). The high rainfall 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 zone 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 farmers knows from the improved technology package, such as improved seed, row planting, fertilizer application, ox-plowing, field pest and disease control, and so on.

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 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 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. 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 Maize Research in Western Tanzania

Maize research in the Western Zone was initiated through the East Africa Agriculture and Forest Research Organization (EAAFRO) at the Agricultural Research and Training Institute (ARTI), Tumbi, in 1969 under the cereal and legume research program. From 1968 to 1970, Tumbi served as the substation of ARTI-Ukiriguru. Research consisted mainly of evaluating materials on the experiment station. In 1971, ARTI-Tumbi acquired independent status but continued to conduct maize research under the supervision of ARTI-Ukiriguru. From 1974, ARTI-Tumbi started to collaborate with ARTI-Ilonga and on-farm maize research was conducted, focusing on Tabora region.

In 1975, the Agricultural Trials and Training Center was established at Mubondo in Kasulu District under the Kigoma Rural Integrated Development Project. In the 1976/77 cropping season, the first maize trials were conducted in Kigoma region. Following the 1977/78 cropping season, the Mubondo substation continued with maize evaluation trials on the station under the NMRP, coordinated by ARTI-Ilonga, while ARTI-Tumbi provided the human resources. In the 1978/79 cropping season, research emphasized on-farm trials and demonstration plots in both regions. The districts covered were Kibondo and Kasulu in Kigoma regions and Tabora, Urambo, and Nzega in Tabora region.

2.3 The Maize Seed Industry in Tanzania

The hybrid CG4141 is multiplied and distributed by Cargill Hybrid Seed Ltd., which is based in Arusha. A locally bred hybrid, H614, is grown mainly by farmers in the high rainfall zone (37.1%); only 14% of sample farmers in the low rainfall zone grew it. This is because the hybrids are late maturing. Locally bred cultivars have flint grain and good pounding and storage qualities, and they yield as well as CG4141. They are marketed mainly by the Tanzania Seed Company (TANSEED), which has not done well in the newly competitive seed industry. This has contributed to reduced adoption of locally bred hybrids. 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 Farmersí 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.

3.0 Maize Production Technology Recommendations

3.1 Varieties

The recommended varieties for the Western Zone are shown in Table 1. The choice of maize variety is determined by the farmer's objectives, the length of growing season, the elevation, and the amount of rainfall at a given locality. For intermediate altitude areas (900-1,500 masl) with low rainfall (<1,000 mm), the following varieties and hybrids have been recommended: Kilima, Katumani, TMV1, CG4142, UCA, H622, and H632.

3.2 Planting Time, Method, and Spacing

Planting time is one of the crucial factors for high yield. The recommended planting time for Tabora region is in November–December, while for Kigoma region it is between mid-October and mid-November (Table 2). Recommended planting depth for maize is 5–7 cm. Row planting is recommended to achieve a desirable plant population. For Tabora and Urambo Districts, a spacing of 30 x 90 cm and one plant per hill is recommended, whereas for Igunga and Nzega the recommended spacing is 30 x 90 cm for late maturing maize and 30 x 75 cm for early maturing maize. For Kigoma region, a spacing of 50 x 80cm and two plants/hill are recommended. Growing maize as a monocrop is recommended throughout Western Tanzania.

3.3 Fertilizer Types, Time, and Method of Application

The major limiting nutrients in the Western Zone are nitrogen (N) and phosphorus (P). As improved varieties require substantial quantities of mineral nutrients for their vegetative and grain development, different rates of inorganic and organic fertilizers have been recommended. In Tabora region, 60 kg P_2O_5/ha in the form of NPK and 70 kg N/ha as sulfate of ammonia (SA), calcium ammonium nitrate (CAN), or urea are recommended. Additionally, given the high livestock population and availability of manure, 7–10 t/ha of farm yard manure (FYM) is recommended. In Kigoma region, the recommendation is 125 kg/ha of triple super phosphate (TSP) and 250 kg/ha of urea (Table 2). Nitrogen applications may be split by applying about 50% of the total amount at

Table 1. Recommended maize varieties by region and district, Western Tanzania

Region/district	Varieties recommended
Tabora region	
Tabora/Urambo	Kilima, Katumani, TMV1, CG4141, UCA
Igunga/Nzega	Katumani, TMV1
Kigoma region	
Kigoma rural	UCA, Kilima, CG4142
Kasulu	H632,UCA, Kilima, H622
Ibondo	H632,H622,UCA, Kilima, CG4142

Table 2. Recommended planting time and recommended fertilizer rate

Variable	High rainfall zone	Low rainfall zone
Time of planting	October–November	November–December
Inorganic fertilizer rate		
Phosphorus (kg/ha)	125 (triple super phosphate)	60
Nitrogen (kg/ha)	250 (urea)	70
Manure (t/ha)	7-10	7-10

planting and the remainder just before tasseling. Fertilizer is normally placed 5 cm below the depth of the seed and about 5–8 cm to the side by digging a single hole beside each seed, placing the fertilizer in the hole, and covering it with soil. (Alternatively, a continuous furrow is made along the length of the planting row. Fertilizer is 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.

3.4 Weed Control

Weeds can seriously affect maize yield, and two weedings with a hand hoe are recommended in the Western Zone. The first weeding is recommended at one to two weeks after germination. For Tabora region, the second weeding is recommended before tasseling, whereas for Kigoma region it is recommended 35 days after germination.

3.5 Pest and Disease Control

The major maize pest in Western Tanzania is stalk borer, and the best method of control is to use resistant varieties. Common stalk 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.

3.6 Harvesting and Storage

Maize is harvested when it is dry, with a moisture content of about 35–40%. Harvested maize should be dried on the cob and shelled and winnowed before it is stored. It is recommended to store shelled maize treated with Actellic Super in gunny bags or unshelled maize in storage structures (*kihenge*) (in which case Actellic 50EC is used to treat maize).

4.0 Demographic and Socioeconomic Characteristics of Maize Farmers in the Study Area

4.1 Demographic Characteristics

Table 3 summarizes the characteristics of sample households in the Western Zone. The mean age of the household head was about 46 years in the high rainfall zone and 49 years in the low rainfall zone. In both zones, sample farmers had lived in the same village for about 20 years and had an average of about 18 years of farming experience. The level of education of the household head was about four years. There were no significant differences for these characteristics between zones.

Average household size was nine in the high rainfall area and about eight in the low rainfall area. High rainfall areas had significantly more female adults and children compared to the low rainfall areas. Compared to farmers in the low rainfall areas, sample farmers in the high rainfall areas also had more male adults and female adults working off of the farm. Only 9% and 5% of the sample farmers in the high and low rainfall zones, respectively, had any off-farm income, and most of this income went to purchase seed and fertilizer.

Farmers in the low rainfall areas used more hired labor (50%) than farmers in high rainfall areas (39%). Most farmers in the high rainfall (21.4%) and low rainfall areas (25.9%) used hired labor for land preparation. About 18% of the farmers in the high rainfall zone and 3% in the low rainfall zone used hired labor for weeding. A large percentage of farmers in the low rainfall area (20.7%) used hired labor for tree crops such as coffee, while only 7% of farmers in the high rainfall area used hired labor for tree crops.

Table 3. Demographic characteristics of sample households, Western Tanzania

	High rainfall zone		Low rainfall zone		
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**t-statistic**
Household head					
Age (yr)	45.8	56	49.2	57	1.3
Education (yr)	4.3	56	4.5	57	0.3
Years lived in the village	20.2	56	20.5	57	0.15
Farming experience (yr)	18.4	56	17.7	57	0.3
Labor availability (no.)					
Male adults	2.1	51	2.3	50	0.5 (NS)
Female adults	2.5	55	2.0	56	1.9*
Children	4.5	53	3.5	50	2.2**
Off-farm employment (no.)					
Male adults	1.7	6	1.3	3	0.6 (NS)
Female adults	1.4	7	1.25	4	0.3 (NS)
	Number of farmers	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	X^2
Off-farm income	5	8.9	3	5.3	0.6 (NS)
Used hired labor	22	39.3	29	50.0	1.5 (NS)

Note: NS= not significant; *= significant at p<0.1; **=significant at p<0.05.

4.2 Land Resources and Allocation

Average farm size in the low rainfall areas (11.6 acres) was higher than in the high rainfall areas (10.2 acres), and cultivated area was also higher in the low rainfall areas (7.2 acres) than in the high rainfall areas (6.5 acres) (Table 4). The land was significantly more fragmented in the high rainfall areas (three plots) compared to the low rainfall areas (two plots) (p=0.01).

High population growth has resulted in higher demand for food and thus expansion in farm and maize area. Figures 2 and 3 show trends in farm size and maize area in the low and high rainfall areas. Farm size is increasing in the low rainfall areas, but over time the percentage of farm area planted to maize is declining. The reduction in maize area from 1990 onwards might be explained by the unfavorable terms of trade for maize. Liberalization of the maize market during this period reduced maize prices and thus reduced the incentive to grow maize.

Table 4. Farm size and land use pattern, Western Tanzania

	High rainfall zone		Low rainfall zone		
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**t-statistic**
Farm size (acres)	10.2	8.0	11.6	8.5	0.9 (NS)
Number of plots	2.7	1.3	1.7	1.0	4.1 ***
Land cultivated (acres)	6.5	5.2	7.2	5.5	0.6 (NS)
Land rented in (acres)	3.3	5.4	2.1	1.2	0.5 (NS)
Land rented out (acres)	1.3	1.8	3.0	—	—

Note: NS= not significant; ***=significant at p<0.01.
[a] Only one farmer in low rainfall area.

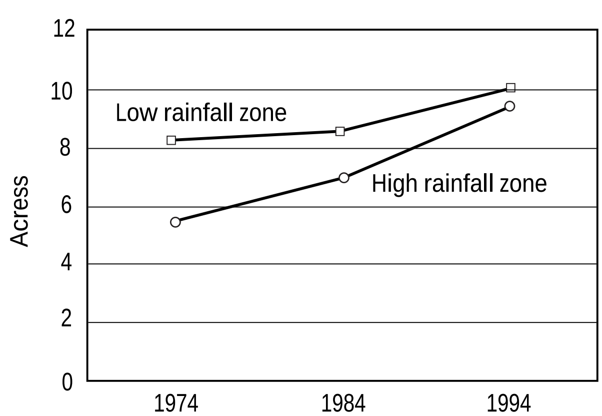


Figure 2. Trends in farm size zones, Western Tanzania.

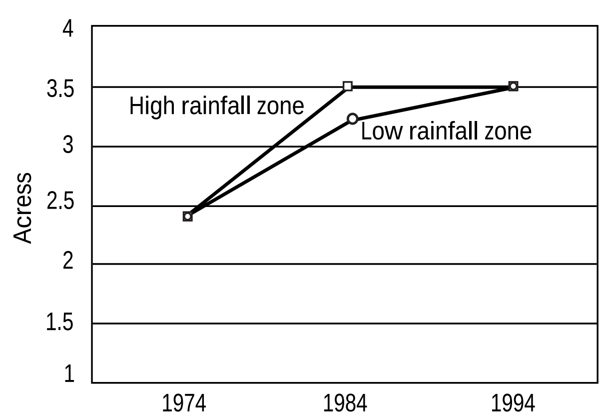


Figure 3. Trends in maize area in high and low rainfall zones, Western Tanzania.

4.3 Livestock Ownership and Farm Mechanization

Livestock production was an important component of the farming system in both the low and high rainfall zones. However, farmers tended to keep more goats than cattle. As more grazing land has been converted into crop land, the remaining marginal land is more suitable for raising goats. The average number of goats and sheep owned by households was relatively similar in both zones (Table 5), but farmers in the low rainfall zone had significantly more cattle compared to farmers in the high rainfall zone.

The average number of hand hoes was four for the high rainfall zone and five for the low rainfall zone (Table 5). An average of four pieces of cutting equipment was owned by households in both zones. No farmer in the sample owned a tractor or cart. About 16% of the farmers in the low rainfall zone hired ox-plows for land cultivation. No farmers in the high rainfall zone hired ox-plows.

Table 5. Numbers of livestock and farm implements owned, Western Tanzania

	High rainfall zone		Low rainfall zone		
	Mean	Standard deviation	Mean	Standard deviation	t-statistic
Number of livestock					
Goats	5.8	6.0	5.2	4.7	0.38 (NS)
Sheep	3.7	2.3	5.0	2.9	0.8 (NS)
Cattle	2.0	1.0	7.0	2.4	3.3 **
Other livestock	12.8	18.0	18.3	17.3	1.3 (NS)
Number of farm implements					
Hand hoes	4.3	2.5	4.8	2.7	1.2 (NS
Cutting equipment[a]	3.6	1.9	3.6	1.5	0.1 (NS)

Note: NS = not significant; ** = significant at p<0.05.
[a] Includes machetes, axes, and knives.

5.0 Maize Production, Marketing, and Seed Practices in Western Tanzania

5.1 Crops and Cropping System

Maize is the major food and cash crop in the study area, and most farmers grow it (Table 6). Forty-four percent of farmers in the high rainfall zone grew maize as a sole crop, compared to 54% of farmers in the low rainfall zone. Maize was intercropped by 56% of farmers in the high rainfall zone and 46% in the low rainfall zone. The main reason for intercropping was to save labor.

5.2 Maize Crop Management Practices

5.2.1 Land preparation

Land preparation depends on the rainfall pattern. Land preparation starts in August and ends in late September for 84% of the farmers in the high rainfall zone (Table 7). In the low rainfall zone, land preparation was mainly done between September and October (78% of the sample farmers). The majority of farmers in both zones used a hand hoe for land preparation.

Table 6. Maize cropping systems, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Cropping pattern				
Monocrop	20	43.5	20	54.1
Intercrop	26	56.5	17	45.9
Reasons for intercropping				
Saves labor	13	46.4	9	52.9
Land scarcity	9	32.1	4	23.5
Spreads risk	2	7.1	4	23.5
Increases income	4	14.3	—	—
Cropping system				
Maize/legumes	15	34.9	10	22.7
Maize	13	30.2	29	65.9
Tuber crops	3	7.0	1	2.3
Tobacco	5	11.6	3	6.8
Other	7	16.3	1	2.3

Table 7. Time and method of land preparation, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Time of land preparation				
August	23	41.0	5	9.3
September	24	42.8	28	51.9
October	7	12.5	14	25.9
November-January	2	3.6	7	13.0
Method of land preparation				
Hand hoe	49	94.2	50	98.0
Hand hoe/oxen	–	–	1	2.0
Other	3	5.8	–	–

5.2.2 Seedbed type, planting time, and weeding

Table 8 shows farmers' agronomic practices. Maize was sown in a flat seedbed by all respondents in both zones. In the 1994 farming season, in the high rainfall zone, maize planting started in October, while farmers in the low rainfall zone mainly started planting in November. Ninety-three percent of the farmers in the high rainfall zone and all farmers in the low rainfall zone plant maize in rows; 67% of farmers in the high rainfall zone and 83% in the low rainfall zone said they adopted row planting because it made it easy to manage the field. Other reasons included increasing yields or saving labor. Most farmers in the low rainfall zone (71%) used the recommended spacing, while 50% of the farmers in the high rainfall zone used the recommended spacing. The average number of seeds per hill was significantly higher in the high rainfall zone (2 seeds/hill) than the low rainfall zone (1.7 seeds/hill) ($t=3.3$, $p=0.01$).

The time for weeding followed the pattern of planting. In the high rainfall zone, most of the farmers (82.1%) weeded their maize for the first time in November–December, while most of the farmers (81%) in the low rainfall zone weeded their maize in December–January. The average number of weedings was 1.6 for farmers in the high rainfall zone and 1.4 for farmers in the low rainfall zone. More farmers in the high rainfall zone (17.9%) performed a second weeding, however, compared to farmers in the low rainfall zone (9.3%).

Table 8. Farmers' major agronomic practices, Western Tanzania

	High rainfall zone		Low rainfall zone	
Practice	**Number of farmers**	**Percentage of farmers**	**Number of farmers**	**Percentage of farmers**
Time of planting				
September	2	3.6	–	–
October	29	52.7	9	16.8
November	18	32.7	31	57.5
December-January	6	10.8	14	29.1
Planting method				
Row	50	92.6	53	100.0
Random	4	7.4	0	0
Reasons for row planting				
Ease of field management	36	66.7	45	83.3
Increase yield	12	22.2	1	1.9
Other	6	11.2	8	14.8
Spacing between rows				
Use recommended spacing	25	50.0	39	70.9
Use other spacing	25	50.0	16	29.1
First weeding				
November	22	39.3	2	3.8
December	24	42.8	25	47.1
January	7	12.6	18	33.9
February	3	5.4	8	15.1
Second weeding				
November-December	9	42.2	–	–
January	9	42.2	5	100.0
February	1	5.3	–	–
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
Number of seeds per hill	2.0	0.5	1.7	0.5
Number of weedings	1.6	0.5	1.4	0.5

5.2.3. Type of fertilizer, quantity, and constraints

Fertilizer was used by 66% and 60% of farmers in the high and low rainfall zones, respectively (Table 9). Farmers in the high rainfall zone used urea (49%), TSP (32%), and SA (19%), and farmers in the low rainfall zone used urea (37%), CAN (37%), SA (21%), and NPK (5%). The average amount of fertilizer used was slightly higher in the low rainfall zone (57.2 kg/ha) than the high rainfall zone (54.2 kg/ha), but both amounts were below the recommended rate. The main constraint to using fertilizer was the high price. Organic manure was used by 5% and 16% of farmers in the high and low rainfall zones, respectively, mainly because of its high price and unavailability.

Table 9. Fertilizer use for maize production, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Use inorganic fertilizers (IF)	37	66.1	34	59.6
Use organic fertilizers (OF)	3	5.4	9	15.8
Reasons for not using IF				
Expensive	11	91.7	15	88.2
Other	1	8.3	2	11.8
Reasons for not using OF				
Expensive	3	42.9	–	–
Unavailability	1	14.3	11	100.0
Don't know about them	3	42.9	–	–

Table 10. Other soil fertility management practices, Western Tanzania

	High rainfall zone		Low rainfall zone	
Practice	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Fallow maize plots				
Yes	30	53.6	40	70.2
No	26	46.4	17	29.8
Reasons for not fallowing				
Land is scarce	14	66.7	13	76.5
Difficult to clear land	4	19.0	3	17.6
Other	3	14.3	1	5.9
Practice crop rotation				
Yes	25	44.6	38	66.7
No	31	55.4	19	33.3
Reason for not practicing crop rotation				
Don't know about them	16	59.3	6	33.3
Land is scarce	9	33.3	7	38.9
Other	2	7.4	5	27.8
Management of crop residues				
Plow under	10	18.2	37	69.8
Burn	35	63.6	4	7.5
Feed to cattle	5	9.1	10	18.9
Other	5	9.1	2	3.8

5.2.4. Fallowing, crop rotation, and crop residue management

About 54% of the farmers in the high rainfall zone and 70% in the low rainfall zone fallowed their land (Table 10), generally to replenish soil fertility. Fallows lasted 1.8 years in the high rainfall zone and 2.1 years in the low rainfall zone. Farmers often grew maize immediately after fallowing (45% of farmers in the high rainfall zone and 52% of farmers in the low rainfall zone), although 15% of farmers in the high rainfall zone and 30% in the low rainfall zone reported planting tobacco after fallow. Other crops mentioned were cassava and legumes. Farmers in the high rainfall zone said that the crop they chose to grow after fallow was chosen because it provided more income (55%). In the low rainfall zone, farmers decided which crop to grow after fallow on the basis of whether the crop needed more fertile soil (38%), provided higher income (25%), or was the only crop grown (25%). The main reason for not fallowing in both zones was land scarcity.

About 44% of respondents in the high rainfall zone and 67% in the low rainfall zone rotated their crops, and this difference was significant (t=5.6; p=0.01). The common crop rotations were maize–tobacco (43.8% of farmers in high rainfall areas, 71% of farmers in low rainfall areas); maize–legumes (33.3% of farmers in the high rainfall zone); and maize–cassava (19.4% of farmers in the low rainfall zone). Farmers in the high rainfall zone rotated crops mainly because the previous crop increased soil fertility (82.2%) or because they wanted to break a disease or pest cycle (14.3%). Similar reasons for crop rotations were advanced by farmers In the low rainfall zone (83.4% to increase soil fertility, 16.7% to break a disease/pest cycle). The main reason that farmers in the high rainfall zone did not rotate crops was that they were not aware of the benefits of the practice (59.3%), while farmers in the low rainfall zone said they did not rotate crops because they lacked land (38.9%).

Farmers who do not apply fertilizer or who applied only a small amount were advised to plow crop residues back into the soil to avoid soil mining. This recommendation was followed by about 18% of farmers in the high rainfall zone and 70% in the low rainfall zone. About 64% of the farmers in the high rainfall zone burned their crop residues.

5.2.5 Pest and disease control

Maize pests, diseases, and control methods are summarized in Table 11. About 78% and 90% of the sample farmers in the high and low rainfall zones, respectively, reported that stalk borers were the most serious field pest. In the high rainfall zone, cutworms and termites were also reported as important field pests (18.3%). More farmers in the high rainfall zone (42.1%) than in the low rainfall zone (22.8%) used no method to control maize field pests. In the high rainfall zone farmers used mostly DDT (24.6%), Thiodan (15.8%), and Marshal (10.8%). In the low rainfall zone farmers used mostly Thiodan (57.9%) and DDT (17.5%).

The most important maize disease in both zones was maize streak virus (reported by 62% of the farmers), while about 31% of the farmers in both zones reported that no diseases affected the maize crop. About 88% and 97% of the farmers in the high and low rainfall zones, respectively, did not control field diseases. Local varieties were affected most by pests and diseases.

Table 11. Major field pests, diseases, and their control, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Field pests				
None	1	1.4	4	6.8
Stalk borers	55	77.5	53	89.8
Cutworms and termites	13	18.3	1	1.7
Vermin	2	2.8	1	1.7
Method of control				
None	24	42.1	13	22.8
Thiodan	9	15.8	33	57.9
DDT	14	24.6	10	17.5
Marshal	6	10.5	—	—
Other	4	7.0	1	1.8
Field diseases				
None	18	31.0	19	31.1
Maize streak virus	36	62.1	38	62.3
Cob rot	3	5.2	2	3.3
Smut	1	1.7	2	3.3
Method of control				
None	49	87.5	55	96.5
Chemical	4	7.1	1	1.8
Other	3	5.4	1	1.8
Most affected varieties				
Local varieties	19	65.5	25	55.6
Hybrids	—	—	5	11.1
UCA	2	6.9	4	8.9
Katumani	8	27.6	11	24.4

5.3 Maize Harvesting, Transportation, and Storage

The maize harvest depends on the time of sowing and the end of the rainy season. Most of the maize crop was harvested in the survey area between April and May (Table 12). The harvested cobs were generally transported by head load and bicycle. About 38% and 47% of farmers in the high and low rainfall zones, respectively, stored maize in a *kihenge*. Other methods included storing maize in gunny bags or on cribs. More farmers in the low rainfall zone (75%) treated their maize before storage, compared to 65% of the farmers in the high rainfall zone. Treatment with Actellic Super was the most common control method in both zones (reported by all farmers in the high rainfall zone and about 93% in the low rainfall zone). Reasons reported in the high rainfall zone for not treating maize were lack of cash (54.4%) or no need for it (42.9%); the main reason in the low rainfall zone was that maize did not need treatment (84.6%). Farmers in the low rainfall zone started treating maize significantly earlier (10 years ago) than farmers in the high rainfall zone (4 years ago) ($t=3.0$; $p=0.01$).

5.4 Seed Selection and Recycling

Most respondents recycled their maize seed. Some farmers have recycled seed for as much as 10 years. About 46% of the respondents have been recycling improved seed for the past 5 years, while about 21% have recycled it for 10 years, and 19% for 15 years. Only 14% of the respondents reported purchasing new seed regularly.

Seed was selected based on the size of the cob (94% of farmers) and grain maturity (6%). Seed was selected during harvesting and shelling for storage, and seed maize was either stored on cribs (56%) or shelled and stored in gunny bags (44%). Other reported seed storage methods were shelling and applying chemicals or shelling and applying ash and then storing in gunny bags.

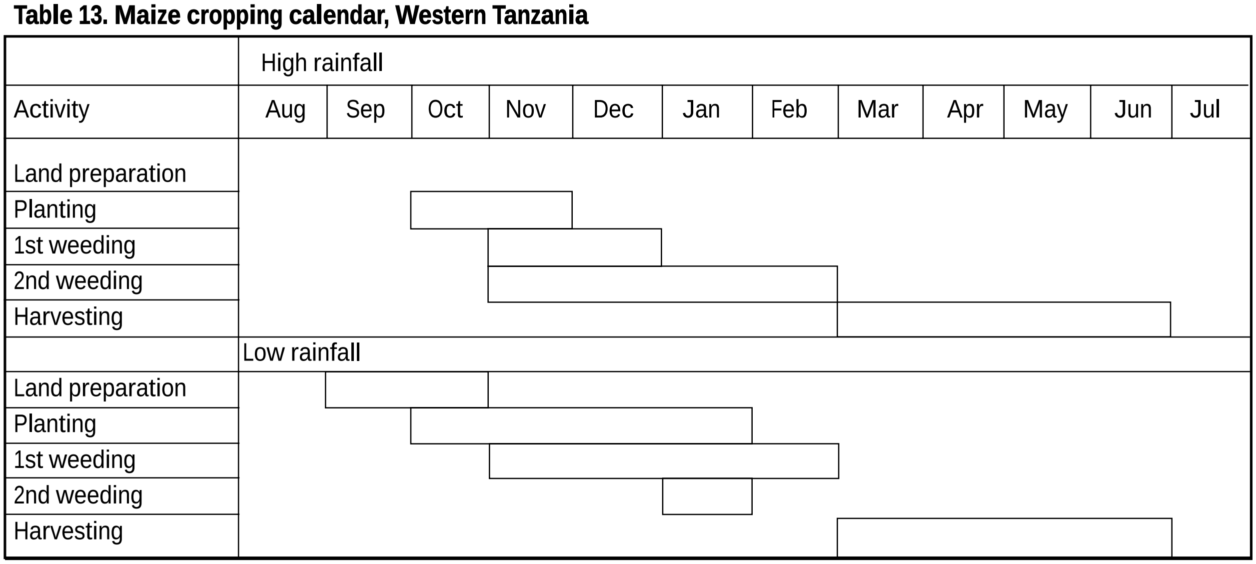
Table 12. Maize harvesting, transportation, and storage, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Month of harvest				
March	4	7.1	4	7.8
April	14	25.0	19	37.3
May	27	48.2	15	29.4
June–July	11	19.6	13	25.5
Method of transportation				
Head load	45	77.6	30	62.5
Bicycle	13	22.4	12	25.0
Cart	–	–	6	12.5
Maize storage				
Shell and store in *kihenge*	20	37.7	17	47.2
On cribs	12	22.6	5	13.9
Gunny bags	20	37.7	14	38.9
Other	1	1.9	–	–

5.5. Maize Cropping Calendar for Western Tanzania

Table 13 summarizes the maize cropping calendar for the Western Zone. In both zones the peak labor demand occurred between November and January, while the remaining part of the year was relatively slack. In the low rainfall zone, only a few farmers carried out a second weeding.

Table 13. Maize cropping calendar, Western Tanzania



6.0 Farmers' Adoption/Disadoption of Improved Maize

6.1 Varieties Currently Grown

Table 14 shows maize varieties grown by the sample farmers in the 1994/95 farming season. In the high rainfall zone, the main varieties grown were H614 (37.1%) and local varieties (34.3%). In the low rainfall zone, the main varieties grown were Tuxpeño (31.0%) and UCA-St (31.0%).

Table 14. Maize varieties and hybrids planted in the 1994/95 season, Western Tanzania

	High rainfall zone		Low rainfall zone	
Variety/hybrid	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Local variety	12	34.3	3	10.3
H614	13	37.1	4	13.8
Tuxpeño	3	8.6	9	31.0
TMV1	1	2.9	ñ	ñ
UCA	2	5.7	2	6.9
UCA-St	1	2.9	9	31.0
ICW	3	8.6	2	6.9

6.2 Preferred Improved Maize Materials and Reasons for Farmers' Preferences

In the high rainfall zone, H6302 andH614 and Tuxpeño were the varieties most preferred by farmers, while farmers in the low rainfall zone preferred Tuxpeño and UCA-St (Table 15). Differences in preferences can be attributed to the marketing strategies of Tanseed. The distribution of maize seed by Tanseed followed the recommendations from research. The most valued seed traits were high yield, drought tolerance, and resistance to field pests and diseases.

In the high rainfall zone, Tuxpeño (71.4%), and H6302/H614 (57.1%) were mainly preferred for their high yields. In the low rainfall zone, Tuxpeño was preferred for its high yield (52.0%) and drought tolerance (44.0%), and UCA-St was mainly preferred for its high yield (72.7%).

Table 15. Preferred maize varieties/hybrids, Western Tanzania

	High rainfall zone		Low rainfall zone	
Variety/hybrid	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Local variety	6	16.2	2	3.9
H6302/H614	16	43.2	3	5.9
UCA	6	16.2	6	11.8
Tuxpeño	7	18.9	25	49.0
UCA-St	1	2.7	11	21.6
ICW	1	2.7	4	7.8

6.3 Farmers' Disadoption of Improved Maize

About 15% and 33% of the sample farmers in the high and low rainfall zones, respectively, had disadopted an improved maize variety. In the high rainfall zone, farmers had disadopted H6302/H614 (81.8%) and UCA (18.2%). Reasons for disadopting H6302/H614 were susceptibility to pests and diseases (37.5%), unavailability of seed (12.%), loss of seed from drought (25%), or replacement with a better variety (25%). All farmers had disadopted UCA because of its low yield.

Table 16. Farmers' reasons for preferring certain varieties/hybrids, Western Tanzania

Zone	Variety/hybrid	High yield (% farmers reporting)	Resists pests/diseases (% farmers reporting)	Tolerates drought (% farmers reporting)
High rainfall	Tuxpeño	71.4	–	14.3
	H6302/H614	57.1	14.3	7.1
Low rainfall	Tuxpeño	52.0	–	44.0
	UCA-St	72.7	9.1	–

Farmers in the low rainfall zone had disadopted H614 (44.4%), UCA (37.0%), and UCA-St (14.8%). The reasons for disadopting H614 were its susceptibility to pests and diseases (25.0%), lost seed (25.0%), late maturity (25%), and replacement with a better variety (25.0%). Farmers had disadopted UCA because of its low yield (50.0%), susceptibility to pests and diseases (20%), or the superiority of the local variety (20%). UCA-St was disadopted for its late maturity (50%), small cobs (25%), and loss of seed from drought (25%).

Table 17. Farmers' sources and use of credit, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Access to credit				
Yes	20	43.5	18	32.1
No	26	56.5	38	67.9
Source of credit				
NGOs	11	57.9	–	–
Cooperative union	3	15.8	15	93.8
Agro-companies	5	26.3	1	6.2
Inputs purchased				
Fertilizer	14	25.0	9	15.8
Seed	11	19.6	–	–
Pesticides	11	19.6	–	–
Availability of credit				
Difficult to obtain	20	42.6	47	90.4
Not difficult to obtain	27	57.4	5	9.6
Constraints				
No collateral	3	20.0	4	13.3
Lack of knowledge	7	46.6	6	20.0
Not a cash crop farmer	–	–	9	30.0
Bureaucracy	5	33.3	7	23.3
Other	–	–	4	13.3

7.0 Credit and Extension Services

7.1 Credit Availability

About 44% of the farmers in the high rainfall zone and 32% in the low rainfall zone used credit (Table 17). Farmers in the high rainfall zone obtained credit from non-governmental organizations (NGOs) (57.9%), agro-companies (26.3%), and the cooperative union (15.8%). Almost all farmers in the low rainfall zone got their credit from the cooperative union (93.8%). The amount borrowed averaged Tsh 20,700 (N=9) in the high rainfall zone and Tsh 41,000 (N=2) in the low rainfall zone. In the high rainfall zone, credit was mainly used for fertilizer, seed, and pesticides; it was used only for fertilizer in the low rainfall zone. Credit was significantly more difficult to obtain in the low rainfall zone (90.4%) than the high rainfall zone (42.6%) ((2 = 25.8; p=0.01). Lack of knowledge and bureaucracy were the main constraints to obtaining credit in the high rainfall zone. Farmers in the low rainfall zone reported that if one was not a cash crop farmer one lacked access to credit.

7.2 Extension Services

All districts in the survey area are covered by the National Agriculture and Livestock Extension Project (NALEP), sponsored by the World Bank and Government of Tanzania (GOT), and the training and visit (T&V) extension system is used in the study area. Farmers' sources of information on the improved maize technology package are shown in Table 18. Most farmers had received information on improved maize varieties, fertilizer, weed and pest management, and storage practices. Information on the use of herbicides, ox-drawn implements, and disease control measures was lower, especially in the low rainfall zone. The most important sources of information were research and extension.

Table 18. Farmers' sources of information about maize production technology, Western Tanzania

	High rainfall zone		Low rainfall zone	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Improved maize varieties				
Received information	43	76.7	45	78.9
Source of information[a]	–	–	–	–
Fertilizer				
Received information	50	98.0	56	100.0
Adopted recommendation	37	72.5	39	69.6
Source of information				
Research/extension	31	60.8	52	94.5
NGOs	10	19.6	2	3.6
Other sources	10	19.6	1	1.8
Weed management				
Received information	54	96.4	55	98.2
Adopted recommendation	54	96.4	56	100.0
Source of information				
Research/extension	30	53.6	37	68.5
NGOs	13	23.2	12	22.2
Other sources	13	23.2	5	9.3
Herbicide				
Received information	13	65.0	20	35.7
Adopted recommendation	0	0.0	0	0.0
Source of information				
Research/extension	8	80.0	17	89.5
NGOs	2	20.0	1	5.9
Other sources	2	20.0	1	5.9
Ox-drawn implements				
Received information	13	61.9	23	41.8
Adopted recommendation	11	55.0	16	29.1
Source of information				
Research/extension	7	58.3	22	88.0
NGOs	1	8.3	3	12.0
Other sources	4	33.3	0	0.0
Pest management				
Received information	34	82.9	46	82.1
Adopted recommendation	25	61.0	41	73.2
Source of information				
Research/extension	24	70.6	39	90.7
NGOs	6	20.0	3	7.0
Other sources	4	13.3	1	2.3
Disease control measures				
Received information	18	66.7	30	53.6
Adopted recommendation	12	44.4	24	42.9
Source of information				
Research/extension	13	76.5	28	96.6
NGOs	1	5.9	1	3.4
Other sources	3	17.6	0	0.0
Storage practices				
Received information	37	86.0	44	78.6
Adopted recommendation	28	66.7	39	69.6
Source of information				
Research/extension	28	80.0	37	86.0
NGOs	3	8.8	4	9.3
Other sources	4	11.4	2	4.7

[a] No data available.

8.0 Factors Affecting Adoption of Agricultural Technologies in the Study Area

8.1 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).

8.2. Adoption of Improved Maize in Western 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:

Yt	=	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 rate of adoption of improved maize in the high and low rainfall zones. In 1994, about 55% of the farmers in the high rainfall zone and 93% in the low rainfall zone had adopted improved maize. The rate of adoption for 1974–94 was 0.10 and 0.08 for the high and low rainfall zones, respectively. The higher rate of adoption in the low rainfall areas can partly be attributed to the influence of research and extension. Most of the evaluation trials were conducted in the low rainfall area. Only recently have research activities been undertaken in the high rainfall area through the Mubondo Research Station.

8.3. Tobit Analysis of Land Allocated to Improved Maize

The tobit model results on the proportion of land allocated to improved maize are presented in Table 19. 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 19, $\delta EY/\delta X_i$ shows the marginal effect of an explanatory variable on the

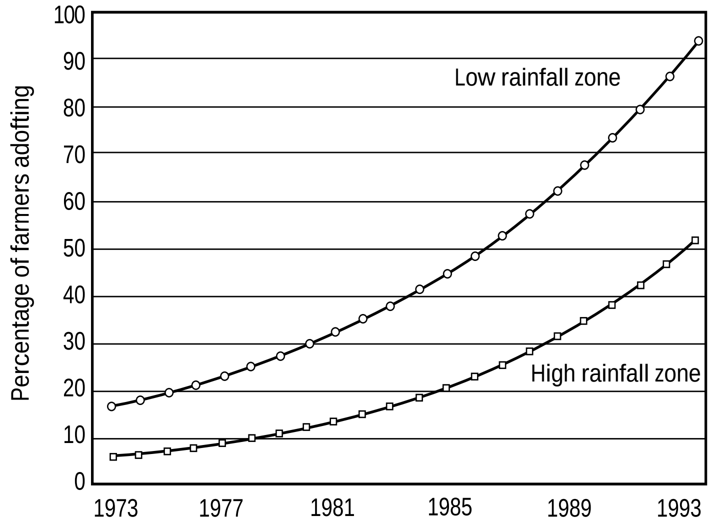


Figure 4. Adoption of improved maize in high and low rainfall zones, Western Tanzania.

Table 19. Tobit model estimates for land allocation to improved maize varieties

Parameter	**Coefficient**	**t-statistic**	***δEY/δXi***	***δEY*/δXi***	***δf(z)/δXi***
Constant	-0.0052	-0.0216	0	-0.004	-0.002
EXPF	0.0001	0.0141	2.19e-09	0	0
LAB	-0.0281	-1.5894***	0	-0.0191	-0.0117
EDVC	0.0071	0.4529	0	0.0048	0.003
WID	0.0114	1.3919	0	0.0077	0.0048
EXI	0.7107	2.4305**	0.110606	0.482757	0.2966
VA1	0.5626	3.1119*	0.06931	0.382157	0.234793
VA2	0.2299	0.8895	0.01157	0.156164	0.09595
VA3	0.1263	1.3871	0.0035	0.08579	0.05271
AEZ1	-0.3317	-3.7645**	0.02409	-0.22531	-0.13843
SIGMA	0.4241	12.1741*			
Sample size		113			
Number of positive observations		84			
Proportion of positive observations		74.33			
Z-score		0.66			
f(z)		0.32086			
Log likelihood function		-72.23			
Likelihood ratio test		35.5*			
X^2		23.59			

Note: *** = significant at p<0/1% level; ** = significant at p<0.5% level; * = significant at p<0.01% level.

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 significant variables were extension, varieties in group one (i.e., varieties that matured rapidly), and high rainfall. The marginal effect of extension on the mean proportion of land allocated to improved maize varieties was 0.11, and extension increased the probability of adoption by 29.7%. The negative sign on the high rainfall variable shows that farmers in the high rainfall zone are more likely to have lower values for the proportion of land allocated to improved maize. The marginal effect of the high rainfall zone on the mean proportion of land allocated to improved maize varieties was 0.11, and the probability of adoption decreased by 13.8% for farmers in the high rainfall zone. Farmers growing the short-maturing maize varieties (Katumani and Kito) were more likely to allocate more land to improved maize than to other groups of varieties. The marginal effect of short-maturing varieties on the mean proportion of land allocated to improved maize was 0.07, and short-maturing varieties increased the probability of adoption by 23.5%.

8.4 Probit Analysis of Fertilizer Use

Results of the probit model for the use of inorganic fertilizer are presented in Table 20. 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 20, the change in probability ($\delta Y/(\delta_i)$ 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 factor for correct prediction was 0.8. The inverse Mills ratio was not significant, indicating that the use of fertilizer was not directly related to the use of improved seed alone. Although the inverse Mills ratio was not significant, the calculated probability that farmers who used improved seed would use fertilizer was high. The use of improved seed increased the probability of using fertilizer by about 12%. The significant variable was the wealth index. An increase in the wealth index by one unit increased the probability of using fertilizer by 13%.

Table 20. Probit model estimates for fertilizer use

Parameter	Coefficient	t-statistic	$\delta EY/\delta X_i$
Constant	-0.9482	-1.0603	-0.2607
EXPF	-0.0056	-1.4326	-0.0015
LAB	0.0129	0.17401	0.0035
EDVC	0.0463	0.8273	0.0127
WID	0.4694	4.7152*	0.1291
EXI	-1.1051	-0.9381	-0.3039
IMR	0.4347	0.8871	0.1195
VA1	-0.6979	-0.7991	-0.1919
VA2	-0.8731	-0.7573	-0.2401
VA3	-0.4957	-1.4407	-0.1363
AEZ1	0.0065	0.0136	0.0018
Sample size	113		
Number of positive observation	69		
Proportion of positive observation	61.06		
R-squared	0.438		
Factor of correct prediction	0.832		
Log of likelihood function	-51.89		
Likelihood ratio test	47.2*		
X^2	23.59		

Note: * = significant at p < 0.01 level.

9.0 Conclusions and Recommendations

9.1 Conclusions

This study has provided information on maize production in Western 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 high and low rainfall zone was about 46 and 49 years, respectively, and farmers in both zones had about 18 years of farming experience. The level of education was about four years for both zones. Farm households in the high and low rainfall zones had about nine and eight family members, respectively. The number of female adults and children was significantly higher in the high rainfall zone.

The time for land preparation, planting, and harvesting depends on the rainfall pattern, but land preparation generally starts in August-September, and planting starts in October-December. Harvesting was mainly done between May and June. The maize plot was weeded twice at most. Most farmers do the first weeding after the first three weeks of planting and the second weeding depends on weed emergence. Most farmers in the high rainfall zone weed in November-December, while farmers in the low rainfall zone weed mostly in December-January. More farmers in the high rainfall zone weed twice compared to farmers in the low rainfall zone.

The use of fertilizer in maize production was constrained because of the high fertilizer price. Mostly farmers used urea; the average amount of fertilizer applied was higher in the low rainfall zone (57.2 kg/ha) than in the high rainfall zone (54.2 kg/ha). To increase soil fertility, farmers plowed crop residues under (mainly in the low rainfall zone). More farmers in the low rainfall zone rotated crops (66.7%) than farmers in the high rainfall zone (44.6%). The most important maize pests and diseases in both zones were stalk borer and MSV.

Most farmers recycled seed for up to five years, although others recycled seed for as many as 10–15 years. Seed was selected during harvesting and shelling for storage, and the chief criteria for selection were the size of the cob and grain maturity. Seed maize was stored separately from the main crop, mainly on cribs. Food maize was shelled and stored in gunny bags, cribs, or the *kihenge*. Most farmers treated stored maize with industrial chemicals to control pests.

The main maize varieties grown during the 1994/95 farming season in the high rainfall zone were local varieties, H614, Tuxpeño, and ICW. In the low rainfall zone, the main varieties grown for the 1994/95 farming season were local varieties, H614, Tuxpeño, and UCA-St. The improved maize varieties preferred by farmers in the high rainfall zone included H6302, H614, and Tuxpeño. Tuxpeño and UCA-St were preferred by farmers in the low rainfall zone. Varieties were preferred for their yield, drought resistance, and pest resistance. Improved maize varieties had been disadopted by about 14% of the farmers in the high rainfall zone and 33% in the low rainfall zone. Farmers in the high rainfall zone disadopted mostly H6302 and H614, and farmers in the low rainfall zone mainly disadopted H614 and UCA.

About 44% and 32% of the farmers in the high and low rainfall zones, respectively, used credit. The important credit institutions were cooperative unions, NGOs, and agro-companies that provided credit in kind. More farmers in the low rainfall zone (90.4%) reported that credit was difficult to obtain compared to farmers in the high rainfall zone (42.6%). Lack of knowledge (information) and bureaucracy were the main constraints to obtaining credit in the high rainfall zone. Farmers in the low rainfall zone reported that those who did not grow cash crops had no access to credit.

Most farmers had received information on improved maize, use of fertilizer, weed and pest management, and storage practices. The most important sources of information were research and extension.

The two-stage least squares analysis showed that extension, short-maturing varieties, and rainfall were significant factors affecting the proportion of land allocated to improved maize. Extension increased the probability of allocating land at the means by about 30%. Short-maturing maize varieties increased the probability of allocating land at the means by about 24%. Farmers in the high rainfall zone are 14% less likely to allocate land to improved maize. An increase in the wealth index by one unit increased the probability of using fertilizer by 13%.

9.2 Recommendations

Large parts of the Western Zone are prone to frequent drought that can destroy the maize crop or reduce yield and increase stalk borer attacks. Research should give priority to developing or screening varieties that yield well and tolerate drought stress and field pests, especially stalk borers. Flexible integrated management packages that combine a drought-tolerant variety with improved cultural practices such as timely planting and weeding can increase yields. Low-cost technologies for controlling stalk borer and MSV using cultural practices or environmentally friendly industrial chemicals should be developed.

More research effort should be directed to strategies for avoiding soil mining, supplementation of chemical fertilizers with different sources of organic manure, crop residue management, and soil conservation. Additional fertility research will be particularly relevant because use of chemical fertilizer is likely to remain low in the foreseeable future because of rising prices.

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.

Extension efforts need to be strengthened to increase the flow of information to farmers. More efforts should be directed toward appropriate recommendations for fertilizer use, as a majority of farmers use inefficient practices. Farmers should be advised on the use of organic manure to supplement chemical fertilizer. Furthermore, extension efforts should be directed toward the adoption of improved varieties, weed control, and the control of field and storage pests and diseases.

Formal credit is not available to all maize farmers. With rising input prices, providing credit to farmers becomes increasingly important. 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 it. 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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