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CIMMYT
Sustainable Maize and Wheat Systems for the Poor

SACCAR
Southern African Centre for Cooperation In Agricultural Research

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Printed in Mexico.

Correct citation: Mafuru, J., R. Kileo, H. Verkuijl, W. Mwangi, P. Anandajayasekeram, and A. Moshi. 1999. *Adoption of Maize Production Technologies in the Lake Zone of Tanzania*. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), the United Republic of Tanzania, and the Southern Africa Center for Cooperation in Agricultural Research (SACCAR).

Abstract: This study of the adoption of maize production technologies in the Lake Zone of Tanzania forms part of a larger study to evaluate the impact of maize research and extension throughout Tanzania over the past 20 years. Using a structured questionnaire, researchers and extension officers interviewed farmers in June-November 1995. Survey data were classified by agroecological zone (the low, intermediate, and high rainfall zones). Major factors affecting the adoption of improved maize practices were technical innovation characteristics and external influences. Tobit analysis showed that education, farmers' experience, farm size, family labor, extension, livestock units, and use of the hand hoe were significant factors affecting the proportion of land allocated to improved maize varieties. With respect to adoption of fertilizer, logit analysis showed that the odds of adopting fertilizer increased by a factor of 6.2 if a farmer received an extension visit. The use of improved varieties in the study area was low, especially in the low and intermediate rainfall zones. Suitable maize varieties should be developed for these areas, and hybrids should be developed for the farmers in the high rainfall zone. Flexible integrated management packages that combine a drought tolerant variety with improved cultural practices to control diseases and pests could increase yields. An efficient marketing system for inputs and outputs would benefit farmers by paying higher prices for maize and reducing the cost of fertilizer. Extension should be strengthened to increase the adoption of fertilizer, and farmers should receive more advice about using organic manure to supplement chemical fertilizer. Extension efforts should also be directed towards promoting the adoption of improved varieties, weeding, and management practices for controlling diseases and field and storage pests. 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 that often impede access to credit.

ISBN: 970-648-030-7
AGROVOC descriptors: AGROVOC descriptors: Tanzania; Lake Victoria; Plant production; Seed production; Seed industry; Production economics; Production factors; Socioeconomic environment; Production policies; Marketing policies; Credit policies; Prices; Demography; Maize; Zea mays; Varieties; High yielding varieties; Cultivation; Cropping patterns; Cropping systems; Inorganic fertilizers; Fertilizer application; Diffusion of research; Economic analysis; Input output analysis; Economic viability; Technology transfer; Mechanization; Innovation adoption; Small farms; Research projects
Additional keywords: Northern Tanzania; Agroecological zones; CIMMYT; SACCAR
AGRIS category codes: E16 Production Economics
E14 Development Economics and Policies
Dewey decimal classification: 338.16

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Abbreviations and Acronyms

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
DRT	Department of Research and Training
FSR	Farming systems research
FYM	Farm yard manure
LMV	Local maize variety
IMV	Improved maize variety
ICW	Ilonga Composite White
MASL	Meters above sea level
MFEC	Mogabiri Farmers' Extension Center
MOA	Ministry of Agriculture
MSV	Maize streak virus
NALRM	National Agricultural Research and Livestock Masterplan
NGO	Non-governmental organization
NMRP	National Maize Research Programme
OPVs	Open-pollinated varieties
RALDO	Regional Agricultural and Livestock Development Officer
SA	Sulphate of ammonium
SACCAR	Southern African Centre for Coordination of Agricultural and Natural Resources Research and Training
SARI	Selian Agricultural Research Institute
SG-2000	Sasakawa Global-2000
TANSEED	Tanzania Seed Company
TFA	Tanganyika Farmers' Association
TMV	Tanzania Maize Variety
TSH	Tanzanian shillings
TSP	Triple super phosphate
UCA-ST	Ukiriguru Composite A–Streak resistant
USAID	United States Agency for International Development
VEO	Village Extension Officer

Acknowledgments

We gratefully acknowledge the support of several individuals and institutions, which enabled this study to be conducted. Financial, institutional, and logistical support provided by the Ministry of Agriculture and Cooperatives (MAC), SACCAR, and CIMMYT is greatly appreciated.

We thank F.M. Shao (former Commissioner for Research and Training, MAC), the Zonal Director of Research and Training in the Lake Zone, Joel Ransom (of CIMMYT–Nairobi and now CIMMYT–Nepal), T.N. Kirway (Assistant Commissioner, FSR, MAC), and D. Martella (REDSO/ESA) for assistance rendered with various aspects of this study.

We are also thankful to E. Nkonya (SARI, Arusha) for supervising the data entry and P. Kamuntu, D. Kibani, H. Kwikwega, M. Mlima, B. Mtilla, F. Nkamu, and J. Ruzo for conducting the survey. We thank all the RALDOs, DALDOs, DIVEOs, and VEOs who helped during the surveys and the farmers who patiently listened and responded to the questions.

We would also like to thank CIMMYT Publications staff for editing and producing this report. Special thanks go to Wzo. Aklilewerk Bekele, CIMMYT secretary, for ably typing the draft report.

Executive Summary

Maize provides 60% of dietary calories and more than 50% of utilizable protein to the Tanzanian population. The crop is cultivated on an average of two million hectares, which is about 45% of the cultivated area in Tanzania. Recognizing the importance of the maize crop to the lives of Tanzanians, the government has committed human and financial resources to developing the industry. A National Maize Research 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 considerable impact in increasing food production.

This reports 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 Lake Zone, which includes Kagera, Shinyanga, Mwanza, and Mara regions. The recommended maize varieties for the low rainfall zone are Katumani, Kito, Staha, and Tuxpeño. Kilima, Staha, Katumani, and Kito maize varieties are recommended for the intermediate rainfall zone. Ukiriguru Composite A and hybrids are recommended for the high rainfall zone.

Survey data were grouped into three agroecological zones (low, intermediate, and high rainfall zones), which are the most important maize production zones. A tobit analysis was used to analyze the factors affecting the allocation of land to improved maize. Logit analysis was used to test for factors affecting the use of inorganic fertilizer.

The mean age of the household head in the low, intermediate, and high rainfall zones was about 43, 46, and 43 years, respectively, and household heads had an average farming experience of about 20 years. Farmers' level of education was low, averaging about 4.5 years in the low and intermediate rainfall zones, and 7 years in the high rainfall zones. Households averaged about 14, 13, and 11 persons in the intermediate, low, and high rainfall zones, respectively. The number of female adults and children was higher in the intermediate rainfall zone. The average farm size was highest in the intermediate rainfall zone (46 acres)[1] compared to the low (20 acres) and high (6.5 acres) rainfall zones. The number of cattle in the intermediate rainfall zone (48) was significantly higher ($p=0.05$) than in the low (24) and high rainfall zones (5.6).

Land preparation, planting, and harvesting dates depend on the rainfall pattern. In the low and intermediate rainfall zones land preparation was done mostly in September–October, while in the high rainfall zone it was done in November–January. Maize was planted between October and November in the low and intermediate rainfall zones and between January and March in the high rainfall zone. Farmers in the high rainfall zone used smaller spacing between rows and hills compared to farmers in the low and intermediate rainfall zones. Most farmers weeded their maize plot twice. Timing of the first and second weeding depended on the rainfall pattern and time of planting, but most farmers weeded after the first two weeks of planting and again after the emergence of weeds. Most farmers in the high rainfall zone weeded between March and June, while farmers in the low and intermediate rainfall zones weeded mostly between November and January. Maize was harvested between April and July in the low and intermediate rainfall zones, while farmers in the high rainfall zone harvested between August and September.

The use of fertilizer for maize production was constrained by its high price and by farmers' lack of knowledge of the technology. Farmers used mainly urea and calcium ammonium nitrate. The average amount of fertilizer used was higher in the high rainfall zone (20 kg/ha) compared to the low (13 kg/ha) and intermediate rainfall zones

[1] 1 acre = 0.4 ha.

(17.5 kg/ha). To increase soil fertility, farmers plowed crop residues into the soil, mainly in the low and high rainfall zone. Farmers in the intermediate zone (58.1%) were more likely to use crop residues as livestock feed. More farmers in the low (76.1%) and high (83.3%) rainfall zones rotated crops compared to farmers in the intermediate rainfall zone (60.4%). The important field pests and diseases for maize in all zones were stalk borer and maize streak virus.

In the low (52.4%) and intermediate rainfall zones (78.6%), farmers recycled maize seed for more than ten years. Farmers in the high rainfall zone (75%) recycled seed for two years. Seed was selected from the previous harvest based on the size of the cob and lack of pests/diseases. Seed selection was mainly done at home after harvesting. Seed was stored separately from the main crop, mainly in cribs. Maize was shelled and stored in gunny bags, cribs, or a local storage structure (*kihenge*). Most farmers in the low (94%) and intermediate rainfall zone (88.6%) treated their stored maize with industrial chemicals to control storage pests, while in the high rainfall zone only 22% of the farmers treated their maize.

The main maize varieties grown during the 1994/95 farming season in the high rainfall zone were local varieties and H625 (imported from Kenya). In the low rainfall zone, the main varieties grown in the 1994/95 farming season were local varieties, Kilima, H614, Tuxpeño, Katumani, H625, and Zambia. In the intermediate rainfall zone, farmers mainly grew local varieties, Kilima, H625, and Zambia. The improved maize variety preferred by farmers in the high rainfall zone was H625. Varieties were preferred for yield potential, resistance to drought, and resistance to field pests. About 29% of the farmers in the low rainfall zone, 25% in the intermediate zone, and 56% in the high rainfall zone had disadopted improved maize varieties. Farmers in the high rainfall zone mainly disadopted H625 and Katumani, and farmers in the low rainfall zone mainly disadopted Tuxpeño. Farmers in the intermediate rainfall zone mainly disadopted Katumani and Tuxpeño.

None of the farmers in the high rainfall zone used credit, and numbers of credit users were also low in zones of low rainfall (about 3% of farmers) and intermediate rainfall (about 2% of farmers). Cooperative unions were the only credit institutions. All farmers in the high rainfall said that credit was difficult to obtain; 82.4% of farmers in the low rainfall zone and 62.5% in the intermediate rainfall zone said the same thing. In all zones, lack of knowledge (information) about credit and lack of credit facilities were the main constraints to obtaining credit. Most farmers had received information on all of the agronomic practices recommended by extension except for disease control and use of herbicides. The most important sources of information were research and extension officials.

The tobit analysis showed that education, farmers' experience, farm size, family labor, extension, livestock units, and use of the hand hoe were significant factors affecting the proportion of land allocated to improved maize varieties. Extension and education increased the probability of allocating land to improved maize at the means by about 12% and 1.8%, respectively. Farmers' experience and farm size increased the probability of allocating land at the means by about 0.5% and 0.7%, respectively. Family labor and livestock units decreased the probability of allocating land at the means by about 1.9% and 0.6%, respectively. Farmers using hand hoes are 13% less likely to allocate land to improved varieties. The odds in favor of adopting fertilizer increased by a factor of 6.2 if a farmer received an extension visit.

Technical innovation characteristics and external influences are the major factors affecting the adoption of improved maize practices. Field pests limit maize production, and flexible integrated management packages that combine a drought tolerant variety with improved cultural practices could increase yields. Low-cost technologies for controlling stalk borer and maize streak virus using cultural practices or environmentally friendly industrial chemicals should also be developed.

Most improved varieties are responsive to fertilizer, and farmers usually obtain economic yields with fertilizer. But the use of fertilizer is constrained by its high price and farmers' lack of knowledge of fertilizer. An efficient marketing system for inputs and outputs would benefit farmers by paying higher prices for maize and reducing the cost of fertilizer. Such a system cannot be established without policy support from the government. Studies of the economics of fertilizer use should be undertaken, especially now that input and output markets have been liberalized.

The use of improved varieties in the study area was low, especially in the low and intermediate rainfall zones. Farmers in the high rainfall zone mainly grew improved maize varieties imported from Kenya (H625). Also, most farmers in the low and intermediate rainfall zone recycled maize seed for more than ten years. Suitable maize varieties should be developed for farmers in the study area, especially for the low and intermediate rainfall zones. Hybrids should be developed for the farmers in the high rainfall zone.

Extension should be strengthened to increase the flow of information to farmers. More effort should be directed toward fertilizer technologies, as the majority of farmers use inefficient practices. Farmers should receive more advice about using organic manure to supplement chemical fertilizer. Furthermore, extension efforts should be directed towards promoting the adoption of improved varieties, weeding, and management practices for controlling diseases and field and storage pests. Farmers in the high rainfall zone need to be encouraged to treat their stored maize against insect infestation.

Credit is not available to most maize farmers through formal channels, although the availability of credit becomes increasingly important as input prices rise. 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 that often impede access to credit. Farmers should also be encouraged to form credit groups, because lending to groups tends to reduce transaction costs and ensures a high rate of loan recovery.

Adoption of Maize Production Technologies in the Lake Zone of Tanzania

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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 38% (Due 1986).

Maize is grown in all 20 regions of Tanzania. The crop is cultivated on an average of two million hectares (about 45% of the cultivated area), mostly 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 produces a surplus in good growing years, when it becomes 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 Tanzanians, the government has been committing significant human and financial resources to develop the industry. Research and extension focusing on 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 many farmers (Maliyamkono and Bagachwa 1990). The food crisis prompted the nation to launch several campaigns, such as "agriculture for survival" (*kilimo cha kufa na kupona*), with the objective of attaining self-sufficiency in food production. The country also initiated a maize project in 1974 with the 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 given the broad objective of developing cultivars suitable for major maize-producing areas.

The NMRP and the extension service have made a considerable impact on 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 in the Lake Zone. The objectives of the study were to describe the maize farming systems in the Lake 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

Tanzania is divided into seven agroecological zones (Samki, Miany, and Dewan 1981; NALRM 1991). The Lake Zone is in the northern part of Tanzania and comprises Mwanza, Mara, Kagera, and Shinyanga regions (Figure 1). The first three regions border Lake Victoria. The zone comprises 25 districts, of which 4 are urban and 21 rural (FSR 1996). The zone occupies 120,271 km^2 (Maliyamkono and Bakuchwa 1990) and has a population of 5,942,232 (Government of Tanzania 1988). Maize is the main food crop in the zone, followed by sorghum and cassava. Soil fertility, precipitation, and the length of the growing period mainly determine an area's suitability for maize production. Maize is grown throughout the Lake Zone, although sometimes under risky conditions. Farmers grow maize even under risky conditions, because they prefer to eat maize, can sell it for cash, and can store and transport it easily. Maize is planted on ridges (in sandy soils) or flat seedbeds (in heavy soils). It is commonly intercropped with legumes such as cowpeas, groundnuts, green gram, and bambara nuts. Other crops, including sweet potato, cassava, and pigeon pea, are also commonly intercropped with maize.

The Lake Zone can be divided into three major agroecological zones: an intermediate zone receiving low rainfall; an intermediate zone with high rainfall; and a highland zone.

1.2.1 Intermediate zone (950–1,500 masl) with low rainfall (850–1,100 mm) (Mwanza, Shinyanga, part of Kagera and Mara region)

The cropping system in this zone comprises several rotations of annual crops. The major food crops are cassava, maize, paddy, beans, sweet potatoes, and groundnuts. Cotton is the only major cash crop, although some food crops, such as rice, maize, and groundnuts, are also sold for cash in local markets. The zone has a bimodal rainfall pattern. The short rains (*vuli*) start in October and peak in December, whereas the long rains (*masika*) start in March and peak in April. The dry season starts in June and ends in September.

The following villages were visited during the survey: Igunda and Bukomela (in Kahama District); Busekeseke (Sengerema District); Nyamigogo (Geita District); and Bwera

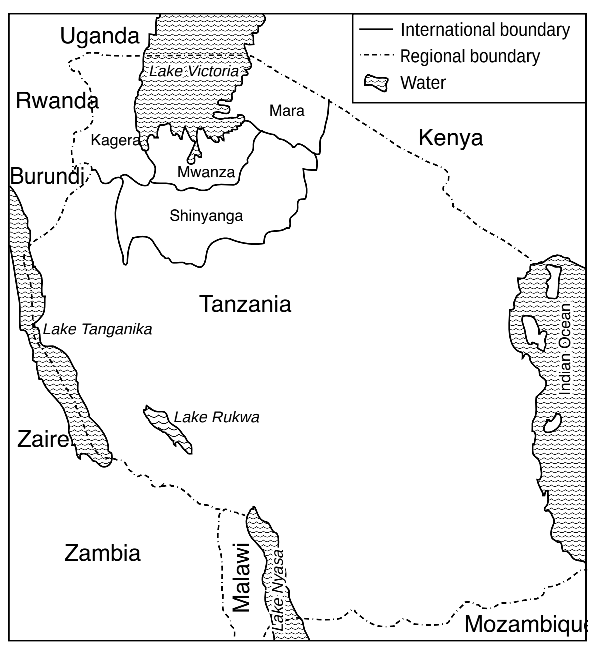

Figure 1. The four regions of the Lake Zone of Tanzania.

(Biharamulo District). These districts (Kahama, Sengerema, Geita) are part of the cotton/cereal/rice-based cropping system (Sukumaland) of the Lake Zone.

1.2.2 Intermediate zone (950–1,500 masl) with high rainfall (>1,100 mm) (parts of Shinyanga [Kahama District] and Mara [Tarime and Serengeti Districts])

Maize is an important crop in the intermediate zone, where it is grown by more than 90% of the small-scale farmers. After the crop was introduced in 1950s, cultivation of maize increased and cultivation of sorghum declined. In areas with sufficient rainfall, maize offers the opportunity to avert food shortages because it responds well to improved management practices and unlike other cereals (e.g., rice, sorghum) is not attacked by birds.

The villages sampled for the survey included Matongo in Bariadi District and Nyang'hwale and Ilolangulu in Kahama District. These villages are part of the Sukuma agropastoral system that is predominant in north central Tanzania. Similar characteristics are shared by Mwanza, Maswa, Bariadi, and Shinyanga Districts. The soils are sandy to sandy clay but vary by location. Soils range from the shallow, perfectly drained soils found on hillcrests to the moderately deep, well-drained soils on hill slopes and the deep, imperfectly drained black clay soils of the vast bottomland.

1.2.3 Highland zone (>1,500 masl) with high rainfall (>1,500mm) (parts of Tarime District and Kagera Region)

The Tarime highlands in northwestern Tanzania range in elevation from 1,500 to 1,850 masl. A slight gradient in altitude is seen from west to east, the lower areas being located near Tarime and Sirari towns and the upper areas in the far east (Bakema et al. 1989). A favorable climate and relatively fertile soils enable farmers to produce most annual crops twice per year. In the long rains, land preparation for crop production starts in November and ends in the beginning of January. In the short rains, land preparation for crop production starts in June. Average rainfall is about 1,550 mm a year.

Maize was introduced into the Tarime highlands by the colonial administration in the 1920s, and now more than 90% of farmers grow the crop. Topography, soils, and access to markets determine the land use pattern. Four major land use patterns are distinguished: (1) the densely populated, densely cropped escarpment area, which has a great diversity of crops, including coffee, banana, maize, cassava, and fallow for grazing; (2) the densely populated northern hills and plateau, which have a slightly less diversified cropping pattern (some coffee and banana; cassava is dominant); (3) the central valley, covered by grasslands mainly used for grazing; and (4) the stony patches on the northern hills, where granite outcrops covered with acacia bushes and short grasses are used for grazing cattle.

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 Lake Zone was allocated 162 farmers or approximately 16% of the national sample. Multistage, purposive sampling procedures were used to select farmers for the survey. Districts in the zone were selected on the basis of maize production figures from the Ministry of Agriculture's statistical unit. Eleven districts were purposively sampled. Within each district, the villages that were important for maize production were selected with the help of extension staff. Nine villages were chosen (Table 1, Figure 2). From each village, approximately 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 and Zinnah 1992; Misra, Carely, and Fletcher 1993); and the farming objective (CIMMYT 1988). Factors in the first category include 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

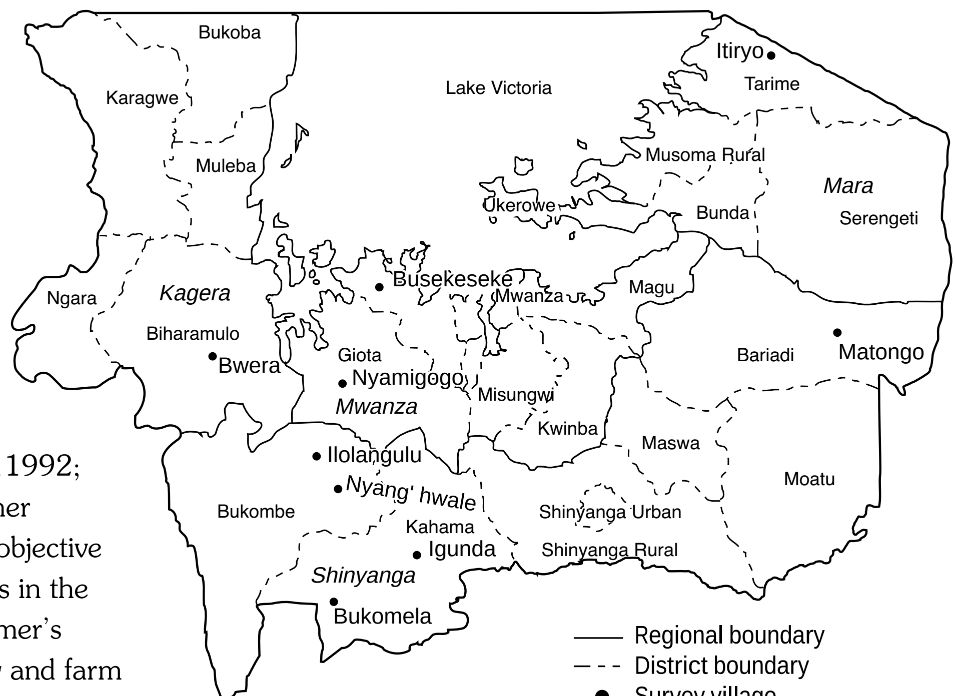

Figure 2. Survey villages in the Lake Zone of Tanzania.

Table 1. Villages visited during the survey, Lake Zone, Tanzania

Zone	Village	District	Region
Mid-altitude, low rainfall	Igunda, Bukomela	Kahama	Shinyanga
	Bwera	Biharamulo	Kagera
	Nyamigogo	Geita	Mwanza
	Busekeseke	Sengerema	Mwanza
Mid-altitude, high rainfall	Matongo	Bariadi	Shinyanga
	Nyang'hwale and Ilolangulu	Kahama	Shinyanga
High altitude	Itiryo	Tarime	Mara

improved maize variety). The third category assesses how different strategies used by the farmer (e.g., commercial versus subsistence farming) influence the adoption of technologies. In this study a tobit model is used to test factors affecting the allocation of land to improved maize varieties, and a logit model is used to test factors affecting the adoption of fertilizer. The tobit model (McDonald and Moffitt 1980; Maddala 1983), which tests factors affecting the incidence and intensity of adoption, can be specified as follows:

$$\begin{aligned} Y_t &= X_t\beta + U_t && \text{if } X_t\beta + U_t > 0 \\ &= 0 && \text{if } X_t\beta + U_t \leq 0 \\ & && t = 1,2,\ldots, N \end{aligned}$$

where:

Y_t = expected amount of land allocated to improved maize varieties at a given stimulus level, X_t;
N = number of observations;
X_t = vector of independent variables;
β = vector of unknown coefficients; and
U_t = independently distributed error term assumed to be normal with zero mean and constant variance σ^2.

The logit model can be specifed as (Gujarati 1988):

$$\ln(P/(1-P)) = X_t\beta + \varepsilon_i$$

where X_t is the index reflecting the combined effect of X independent variables that prevent or promote adoption. The index level X_t can be specified as:

$$X_t = \beta_0 + \beta_1 X_1 + \ldots + \beta_8 X_8 + \varepsilon_i$$

where:

β_0 = constant;
X_1 = FARMS (farm size, in acres);
X_2 = EXP (farming experience of household head, in years);
X_3 = EDUC (education level of household head, in years);
X_4 = LUNITS (livestock units, expressed as an index in which livestock numbers are aggregated using weighting factors: cow = 0.8; goat = 0.4; sheep = 0.4);
X_5 = EXT (dummy variable for whether farmer received an extension visit);
X_6 = FLABOR (family labor, expressed as an index in which family members are aggregated using weighting factors: male and female adults above 16 years = 1; children between 12 and 15 years = 0.5);
X_7 = HANDHOE (dummy variable for the use of a hand hoe to prepare land; the ox-plow was not included in the model to avoid multicollinearity (Griffiths, Hill, and Judge 1993; Greene 1993);
X_8 = HLAB (dummy variable for hired labor); and
ε = error term.

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 (CIMMYT 1993). The following variables were hypothesized to influence the adoption of improved maize varieties and fertilizer:

Farm size: Farm size is an indicator of wealth and perhaps a proxy for social status and influence within a community. A larger farm size is expected to be positively associated with the decision to adopt improved maize technology. Farm size can also encourage farmers to intensify agricultural production, in which case a larger farm size is expected to be negatively related to the adoption of improved maize technology.

Farmer's experience: A farmer's experience can generate or erode confidence. With more experience, a farmer can become more or less averse to the risk implied by adopting a new technology; thus this variable can have a positive or negative effect on a farmer's decision to adopt an improved maize technology.

Education: Exposure to education should increase a farmer's ability to obtain, process, and use information relevant to the adoption of improved maize technology. Education thus is thought to increase the probability that a farmer will adopt an improved maize technology.

Livestock ownership: Ownership of livestock is hypothesized to be positively related to the adoption of improved maize technologies.

Contact with extension: Agricultural extension services provided by the Ministry of Agriculture are the major source of agricultural information in the study area. It is hypothesized that contact with extension workers will increase farmers' likelihood of adopting improved maize technologies.

Household size: Because larger households are more likely to provide the labor that might be required by improved maize technologies, a larger household size would be expected to increase the probability of adopting improved maize technologies.

Hand hoe: Use of a hand hoe to prepare land should have a negative influence on the adoption of improved maize technologies.

Hired labor: The use of hired labor is hypothesized to be positively related to the adoption of improved maize technologies.

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 is produced on medium-scale commercial farms (10–100 ha), and the remaining 5% is grown 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. 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 agronomic research, which later formed the basis for recommendations that were applied to the entire country.

Before 1966, maize research in Tanzania was conducted at regional centers, each of which was responsible for a geographical area (Jones and Nyambo 1982), but this system resulted in some duplication of effort. The National Maize Research Programme (NMRP) was established in the Lake Zone at Ukiriguru Research Center in 1966 to coordinate maize research and improve the utilization of research resources. The NMRP coordinates all phases of maize research, from varietal development and crop management research on the experiment station to verification trials in farmers' fields. In 1974, the NMRP was moved to Ilonga Research Center in the Eastern Zone. The NMRP has divided the country into three major agroecological zones for varietal recommendations:

1. The highlands (elevations >1,500 masl), with a growing period of 6–8 months.
2. The intermediate (mid-altitude) zone (900–1,500 masl), which is further divided 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).
3. 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 intermediate zone. Kito is an early maturing variety adapted to both low and intermediate 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 intermediate 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 MSV-resistant versions of Kilima, UCA, Kito, and Katumani: 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 the choice of variety, plant spacing, plant density, fertilizer rate, weeding regime, and pesticide use.

2.2 Maize Research in the Lake Zone

For many years, the main food crops produced on the lighter soils of the Lake Zone were bulrush millet, cassava, sorghum, sweet potatoes, and maize. Sorghum was the dominant crop on the heavier soils and was often intercropped with legumes (groundnuts, cowpeas, bambara nuts, and beans). Since 1962, however, the cultivation of bulrush millet has declined in favor of maize. During the last 50 years maize has gradually become the most important crop in the Lake Zone. Farmers moved away from millet production partly because of the losses from bird damage. The excellent palatability of maize and its easier management compared to sorghum and bulrush millet have also helped increase its popularity.

With the exception of some areas, such as the North Mara Highlands, part of Kagera region, and most of Geita and Bariadi Districts, the Lake Zone is not considered “suitable” for maize production because of low rainfall at flowering and low soil fertility. Even so, farmers’ preference for maize over other crops has continued to increase. Because dry spells, poor soils, and post-harvest problems render maize production conditions far from optimal in most parts of the Lake Zone, special recommendations had to be developed for maize production. More recently, high demand for maize and its high unofficial market price have also contributed to the increase in maize area and to the decline in the area planted to other food crops and cotton.

Since Ilonga assumed responsibility for coordinating maize research in Tanzania, Ukiriguru Research Institute has been responsible for screening progenies, testing varieties and hybrids emerging from the NMRP, and conducting agronomy trials to solve specific problems. Varieties and hybrids suited to the Lake Zone can be classified as early maturing (Katumani and Kito/Kito–St), medium maturing (Kilima/Kilima–St, Staha, and TMV1), and long maturing (UCA and hybrids H613, H614, and H622). In Tarime highlands, farmers also use hybrid maize imported from Kenya. The choice of variety depends on farmer’s objectives, the length of the rainy season, and the amount of rainfall received. Varieties suitable for high rainfall areas are hybrids and UCA. Other varieties are available for a range of sowing dates. In low rainfall areas where the growing season is short, Kito, Katumani, and TMV1 are considered suitable varieties.

The agronomy program in the Lake Zone has carried out studies on weed control (with special attention to weeding regimes and *Striga* control), fertilizer trials in relation to new varieties, planting densities, other management practices such as intercropping and related cropping systems, and disease and pest control. On-farm trials and demonstrations of improved technologies are undertaken in collaboration with the Farming Systems Research Program.

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. Locally bred cultivars have flint grain, good pounding and storage qualities, and yield as well as CG4141. They are marketed mainly by the Tanzania Seed Company (TANSEED), which has not done well in the newly competitive seed industry. This has contributed to the reduced adoption of locally bred hybrids. About 83% of the farmers in the high rainfall areas of the Lake Zone grew H625 from Kenya, while only 12% and 6% of the farmers in the low rainfall and intermediate rainfall zones grew imported improved varieties. 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 also 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 that are 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 the private companies is purer, more uniform, and higher yielding than seed from TANSEED, which has served to reduce demand for TANSEED products.

The drawbacks of the new varieties sold by Cargill and Pannar are their high price, poor storability, poor pounding quality, and unsatisfactory taste. Pounded maize is used to make a local dish prepared from grains whose seedcoat has been removed (*kande*). Some farmers also pound their maize before milling to make a whiter and softer dough (*ugali*). When pounded, maize grain with a soft seedcoat 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 (CG4141) and Pannar (PAN 6481) seed 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 input 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 persistent 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 can now 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.

2.4 Maize Production Technology Recommendations

The recommendations issued by regional and national research programs are related to improved varieties, optimum sowing dates, the use of fertilizer and farmyard manure (FYM), weed control, and disease and pest control. These recommendations are summarized in Table 2.

2.4.1 Varieties

As noted, maize research in Tanzania has resulted in the release of several varieties. The recommended varieties, fertilizer rates, spacing, pest control, and weeding are shown in Table 2. Depending on their time to maturity, resistance to diseases, and tolerance to certain weather conditions, varieties are suitable for different ecological conditions. Local flint varieties are better adapted to adverse conditions. Staha, Tuxpeño, Kito, and Katumani are recommended for the lowlands. Kilima, Staha, Katumani, and Kito maize varieties are recommended for the intermediate zone with low rainfall. Ukiriguru Composite A and hybrids are recommended for the high rainfall areas.

2.4.2 Land preparation, planting time, method, and spacing

Land preparation should start early enough so that planting can be done on time. Good tillage is important, as it allows free movement of water and air, which are vital for maize plant growth, and minimizes weed infestation at the early stages of maize growth. It is recommended that in light sandy

Table 2. Maize production recommendations for the Lake Zone, Tanzania

Variety	Last planting date	Fertilizer rate/ha	Spacing (cm)	No. of plants per hill	Insecticides for stalkborers	Weeding
UCA	Late Dec.– early Feb.	3–6 bags of SA and 2 bags TSP	75x30 75x60 90x25 90x50	1 2 1 2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP
Kilima	Late Dec.– early Feb.	3–6 bags of SA and 2 bags TSP	75x30 75x60 90x25 90x50	1 2 1 2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP
TMV1	Early Feb.	3–6 bags of SA and 2 bags TSP	75x30 75x60 90x25 90x50	1 2 1 2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP
Katumani	Early Feb.	3–6 bags of SA and 2 bags TSP	75x40	2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP
Kito	Early Feb.	3–6 bags of SA and 2 bags TSP	75x40	2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP
Hybrids (H632, H622, H6302, H614)	Late Dec.– early Feb.	3–6 bags of SA and 2 bags TSP	75x30 75x60 90x25 90x50	1 2 1 2	Thiodan 4% and Cymbush 0.5% dusts	2–3 WAP and 5 WAP

Note: WAP = weeks after planting; SA = sulphate of ammonium; and TSP = triple super phosphate.

soils maize should be planted on ridges to conserve moisture and prevent soil erosion. Ridges can be prepared by hand hoe, oxen, or tractor. Heavy soils can be cultivated on the flat.

Time of planting is a complex issue in the Lake Zone, where rainfall patterns and distribution vary. Farmers are advised to plant maize so that flowering and seed setting coincide with the months of reliable rainfall. The planting date for a given area is chosen depending on the rainfall pattern in the area and the number of days that a given variety or hybrid requires to reach tasselling. In areas where there are two rainfall peaks with a dry spell in between, when rainfall is unreliable, maize should be planted during and up to the end of the first peak so that vegetative growth occurs during the drier months and flowering occurs at the beginning of the second rainfall peak. The last dates for maize planting in the different areas of the Lake Zone are:

1. For the Tarime highlands in Mara region, the last planting date for maize in the short rains should be mid-November. Maize grown in the long rains should be planted before mid-March.
2. In Mwanza and Shinyanga regions, maize should be sown before mid-October for the short rains and at least before mid-February for the long rains.
3. In Kagera region, maize should be sown before the end of October for the short rains and before the end of March for the long rains.

Only high quality and well-graded seed should be planted. Seed can be obtained by selecting good ears from the previous harvest. Seed of open-pollinated varieties (composites) should be dried, processed, and treated with insecticides to control soil-borne organisms and pests of stored grain. Unlike seed of open-pollinated varieties, hybrid seed should not be recycled from one season to the next but should be purchased every year.

Seed should be planted immediately after the soil is ridged or after the soil surface has been loosened to ensure germination and a good stand. Grain yield is associated with plant spacing and the type of variety or hybrid. Early maturing varieties require less space between plants than medium and late maturing cultivars (Table 2). On light soils, farmers prepare larger ridges of 150 cm, and usually two rows of maize are grown on each ridge. The recommended spacing is 75 x 30 cm or 90 x 25 cm with one plant left after thinning. A similar plant population can be obtained by sowing maize at 50 x 90 cm or 75 x 60 cm with two plants per hill. The spacing between and within rows can be manipulated to get similar plant populations of 40,000–50,000 plants per hectare. If rainfall is reliable, 3 plants per hill at 90 x 75 cm can produce similar yield. For short maturing maize varieties (Kito and Katumani), a spacing of 75 x 40 cm with 2 plants per hill is recommended.

2.4.3 Fertilizer types and method of application

The maize plant has a relatively high demand for nutrients, particularly nitrogen (N) and phosphorus (P). These nutrients may be obtained through the application of farmyard manure (FYM) or inorganic fertilizers. Farmyard manure is applied at a rate of 5–10 t/ha by spreading 15 kg of FYM after every five steps or 4–5 m. The manure is put in the furrow before the ridges are made or spread on the field before the land is cultivated.

Nitrogen is a major limiting nutrient and is needed in large amounts for higher maize yield. An adequate supply of N is needed throughout the growing season and is one of the most important factors for improved soil management practices. In the intermediate and high rainfall areas, where moisture is reliable, the use of N fertilizers results in greater economic returns. In medium and low rainfall areas, response to N fertilizers is unreliable and poor.

The recommended rate of N fertilizer is 60 kg N/ha applied as a top dressing (Jones and Nyambo 1982; Mowo et al. 1993). Nitrogen applications may be split by applying about 50% of the total amount at planting and the remainder just before tasseling. Calcium ammonium nitriate (CAN) or nitrochalk is the preferred type of fertilizer. Sulphate of ammonium (SA) is not recommended because it rapidly acidifies the soil. Nitrogen fertilization is not recommended for the heavy *mbuga* soils.

Phosphorus is also essential for plant growth, as it is involved in the transfer of energy within the plant and has a structural role in a number of compounds. Farmers are presently advised to apply 40 kg P_2O_5/ha as basal fertilizer. Phosphorus should be applied in a single dose at planting.

Fertilizer is normally placed 5 cm below the depth of the seed and about 5–8 cm to the side. This is accomplished 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.

2.4.4 Weeding time, frequency, and method

Weeds seriously affect maize yield and can cause major yield reductions by competing with the maize crop for water, light, and nutrients. Some weeds may also harbor insect pests and diseases that directly infest the plants, also causing yield losses.

Two weedings are recommended for maize production in the Lake Zone, using hand hoes. The first weeding should be done two weeks after germination and the second before tasseling. The introduction of the ox-weeder has reduced the labor requirement for weeding if the crop is sown in rows. For large-scale maize production, the use of herbicide in combination with other practices is an economical method of weeding if labor is a constraint.

2.4.5 Pest and disease control

The diseases common to maize in the Lake Zone are leaf blight and leaf rust, but resistant varieties have been released. Maize streak virus still poses a threat to susceptible maize cultivars and can cause complete crop loss. Cultural practices such as early planting have always been important for reducing disease losses.

Stalkborer is a major insect pest in some areas and has caused yield losses of 25% or more. These pests do not breed during the dry season, so the number of larvae surviving the dry season primarily determines the extent to which the maize crop will be infested at the beginning of a new growing season. Survival of the stalkborers depends on the amount of maize plant residue left from the preceding season. Burning maize stalks after harvest is one means of controlling stalkborers. The recommended chemical control is to apply 5 kg/ha Thiodan 4% dust in the plant funnel when early evidence of damage appears.

Striga (a parasitic weed) can seriously damage the maize crop. Farmers are advised to uproot all *Striga* plants in the field and throw them far away or burn them to ash before they set seed.

2.4.6 Harvesting and storage

Harvesting may begin as soon as maize grain is physiologically mature. This occurs when the grain contains 30–40% moisture, depending on the variety. The bulk of the crop may be harvested at 25–35% moisture. Large harvest losses from storage pests occur when harvesting is done at a moisture level below 18–20%.

When seed has dried to about 12–14% moisture content, it should be stored in a cool, dry place free from rodents and storage pests. One 90–100 kg bag of well-dried maize should be stored with 90–100 g of Actellic Super dust.

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

3.1 Demographic Characteristics

Table 3 lists characteristics of households in the Lake Zone. The average age of the household head was 43 years in the low and high rainfall zones and 46 years in the intermediate rainfall zone. However, the average age of farmers was not significantly different between the zones. Farming experience in all zones was about 20 years, implying that on average farmers started farming in their early twenties. Farmers in the high rainfall zone had lived significantly longer (36 years, p=0.05) in the same village than farmers in the low (22 years) or intermediate rainfall zones (19 years). The level of education of the household head in the low and intermediate rainfall zones was 4.5 years, while in the high rainfall zone it was significantly longer (7 years, P=0.05). Most farmers in the high rainfall zone had completed their primary education in the neighboring country (Kenya).

The average household size was highest in the intermediate rainfall zone (14), compared to 13 and 11 in the low and high rainfall zones, respectively. These differences can be explained by the fact that households in the high rainfall zone tend to have fewer children and that households in the intermediate rainfall zone have a higher average of female adults. These differences were not significant, however.

Most adult family members (85% of men and 82% of women) work on the farm permanently. The remaining adult members of the household (1.5 men and 1.4 women) work on the farm part time. In the low rainfall zone, 92% of the men in the household participate in farm activities, followed by

Table 3. Demographic characteristics of sample households, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Household head						
Age (yr)	43.1	11.8	46.2	14.8	43.4	12.4
Years lived in village	22.1	11.8	19.2	11.7	36.1	11.6
Experience in farming (yr)	20.1	11.2	22.1	14.2	20.3	14.2
Education (yr)	4.5	2.8	4.5	3.0	6.9	1.8
Labor availability (no.)						
Male adults	2.7	2.6	3.3	2.8	3.0	2.2
Female adults	2.9	3.0	3.5	2.8	2.7	1.9
Children	7.3	10.5	7.2	6.2	5.4	2.7
	Number of farmers	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	**Number of farmers**	**Percent of farmers**
Off-farm income	8	18.2	3	10.7	0	0.0
Used hired labor	70	78.7	39	73.6	14	77.8

91% of household men in the intermediate rainfall zone and 72% in the high rainfall zone. For women, the participation rates are 87% in the low rainfall zone, 77% in the intermediate rainfall zone, and 82% in the high rainfall zone.

Non-farm income was not widely available to the survey respondents. About 18% and 11% of the farmers in the low and intermediate rainfall zones had access to non-farm income, while no farmers in the high rainfall zone did. Most of the farmers in all zones used hired labor, however. Farmers in the high rainfall zone hired labor mainly for weeding (72.7%) and harvesting (38.9%). In the intermediate rainfall zone, farmers hired labor mainly for land preparation (41.5%) and weeding (62.3%), and in the low rainfall zone hired labor was used for land preparation (46.7%) and weeding (53.3%).

3.2 Land Resources and Allocation Pattern

Land is not a limiting factor in most parts of the Lake Zone, except in the highlands of Kagera region and Tarime District (Bakema et al. 1989; FSR 1989). The average farm size is still large enough to support agricultural production. The largest farm size per household was in the intermediate rainfall zone, while the smallest farm sizes were observed in the high rainfall zone.

In the low rainfall zone, about 74% of the farm was under cultivation; the corresponding figure in the intermediate rainfall zone was 65.7%. The remaining arable portion was hired out to neighbors and friends, left for grazing, and/or used for planting trees. In the high rainfall zone almost the whole farm was under cultivation (98.4%).

Only a few farmers rented land. Respondents rented about 26.1% of the cultivated area during the survey season. The largest rented area was 2.0 acres in low and high rainfall zones, followed by 0.5 acres in the intermediate rainfall zone. For farmers who rented land during the survey season, on average 27% of the farm area was rented to other farmers. The largest area rented out was observed in the low rainfall zone. In the high rainfall zone none of the households rented out land because of land shortages. According to farmers it was difficult to rent out land because almost all land was cultivated.

Figures 3, 4, and 5 show trends in farm size and maize area in the three rainfall zones over the past 20 years. On average, farm size per household increased between 1974 and 1994 in all zones. The area under maize shows a similar trend. In the high rainfall zone, however, growth in farm size and maize area has been small, because the initial farm sizes were small. Farm size has been expanding rapidly in low and intermediate rainfall zones, mainly because family sizes are larger and because farmers needed the income. Farmers' responses imply that maize is the main source of both food and

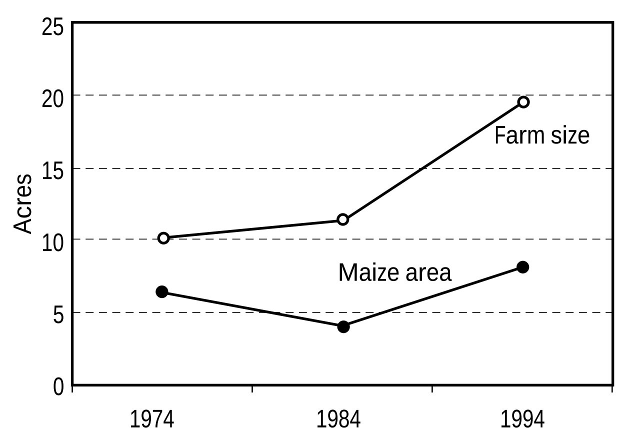

Figure 3. Trends in farm size and maize area in the low rainfall zone, Lake Zone, Tanzania.

income for the farming families in all three zones, and they said they reduced farm sizes only because of labor and land shortages. Fallow and low soil fertility were mentioned by only 3.1% of farmers in the low rainfall zone and by no farmers in the other zones.

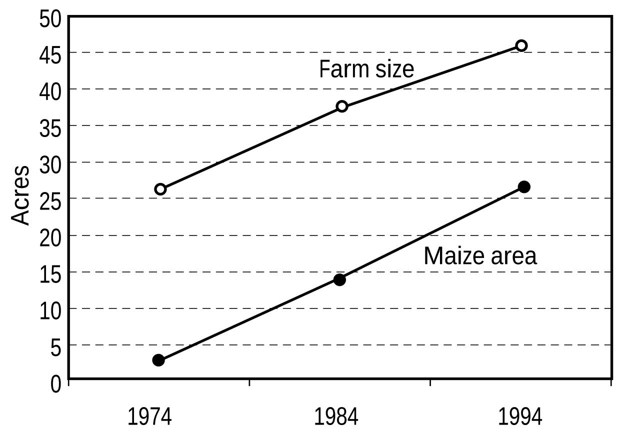

Figure 4. Trends in farm size and maize area in the intermediate rainfall zone, Lake Zone, Tanzania.

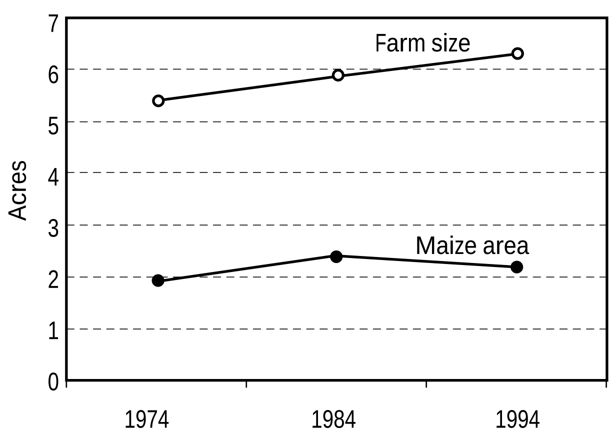

Figure 5. Trends in farm size and maize area in the high rainfall zone, Lake Zone, Tanzania.

3.3 Livestock Ownership

Livestock, especially cattle, play important social, economic, and agricultural roles in the Lake Zone (Ahmed et al. 1990), and farmers keep large herds of livestock. The most common livestock were cattle (kept by about 64% of farmers), goats (kept by 51.9%), and sheep (29.6%). A few households kept donkeys. The average number of cattle per household was 41.5. The low and intermediate rainfall zones had higher livestock populations compared to the high rainfall zone (Table 4). The number of cattle across zones differed significantly between the intermediate (48.2), low (23.7), and high rainfall zones (5.6) (p=0.05).

Farmers who used hand hoes kept more cattle (26.0) than those who used ox-plows (17.6). This result was surprising, as farmers who used ox-plows were expected to have more cattle than hand hoe users. The explanation for this finding is that most farmers who used ox-plows were from the high rainfall zone where smaller numbers of cattle were kept. Farmers using ox-plows had slightly more goats (8.8) and sheep (6.8) on average, however, than farmers using hand hoes (who had about 7 seven goats and 5 sheep). Livestock ownership was not significantly different for different methods of land preparation (Table 5).

Table 4. Livestock ownership (numbers of animals) by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Type of livestock	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Cattle	23.7	33.6	48.2	54.1	5.6	3.1
Goats	7.2	5.4	9.2	6.0	6.5	3.6
Sheep	4.3	3.6	7.1	6.0	6.0	6.1

3.4 Farm Mechanization

The most common farm implement used by farmers in the Lake Zone was the hand hoe, followed by the ox-plow and cutting tools (i.e., machetes) (Table 6). Only two households in Bariadi owned a tractor. Ox-carts were common in the intermediate rainfall zone but not in the high rainfall zone, which may have been because the topography makes the use of carts difficult. Farmers who used ox-plows for land preparation owned about three plows per household, whereas hand hoe users owned slightly fewer plows. The number of farm implements owned per household was not significantly different across zones and method of land preparation.

About 49% of the respondents rented farm implements for their farm operations. The number of farmers renting implements was 58.8% in the intermediate rainfall zone, 44.6% in the low rainfall zone, and 35.7% in the high rainfall zone. Farmers rented mainly ox-plows and ox-carts. No farmer rented a tractor.

Table 5. Livestock herd size by method of land preparation, Lake Zone, Tanzania

	Hand hoe		Ox-plow		
Type of livestock	Mean	Standard deviation	Mean	Standard deviation	t-statistic
Cattle	26.0	39.3	17.6	25.2	0.96 (NS)
Goats	7.2	4.9	8.8	6.9	1.1 (NS)
Sheep	4.9	4.5	6.8	6.7	0.9 (NS)

Note: NS = not significant.

Table 6. Number of farm implements owned, by agroecological zone and land preparation method, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Implement	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Ox-plow	1.5	0.6	2.3	2.0	1.3	0.8
Cart	1.6	0.9	1.3	0.5	–	–
Hand hoe	5.2	5.2	6.0	5.1	4.9	2.8
	Ox-plow		**Hand hoe**			
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**t-statistic**	
Ox-plow	2.0	2.0	1.6	1.0	0.9 (NS)	
Cart	1.3	0.5	1.6	0.9	0.7 (NS)	
Hand hoe	5.4	2.9	5.0	4.8	0.4 (NS)	

4.0 Maize Production Practices and Adoption of Recommendations in the Study Area

4.1 Crops and Cropping Systems

The main crops grown by survey farmers in the Lake Zone were maize, cassava, sweet potato, beans, groundnuts, sorghum, millet, cotton, coffee, paddy, tobacco, and bananas. The relative importance of these crops varied from one district to another. Tobacco was grown in Kahama, which borders Tabora region. Most farmers grew maize with other crops, mainly legumes (cowpeas, beans, and groundnuts). Other intercrops included cassava and sweet potato. More than 60% of the households in all zones intercropped maize with legumes (Table 7). The major reasons for intercropping maize in the low and intermediate rainfall zones were land scarcity and labor shortages, while the major reasons in the high rainfall zone were land scarcity and the need for more food/ income.

4.2 Maize Crop Management Practices

4.2.1 Land preparation methods

Land preparation for maize depends on the onset of the rains. Land preparation starts in August and ends in the beginning of January. About 63% and 62% of the farmers in the low and intermediate rainfall zones, respectively, prepared their land between September and October, while 61.4% of the farmers in the high rainfall zone prepared their land between November and January (Table 8). The high rainfall zone received rain from early August to early January, so farmers could prepare their land later than farmers in the other zones, where the short rains ended earlier.

Table 7. Maize cropping systems, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Cropping system	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Cropping pattern						
Monocrop	24	28.6	20	40.0	6	33.3
Intercrop	60	71.4	30	60.0	12	66.7
Reasons for intercropping						
Land is scarce	28	44.4	21	55.3	6	50.0
Saves labor	18	28.6	10	26.3	1	8.3
Spreads risk	8	12.7	2	5.3	0	0.0
More food/income	3	4.8	4	10.5	4	33.3
Traditional	6	9.5	1	2.6	1	8.3
Cropping system						
Maize/legumes	52	61.2	27	51.9	11	61.1
Maize	24	28.2	20	38.5	4	22.2
Coffee/banana	2	2.4	–	–	2	11.1
Tuber crops	2	2.4	1	1.9	1	5.6
Other	5	5.9	4	7.2	–	–

4.2.2 Seedbed type, planting time, and weeding

Table 9 shows farmers' adoption of major agronomic practices. The most common seedbed type in the low (95.6%) and intermediate rainfall zones (66.0%) was ridges, mainly because of the sandy soils. Ridges conserve water and minimize soil erosion. However, seedbed type also depends on the method of land preparation. Where the ox-plow was used, flat cultivation was common, whereas the use of hand hoes allowed farmers to make ridges. Most farmers in the high rainfall zone grew maize on the flat (94.4%) because of their greater use of the ox-plow.

Farmers' major reason for using ridges in the low (40.8%) and intermediate rainfall zones (42.4%) was that it eased field management. The same reason was given by about 64% of the farmers in the high rainfall zone who practiced flat cultivation. This type of cultivation increased yields by about 25%, 9%, and 29% for the farmers in the low, intermediate, and high rainfall zones, respectively.

As mentioned previously, maize planting depends on the rainfall pattern. In the 1994 farming season, maize in the low (62.5%) and intermediate rainfall zones (62.9%) was planted mainly between October and November, whereas in the high rainfall zone (82.4%) maize was planted mainly between January and March. All farmers in the zones planted their maize in rows. Farmers in the low and intermediate rainfall zones used a larger spacing between rows and hills compared to farmers in the high rainfall zone. Most of the respondents in the low (69.7%) and intermediate rainfall zones (65.3%) used a row spacing of 90 or 100 cm. In the high rainfall zone, about 45% of the farmers used a row spacing of 60 or 75 cm. In the low and intermediate rainfall zones, about 70% and 46% of farmers, respectively, had spaces of 30 or 60 cm between hills, while most farmers in the high rainfall zone (76.5%) used a spacing of 30 cm.

The average number of seeds per hill was significantly higher ($p=0.05$) in the intermediate rainfall zone (2.4) compared to the low (1.9) and high rainfall zones (1.7).

Table 8. Time and method of land preparation by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Cropping system	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of land preparation						
August	16	19.1	4	8.0	2	11.2
September	36	42.8	18	36.0	1	5.6
October	17	20.4	13	26.0	4	22.3
November	14	16.7	12	24.0	2	11.1
December–January	1	1.2	3	6.0	9	50.3
Method of land preparation						
Hand hoe	82	94.3	37	72.5	4	22.2
Ox-plow	3	3.4	6	11.8	14	77.8
Tractor	–	–	4	7.8	–	–
Hand hoe/ox-plow	1	1.1	3	5.9	–	–
Zero tillage	1	1.1	1	2.0	–	–

The time of weeding depended on the time of planting. In the low rainfall zone, about 95% and 40% of the sampled farmers performed a first and second weeding, respectively. The first weeding was mainly done (by 67.4% of farmers) between November and December, while the second weeding was mainly done (75.1% of farmers) between December and January. In the intermediate rainfall zone, about 96% and 8% of the farmers performed a first and second weeding, respectively. The first weeding (70.6%) was done mainly between November and January. In the high rainfall zone, about 94% and 89% of the farmers performed a first and second weeding, respectively. The first weeding was mainly done (by 53% of farmers) between January and March, while the second weeding was

Table 9. Farmers' adoption of major agronomic practices by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Planting time						
August–September	5	6.0	3	6.0	3	17.6
October	36	43.3	19	37.3	–	–
November	34	19.2	13	25.6	–	–
December	8	10.6	3	6.0	–	–
January–March	–	–	13	25.5	14	82.4
Seedbed type						
Flat	4	4.4	18	34.0	17	94.4
Ridges	86	95.6	35	66.0	1	5.6
Spacing between rows						
60 cm	1	1.1	1	2.0	5	27.8
75 cm	7	7.9	7	14.3	3	16.7
90 cm	28	31.5	17	34.7	1	5.6
100 cm	34	38.2	15	30.6	2	11.1
Other	19	21.3	9	18.4	7	38.8
Spacing between hills						
30 cm	28	32.2	11	22.9	13	76.5
60 cm	33	37.9	12	25.0	1	5.9
75 cm	2	2.3	6	12.5	1	5.9
100 cm	5	5.7	10	20.8	–	–
Other	19	21.9	9	18.8	2	11.7
First weeding						
August–October	5	5.9	1	2.0	4	23.6
November	31	36.0	10	19.6	1	5.9
December	27	31.4	17	33.4	–	–
January	19	22.1	9	17.6	1	5.9
February	4	4.7	11	21.5	2	11.8
March–April	–	–	3	5.9	9	53.0
Second weeding						
August–November	2	5.6	–	–	4	29.1
December	11	30.6	1	25.0	–	–
January	16	44.5	2	50.0	–	–
February	3	8.4	1	25.0	–	–
March–June	4	11.2	–	–	12	70.9
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Number of seeds per hill	1.9	0.6	2.4	0.6	1.7	0.5
Number of weedings	1.5	0.6	1.1	0.3	2.0	0.0

mainly done (70.9% of farmers) between January and June. The average number of weedings was significantly higher (p=0.05) in the high rainfall zone (2.0) compared to the low (1.5) and intermediate rainfall zones (1.1). Also, the number of weedings was significantly higher (p=0.05) in the low rainfall zone compared to the intermediate rainfall zone.

4.2.3 Soil fertility management

Fertilizer was used by 49%, 48%, and 100% of farmers in the low, intermediate, and high rainfall zones, respectively (Table 10). The most common type of fertilizer used in the low rainfall zone was urea (43.8%) and CAN (31.3%). The types of fertilizer used in the intermediate and high rainfall zones cannot be established because enumerators received few responses from farmers. The amount of inorganic fertilizer used was about 20 kg/ha in the high rainfall zone, 17.5 kg/ha in the intermediate rainfall zone, and 13 kg/ha in the low rainfall zone. In the low (48.9%) and intermediate rainfall zones (36.7%), lack of knowledge about inorganic fertilizers was farmers' major reason for not using it, while high price (83.3%) was farmers' major reason in the high rainfall zone. Most farmers in the low (39.1%), intermediate (50%), and high rainfall zones (87.5%) applied fertilizer by making a hole.

Most farmers used organic fertilizer. In the low rainfall zone, about 80% of the sampled farmers used FYM, while 20% used crop residues. Among farmers in the intermediate rainfall zone, 64.5% reported using FYM and 37.5% reported using crop residues, whereas 89% of the farmers in the high rainfall zone used FYM and 11% used crop residues. The amount of FYM used in the low rainfall zone was about 17 t/ha, while farmers in the intermediate and high rainfall zones used about 9 t/ha and 4 t/ha, respectively. The major reason why farmers did not use FYM was that they owned no livestock.

Table 10. Fertilizer use for maize production by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Use inorganic fertilizer (IF)	38	49.7	19	47.5	18	100.0
Reasons for not using IF						
Expensive	20	44.4	4	13.3	5	83.3
Lack of knowledge	22	48.9	11	36.7	1	16.7
Don't need fertilizer	2	4.4	14	46.7	–	–
Other	1	2.2	1	3.3	–	–
Use organic fertilizer (OF)						
Farmyard manure (FYM)	35	79.5	18	64.3	16	88.9
Crop residue	9	20.5	10	35.7	2	11.1
Reasons for not using OF						
Expensive	6	30.0	–	–	1	20.0
No livestock	10	50.0	2	50.0	3	60.0
Other	4	20.0	2	50.0	1	20.0
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
IF used in 1994 (kg/ha)	12.7	9.4	17.5	6.2	19.8	14.7
FYM used in 1994 (t/ha)	17.0	22.7	9.2	7.3	3.6	1.8

About 37% of the farmers in the low rainfall zone, 40% in the intermediate zone, and 22% in the high rainfall zone fallowed their land (Table 11). The main reasons for fallowing land were to replenish soil fertility and suppress weeds, particularly *Striga*. Farmers in the low rainfall zone practiced fallowing for two years, and farmers in the intermediate and high rainfall zones practiced fallowing for 1.8 and 1.0 year, respectively. The crop grown immediately after fallowing was maize (grown by 44% of farmers in the low rainfall zone and 62% in the intermediate rainfall zone). All farmers in the high rainfall zone grew maize immediately after the fallow cycle. Maize was grown after fallow because it was the only crop grown. Across zones, the main reason for not fallowing was land scarcity.

Crop rotation was practiced by about 76% of the farmers in the low rainfall zone, 60% in the intermediate rainfall zone, and 83% in the high rainfall zone. The most common crop sequence in the low (52.6%) and intermediate rainfall zones (47.8%) was maize-cotton. The second important crop sequence was maize-cassava, practiced by 21.4% of farmers in the low rainfall zone and 30.3% in the intermediate rainfall zone. In the high rainfall zone, the most common crop sequences were maize followed by millet and/or sorghum (50.6%), and maize-cassava (35.1%). Other crop sequences observed in all zones were maize-legumes; maize–tobacco was seen in the low and intermediate rainfall zones.

The major reason for crop rotation in the low (83%), intermediate (92%), and high rainfall zones (100%) was that the previous crops did not utilize all the fertilizer, which then benefited the second crop. For farmers in the low rainfall zone (15%), a secondary reason for rotating crops was to break disease/pest cycles. Land scarcity was the main reason why farmers in the highland zone did not

Table 11. Other soil fertility management practices by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Fallow maize plots	33	37.1	21	39.6	4	22.4
Reasons for not fallowing						
Land is scarce	39	86.7	29	90.6	12	100.0
No need	4	8.9	1	3.1	–	–
Other	2	4.4	2	6.2	–	–
Rotate crops	67	76.1	32	60.4	15	83.3
Reasons for not rotating crops						
Do not know about practice	5	31.3	4	44.4	–	–
Land is scarce	2	12.5	3	33.3	1	33.3
Pests/diseases	6	37.5	1	11.1	1	33.3
Other	3	18.8	1	11.1	1	33.3
Management of crop residue						
Plow under	37	61.7	17	39.5	12	70.6
Burn	6	10.0	1	2.3	4	23.5
Feed to cattle	17	28.3	25	58.1	1	5.9

rotate crops. In the low and intermediate rainfall zones, farmers did not rotate crops because they either did not know about the benefits of crop rotation, or because the presence of certain diseases and pest cycles did not favor rotation of the crops grown in the area.

Farmers who did not apply fertilizer or who used only small amounts were advised to plow crop residues back into the soil to avoid soil mining. This recommendation was followed by about 62% of the farmers in the low rainfall zone, 40% in the intermediate rainfall zone, and 71% in the high rainfall zone. About 58% of the farmers in the intermediate rainfall zone fed crop residues to their cattle. None of the farmers in the other zones fed residues to cattle, but farmers in the intermediate zone had significantly more cattle than farmers in the other two zones.

4.2.4 Pest and disease control

Field pests, diseases, and their control methods are summarized in Table 12. Stalkborers were identified as the most serious field pest by about 76% of low rainfall zone farmers, 73% of intermediate zone farmers, and 80% of high rainfall zone farmers. In Kahama District, yield losses from maize stalkborer have been reported at more than 50% (Bakema et al. 1989). Pests of minor importance were cutworms, termites, vermin, and maize weevils. Armyworms, maize weevils, and grain borers were reported only in the low and intermediate rainfall zones. Most farmers used no form of insect pest control. A few farmers used thiodan (14.4% of farmers in the low rainfall zone, 7.5% in the intermediate zone, and 5.6% in the high rainfall zone). DDT was used only in the low (7.8% of farmers) and intermediate rainfall zones (3.8% of farmers).

Table 12. Major field pests, diseases, and their control by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Field pests						
Stalkborers	83	76.1	46	73.0	12	80.0
Cutworms and termites	9	8.3	7	11.1	1	10.0
Vermin	7	6.4	4	6.3	2	20.0
Maize weevils	2	1.8	1	1.6	0	0.0
Grain borer	5	4.6	3	4.8	0	0.0
Armyworm	3	2.8	2	3.2	0	0.0
Pest control method						
None	63	70.0	42	79.2	17	94.4
Thiodan	13	14.4	4	7.5	1	5.6
DDT	7	7.8	2	3.8	–	–
Other	7	7.8	5	9.5	–	–
Field diseases						
Maize streak virus	51	92.7	25	92.6	7	58.3
Cob rot	1	1.8	1	3.7	1	8.3
Smut	3	5.5	1	3.7	4	33.3
Disease control method						
None	87	96.7	47	88.7	16	88.9
Chemical	1	1.1	4	7.5	–	–
Rogue	2	2.2	2	3.8	2	11.1

The most important field disease was MSV, reported by 92.7% of farmers in the low rainfall zone, 92.6% in the intermediate zone, and 58.3% in the high rainfall zone. Along with MSV, smut was an important disease in the high rainfall zone (reported by 33.3% of farmers). Most farmers used no disease control method (96.7% of farmers in the low rainfall zone, 88.7% in the intermediate zone, and 88.9% in the high rainfall zone). Disease affected mostly local varieties in the low rainfall (63.9%) and intermediate rainfall zones (79.3%), whereas hybrids were more affected in the high rainfall zone (87.5%).

4.2.5 Maize harvesting, transportation, and storage

The timing of the maize harvest depends on the time of planting and the length of time it takes for the crop to mature. In the low rainfall zone, most maize (78.8%) was harvested between February and May (Table 13). In the intermediate rainfall zone, maize was harvested between May and July (85.8%). In the high rainfall zone, most farmers planted maize in the long rains (92%), so the crop was harvested from July to September (66.7%). In the low and intermediate rainfall zones, about 50% of all maize was grown during the short (*vuli*) rains, whereas in the high rainfall zone only 8% of the maize was grown at that time. Maize sown during the short rains was harvested between February and April, which was earlier than the maize sown during the long rains, which matures between July and August.

Harvested maize was transported from the field using different methods. Ox-carts were the most common means of transporting the maize harvest in the low rainfall zone (41.6%) and the intermediate rainfall zone (59.6%). Most farmers in the high rainfall zone carried harvested maize by headload (50.0%) (women mainly carried headloads). The second most common mode of transporting maize was by bicycle (26.9%). A few farmers in the high rainfall zone used pick-up trucks.

Table 13. Maize harvesting, transportation, and storage by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Month of harvest						
February–March	12	15.6	2	4.8	1	6.7
April	22	29.0	3	7.2	–	–
May	26	34.2	8	19.1	–	–
June	8	10.5	9	21.4	1	6.7
July	8	10.5	19	45.3	5	33.4
August–September	–	–	1	2.4	10	53.3
Method of transporting harvest						
Headload	27	30.3	14	26.9	13	50.0
Bicycle	25	28.1	7	13.5	4	15.4
Cart	37	41.6	31	59.6	7	26.9
Pick-up truck	0	0.0	0	0.0	2	7.7
Maize storage						
Shell and store in *kihenge*	33	39.3	8	15.7	–	–
In crib	50	59.5	43	84.3	18	100.0
In gunny bags	1	1.2	–	–	–	–

In the low rainfall zone, farmers stored maize in cribs (59.5%) or in a traditional storage structure (*kihenge*) (39.3%). In the intermediate rainfall zone about 84% and 16% of the farmers stored maize in cribs and in a *kihenge*, respectively. In the high rainfall zone, all farmers stored their maize in cribs. Farmers in the low (94%) and intermediate rainfall zones (88.6%) treated their maize seed, although only 22% of the farmers in the high rainfall zone did so. Treatment with chemicals was most common in the low rainfall (87%) and intermediate rainfall zones (61.3%). Half of the farmers in the high rainfall zone used ash or other local materials rather than chemical seed treatment. Farmers in the low (66.7%) and high rainfall zones (92.3%) did not treat their maize, because they thought it was not important, while 90% of the farmers in the high rainfall zone said they had no money to purchase the required chemicals.

4.2.6 Seed selection and recycling

About 24%, 44%, and 20% of the farmers in the low, intermediate, and high rainfall zones, respectively, selected their seed in the field, but the majority of farmers selected maize seed at home after harvesting. Cob size was the main criterion for selecting maize seed for 56% of farmers in the low rainfall zone, 60% in the intermediate rainfall zone, and 50% in the high rainfall zone. Seed that was free from pests and diseases was the second most important criterion used by farmers in selecting seed (28.6% of farmers in the low rainfall zone, 26.1% of farmers in the intermediate rainfall zone, and 50% of farmers in the high rainfall zone). Mature grain was the third most important seed selection characteristic, reported by 13.4% of farmers in the low rainfall zone and 13% of farmers in the intermediate rainfall zone.

In the low rainfall zone, selected seed was generally shelled, chemically treated, and stored in gunny bags (77.2%), or maize cobs were hung above a fire where the smoke would kill insects (10.1%). In the intermediate rainfall zone, selected seed was generally shelled, chemically treated, and stored in gunny bags by 40% of the farmers; 26.7% shelled the seed, applied ash, and stored the seed in gunny bags; and 22.2% hung maize cobs over a fire where the smoke would kill insects. In the high rainfall zone, 66.7% of farmers stored shelled maize, covered with ash, in gunny bags.

Nearly all farmers in the high rainfall zone said that seed was readily available (94.1%), whereas farmers in the other zones said they had difficulty obtaining seed (62.5% in the low rainfall zone and 93.7% in the intermediate rainfall zone). Farmers in the intermediate (100%) and low rainfall zones (61.1%) did not purchase seed regularly, while farmers in the high rainfall zone (87.5%) purchased seed regularly.

Farmers in the Lake Zone commonly recycled their maize seed from one season to the next, especially in the low and intermediate rainfall zones. Recycling seed of composite varieties beyond three years can substantially decrease the yield, whereas hybrids should not be recycled at all. Table 14 shows the average number of years farmers recycled maize seed. Farmers reported recycling seed for more than 10 years in the low rainfall (52.4% of farmers) and intermediate rainfall zones (78.6% of farmers), well beyond the recommended time of recycling. Farmers in the low (42.9%), intermediate (14.3%), and high rainfall zones (75%) recycled seed every 2 years.

Farmers purchased maize seed from local markets, the cooperative union, NGOs, or other farmers. In the low rainfall zone, farmers mainly purchased seed from the cooperative union (36.4%) or the local market (36.4%), while most farmers in the intermediate rainfall zone purchased seed from the cooperative union (66.7%). In the high rainfall zone, most farmers (84.4%) purchased seed from NGOs.

4.2.7 Maize cropping calendar for the Lake Zone

Figure 6 depicts the maize cropping calendar for the Lake Zone by agroecological zone. In the low and intermediate rainfall zones, the demand for labor peaks between November and January; the remaining part of the year is relatively slack. In the high rainfall zone, demand for labor is spread more evenly throughout the year.

4.2.8 Maize marketing

Farmers in the Lake Zone sell part of their food crops to obtain income for the family. Figure 7 shows the amount of local and improved maize sold by zone between 1974 and 1994. Improved varieties were mostly sold in the high rainfall zone, whereas local varieties were mainly sold in the intermediate rainfall zone. The availability of markets for food crops was an important factor for the adoption of

Table 14. Recycling of improved maize seed by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Maize type	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Hybrids	4.0	4	–	–	2.0	1
Katumani	7.2	6	–	–	–	–
Tuxpeño	5.8	6	8.7	6	–	–
Kilima	4.6	12	–	–	–	–
Imported improved varieties	10.0	1	–	–	1.7	3

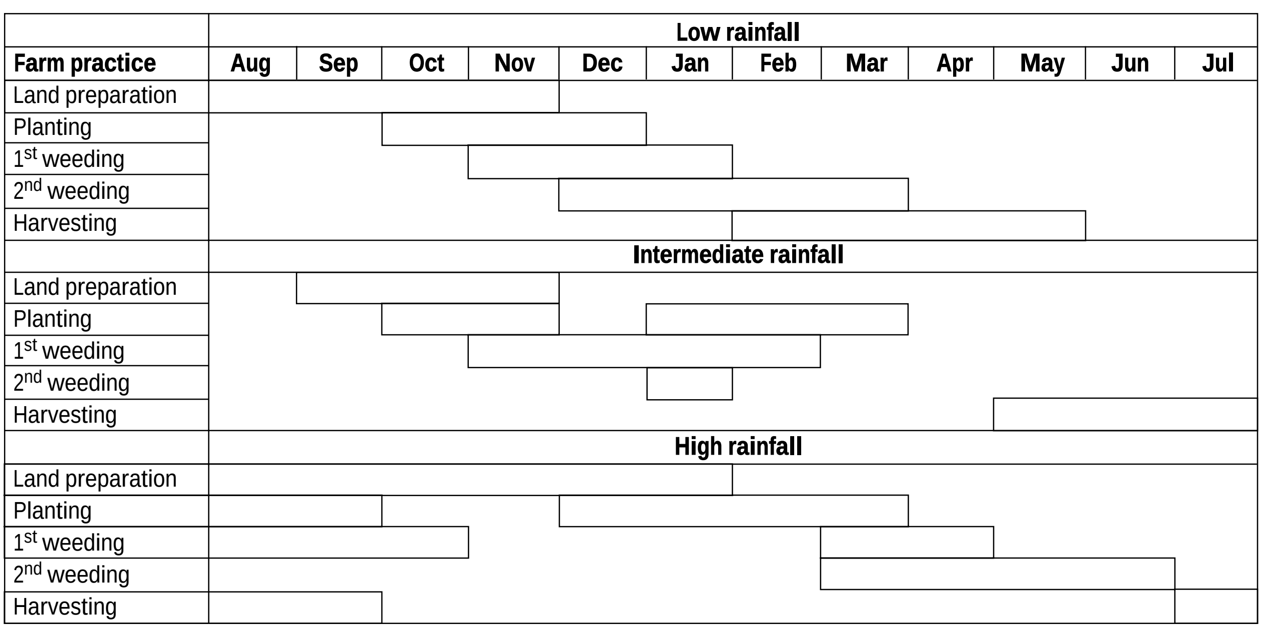

Figure 6. Maize cropping calendar for the agroecological zones in the Lake Zone, Tanzania.

improved technologies. In many parts of the Lake Zone, markets for food crops are not easy to reach. Farmers in the low (19.3 km) and intermediate rainfall zones (22.2 km) had to travel long distances compared to farmers in the high rainfall zone (10.6 km) to get to markets. Half of the farmers in the low and intermediate rainfall zones sold their maize between harvests, while most of the farmers in the high rainfall zone sold their maize immediately after harvest (Table 15). The price of maize before harvest was higher than the price of maize afterward (Figure 8). The price difference was higher in the low and intermediate rainfall zones than in the high rainfall zone because of the kinds of markets prevailing in each zone. Farmers in the high rainfall zone sold their maize in formal markets in Kenya, while farmers in the low and intermediate rainfall zones sold their maize in informal markets in Tanzania.

4.3 Adoption of Improved Maize Varieties

4.3.1 Current varieties grown

Table 16 shows the maize varieties grown by sample farmers in the 1994/95 farming season. The proportion of improved varieties currently grown by farmers differed from zone to zone. Most farmers in the high rainfall zone (83.3%) grew improved maize varieties, while only 12% and 6% of

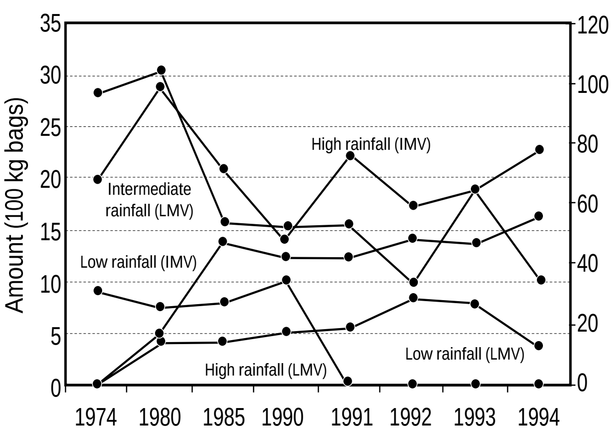

Figure 7. Amount of local and improved maize sold by agroecological zone, Lake Zone, Tanzania, 1974–97.
Note: IMV = improved maize varieties; LMV = local maize varieties. The amount improved maize sold in the intermediate rainfall zone is zero. The right axis is for local maize varieties sold in the intermediate rainfall zone. The left axis is for all other varieties.

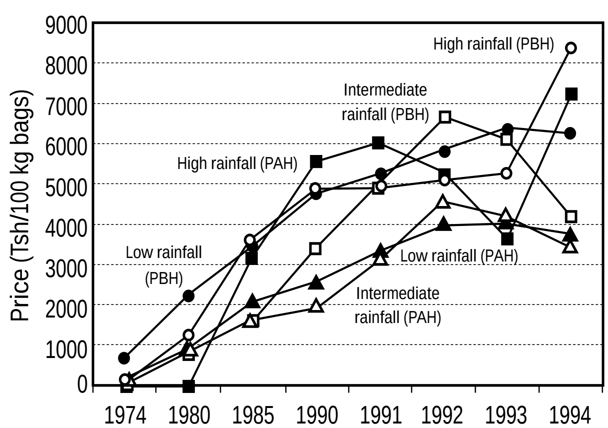

Figure 8. Maize price before and after harvest, by agroecological zone, Lake Zone, Tanzania, 1974–94.
Note: PAH = price after harvest; PBH = price before harvest.

Table 15. Time when maize is sold, by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Immediately after harvest	13	29.5	8	26.7	5	45.5
Between harvests	22	50.0	15	50.0	2	18.2
Just before next harvest	9	20.5	7	23.3	4	36.4

the farmers in the low and intermediate rainfall zones, respectively, grew improved maize. The only improved varieties grown by farmers in the high rainfall zone were hybrids from Kenya (H625), and no farmers grew composite varieties. In the low rainfall zone the majority of farmers (37.8%) grew composite varieties (Kilima). Local varieties were mainly grown in the intermediate rainfall zone (87.8%).

The adoption of improved varieties varied between villages. In Igunda, Bukomela, and Nyang'hwale villages (Kahama District) and Matongo village (Bariadi District), about 58% of the respondents planted local varieties during the survey season. In the other village about 24% of respondents planted local varieties. In Busekeseke village (Sengerema District) and Itiryo village (Tarime District), all households planted improved maize varieties during the survey season. In Nyamigogo village (Geita District), 94% of the farmers grew improved varieties.

Varieties grown in the high rainfall zone were imported from Kenya, while those grown in the other zones were imported from Zambia and Kenya, but farmers did not know their names.

4.3.2 Preferred improved maize varieties and reasons

The most preferred maize cultivars are shown in Table 17, and reasons for farmers' preferences are given in Table 18. The most preferred varieties were Kilima, Katumani, Tuxpeño, and imported

Table 16. Maize varieties planted in the 1994/95 season by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Local varieties	29	39.2	43	87.8	3	16.7
H614	1	1.4	0	0.0	0	0.0
Katumani	5	6.8	0	0.0	0	0.0
Tuxpeño	1	1.4	0	0.0	0	0.0
Kilima	28	37.8	2	4.1	0	0.0
Imported improved varieties (H625 and Zambia)	9	12.2	3	6.1	15	83.3

Table 17. Farmers' preferred maize varieties, by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Hybrids	1	2.2	0	0.0	1	7.1
UCA	2	4.4	2	22.2	0	0.0
Katumani	5	10.9	0	0.0	0	0.0
Tuxpeño	5	10.9	4	44.4	0	0.0
Kilima	28	60.0	0	0.0	0	0.0
ICW	0	0.0	1	11.1	0	0.0
Imported improved varieties (H625 and Zambia)	5	10.9	2	22.2	13	92.9

hybrids from Kenya. Few farmers preferred hybrids bred in Tanzania. Farmers in the low rainfall zone had a wider choice of varieties than farmers in the other zones, but they preferred composites such as Kilima (60%) and Katumani (10.9%) for their high yield and drought tolerance. In the intermediate rainfall zone, farmers preferred Tuxpeño (44.4%) for its drought tolerance. Farmers in the high rainfall zone mainly preferred hybrids (92.9%) for their high yield.

4.3.3 Disadoption of improved maize varieties

Forty-five percent of farmers who grew improved varieties had stopped growing them. The highest rate of disadoption was observed in the high rainfall zone (58.8%). In the low (39.2%) and intermediate rainfall zones (48.1%), improved varieties were disadopted less (Table 19). In the low rainfall zone, farmers had disadopted Tuxpeño (50%), Katumani (18.2%), and hybrids (18.2%). The major reasons for disadopting Tuxpeño were its low yield (41.7%), attack by storage pests (16.7%), or the loss of seed during drought (25%). In the intermediate rainfall zone, farmers disadopted Katumani (35.3%), Tuxpeño (29.4%), and hybrids (23.5%). Unavailability of seed was farmers' major reason for disadopting Katumani (57.1%), Tuxpeño (33.3%), and hybrids (33.3%). The high price of seed was another important reason for disadopting Tuxpeño (33.3%) and hybrids (33.3%). In the high rainfall zone, farmers mainly disadopted Katumani (41.7%) and imported improved varieties (41.7%). Katumani was disadopted for its low yield (50%) and unavailability (50%), while imported improved maize varieties were mainly disadopted because seed was no longer available (71.4%).

Table 18. Reasons for farmers' varietal preferences, Lake Zone, Tanzania

Zone and variety	High yielding	Drought tolerant	Resistant to pests
		Percentage of farmers preferring	
Low rainfall			
Katumani	42.8	57.2	0.0
Tuxpeño	50.0	50.0	0.0
Kilima	75.0	25.0	0.0
Imported improved varieties	37.5	62.5	0.0
Intermediate rainfall			
Tuxpeño	–	75.0	25.0
High rainfall			
Imported improved varieties	100.0	0.0	0.0

Table 19. Varieties no longer grown by farmers, by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
Variety	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
All improved varieties	20	39.2	13	48.1	10	58.8
Hybrids	4	18.2	4	23.5	2	16.7
Katumani	4	18.2	6	35.3	5	41.7
Tuxpeño	11	50.0	5	29.4	0	0.0
Kilima	1	4.5	1	5.9	0	0.0
Imported improved varieties	0	0.0	0	0.0	5	41.7
Other	2	9.0	1	5.9	–	–

5.0 Credit and Extension Services

5.1 Credit Availability

Small-scale farmers generally do not receive credit from banks or other credit institutions. In the past, cooperative unions provided agricultural credit in kind to growers of cash crops, and the credit was recovered when the crops were sold. Food crops, however, did not qualify for such credit because the many marketing channels for these crops made it difficult to recover the loans. Even for cash crops credit recovery was poor, which led the cooperatives to abolish their credit services. Some NGOs (i.e., Sasakawa Global-2000) have provided credit in the form of inputs to farmers for food crop production.

Only 3% of the farmers in the low rainfall zone and about 2% in the intermediate rainfall zone had received credit from the cooperative union (Table 20). Credit was not readily available to most farmers in the low (82.4%), intermediate (62.5%), and high rainfall zones (100%). About 22%, 16%, and 36% of the farmers in the low, intermediate, and high rainfall zones, respectively, did not know how to get credit, while most farmers reported the lack of credit facilities.

5.2 Sources of Information

In Tanzania, agricultural extension agencies have been the main source of new information on improved production practices. Other sources of information include the media (booklets, bulletins, radio programs, etc.), seminars, NGOs, and other farmers. Recent studies have shown that farmer-to-farmer technology transfer plays an important role in the diffusion of both local and introduced production practices in farming communities (Starkey and Mutagubya 1992).

Sources and adoption of improved maize technologies for the low, intermediate, and high rainfall zones are shown in Table 21. Farmers have received most of the recommendations on maize production. However, in all zones farmers received less information about controlling weeds (i.e., information on herbicides) and diseases than about other practices, so it is not surprising that adoption of disease and weed control practices was low across zones. The adoption of pest control methods was low in the intermediate and high rainfall zones.

Table 20. Sources and use of credit by agroecological zone, Lake Zone, Tanzania

	Low rainfall		Intermediate rainfall		High rainfall	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Access to credit	3	3.3	1	1.9	0	0.0
Source of credit						
Cooperatives	3	100.0	1	100.0	0	0.0
Constraints						
No collateral	2	3.1	0	0.0	0	0.0
Cumbersome procedure	5	7.8	2	6.3	0	0.0
Lack of credit facilities	14	21.9	5	15.6	6	35.3
Other	43	67.2	25	78.1	11	64.7

Extension agencies have played a major role in transferring almost all technological components in all zones, except for the use of herbicides and ox-drawn implements. The use of ox-drawn implements has been widely disseminated by farmers themselves, and farmers generally know more than the extension workers about animal traction.

Non-governmental organizations have been active in extension in the low and intermediate zones but not in the high rainfall zone. Mogabiri Farmers' Extension Center (MFEC), a church organization, has been active in the high rainfall zone through the existing extension services, however. This linkage/collaboration has improved the services of the extension department.

Other means of technology transfer included radios and researchers. Traders and bulletins/books played a minor role in informing farmers of new technologies, but they are likely to be an important means of technology transfer in the future.

Table 21. Sources of improved maize technologies and their adoption, by agroecological zone, Lake Zone, Tanzania

			Information source			
Zone and technology	Received information	Adopted recommendation	Extension	Other farmers	NGO	Other[a]
Low rainfall zone						
Improved variety	87.3	65.2	68.9	14.8	9.8	6.5
Planting method	92.2	80.0	75.7	12.7	5.7	5.9
Fertilizer	95.4	76.6	74.2	8.1	9.7	8.0
Weed management	84.1	77.4	64.2	26.4	7.5	1.9
Herbicide use	32.6	0.0	57.1	21.4	7.1	14.3
Pest control	69.5	55.0	85.4	7.3	4.9	2.4
Disease control	31.1	14.6	77.8	11.1	5.6	5.5
Storage method	97.3	94.4	77.9	10.3	8.8	3.0
Animal draft	64.9	41.6	33.3	50.0	5.6	11.1
Intermediate rainfall zone						
Improved variety	76.7	46.7	78.3	8.7	8.7	4.3
Planting method	75.9	74.1	82.6	4.3	8.7	4.4
Fertilizer	82.1	26.9	81.8	0.0	9.1	9.1
Weed management	69.0	61.5	65.0	5.0	20.0	10.0
Herbicide use	20.0	0.0	100.0	0.0	0.0	0.0
Pest control	48.3	3.3	78.6	0.0	0.0	21.4
Disease control	16.0	9.5	50.0	30.0	20.0	0.0
Storage method	58.6	59.3	63.2	15.8	21.1	0.0
Animal draft	69.0	66.7	9.5	42.9	33.3	14.3
High rainfall zone						
Improved variety	100.0	92.9	57.1	14.3	0.0	28.6
Planting method	100.0	92.3	78.6	7.1	0.0	14.3
Fertilizer	100.0	92.3	92.3	0.0	0.0	7.7
Weed management	100.0	100.0	100.0	0.0	0.0	0.0
Herbicide use	50.0	0.0	66.7	0.0	0.0	33.3
Pest control	100.0	44.4	62.5	25.0	0.0	12.5
Disease control	57.1	0.0	50.0	0.0	0.0	50.0
Storage method	87.5	44.4	62.5	12.5	0.0	25.0
Animal draft	100.0	100.0	11.1	55.6	22.2	11.1

a "Other" includes mainly researchers and traders.

6.0 Factors Affecting Adoption of Agricultural Technologies in the Study Area

6.1 Definitions

Feder, Just, and Zilberman (1985) have 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 the farmer's decision to apply a new technology in the production process. On the other hand, aggregate adoption is the process by which a new technology spreads or diffuses 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).

6.2 Rate of Adoption of Improved Maize Varieties and Fertilizer

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 a 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:

$$Y_t = K/(1+e^{-a-bt})$$

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;
a = a constant, related to the time when adoption begins.

Figure 9 shows the rate of fertilizer adoption in the low, intermediate, and high rainfall zones. In 1994, the cumulative adoption of fertilizer was 38.9% for the low rainfall zone, 13.2% for the intermediate zone, and 61.1% for the high rainfall zone. The rate of adoption for 1979–94 was 0.24, 0.33, and 0.10 for the low, intermediate, and high rainfall zones, respectively. Figure 9 shows that more farmers in the high rainfall zone were using chemical fertilizer compared to other zones. This could be the result of the land shortage in the high rainfall zone, which has forced farmers to adopt intensive crop production methods. Furthermore, farmers in the low rainfall zone have reduced their use of fertilizer because of drought.

Figure 10 shows the rate of adoption of improved maize varieties for the low, intermediate, and high rainfall zones. In 1994, the cumulative adoption of improved varieties in the low, intermediate, and high rainfall zones was 62.2%, 45.3%, and 100%, respectively. The rate of adoption for 1970–94 was 0.38, 0.52, and 0.08 for the low, intermediate, and high rainfall zones, respectively. Figure 10 also shows that more farmers in the high rainfall zone used improved varieties earlier than farmers in the other zones.

6.3 Tobit Analysis of Land Allocated to Improved Maize Varieties

Results of the tobit model for the proportion of land allocated to improved maize varieties are presented in Table 22. 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 and Moffitt 1980). In Table 22, $\delta EY/\delta X_i$ 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 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 $p<0.01$.

The farmer's experience, farm size, family labor, livestock units, hand hoe use, education, and extension significantly influenced the probability that land would be allocated to improved maize varieties. Among adopters, a unit increase in farmer's experience increased the probability of adoption by 0.5%, and a unit increase in farm size increased the probability of adoption by 0.7%. Feder, Just, and Zilberman (1985) have cited several studies that found a positive relationship between farm size and adoption of improved varieties. Contrary to expectations in this study, a unit increase in family labor among adopters reduced the probability of adoption by 1.9%. A unit increase in the number of livestock among adopters decreased the probability of adoption by 0.6%.

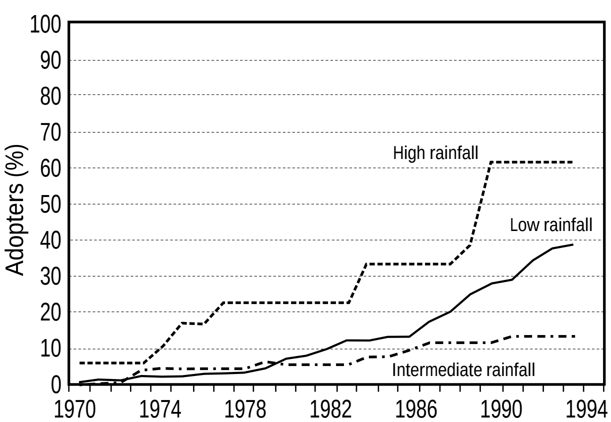

Figure 9. Adoption of inorganic fertilizer by agroecological zone, Lake Zone, Tanzania.

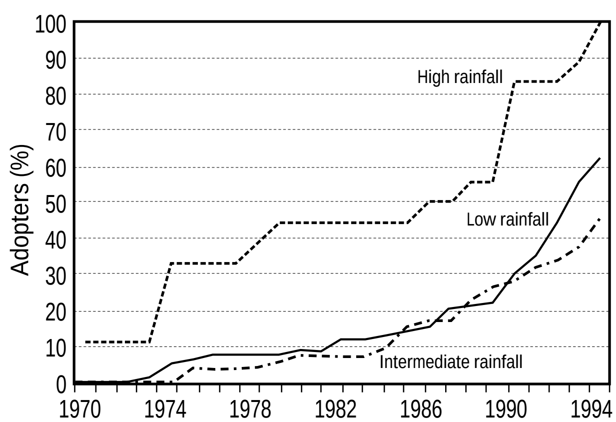

Figure 10. Adoption of improved maize by agroecological zone, Lake Zone, Tanzania.

Education level showed a positive impact on farmers' choice to allocate land to improved maize varieties. A unit increase in the level of education increased the probability of adoption among adopters by 1.8%. Literate farmers are more disposed to understand new ideas and concepts provided by extension workers and other informants. Other studies have shown similar effects for education (Shultz 1975; Gerhart 1975; Demir 1976; Ruttan and Thurtle 1987; Nkonya et al. 1997; Ntege-Nanyeenya et al. 1997). This underlines the importance of human capital development in increasing the area under improved maize varieties.

Extension increased the probability of adoption among adopters by about 12%. Extension is an important support service for delivering information about improved maize technologies to farmers. Elsewhere exposure to extension has been found to be a significant determinant of technology adoption (Asfaw et al. 1997; Ntege-Nanyeenya et al. 1997; Nkonya et al. 1997; Hassan et al. 1998). The use of hand hoes to prepare land decreased the probability of adoption among adopters by about 13%.

Table 22. Tobit model estimates for land allocated to improved maize varieties, Lake Zone, Tanzania

Parameter	Coefficient	t-statistic	dEY/dX_i	dEY^*/dX_i	$dF(z)/dX_i$
Constant	–0.76354***	1.86	–0.092331	-0.226931	–0.013963
Farmer's experience	0.01684***	1.83	0.002036	0.005005	0.000308
Education (yr)	0.06093***	1.67	0.007368	0.018109	0.001113
Extension services	0.40732**	2.04	0.049253	0.121059	0.007443
Farm size (acres)	0.025476*	9.51	0.003081	0.007572	0.000466
Family labor (no.)	–0.063057*	3.80	–0.007625	–0.018741	–0.001152
Hired labor	–0.000978	0.04	–0.000118	–0.000291	–0.000018
Livestock units (no.)	–0.020291*	3.82	–0.002454	–0.006031	–0.000371
Hand hoe	–0.42314***	1.85	–0.051166	–0.125761	–0.007732
SIGMA			20.992		
Number of samples			160		
Number of positive observations			62		
Proportion of positive observation (%)			38.75		
Z-score			–0.28		
F (*z*)			0.3836		
Log of likelihood function			–322.31		
Wald Chi-square (β_i=0)			159.74*		

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

6.4. Logit Analysis of Fertilizer Use

The coefficients of the model used to investigate factors affecting the adoption of fertilizer are shown in Table 23. The model is significant at the 1% level on the basis of the Wald chi-square statistic with 11 degrees of freedom. Extension was significantly and positively associated with the adoption of fertilizer. The odds of adopting fertilizer increased by a factor of 6.2 if a farmer received an extension visit. Elsewhere exposure to extension advice has been found to be a significant determinant of technology adoption, including fertilizer adoption (Asfaw et al. 1997; Nkonya et al. 1997; Hassan et al. 1998).

Table 23. Logit model estimates for fertilizer use, Lake Zone, Tanzania

Parameter	Coefficient	Exp (b)	Wald-statistic
Constant	–3.6643	–	3.51
Low rainfall zone	1.1901	3.29	0.97
Intermediate rainfall zone	–0.0066	0.99	0.00
Farm size (acres)	0.0009	1.00	0.04
Hand hoe	0.1218	1.13	0.01
Ox-plow	0.7209	2.06	0.20
Extension	1.8274*	6.22	11.26
Experience (yr)	–0.0101	0.99	0.16
Livestock units (no.)	–0.0188	0.98	0.85
Labor (no.)	–0.0161	0.98	0.09
Hired labor	0.3358	1.4	0.31
Education (yr)	0.0766	1.08	0.65
Percentage correctly predicted		83.1%	
Model chi-square		28.3*	
Sample size		160	

Note: * = significant at 1% level.

7.0 Conclusions and Recommendations

7.1 Conclusions

Among the farmers sampled for the survey, the mean age of the household head in the low, intermediate, and high rainfall zones was about 43, 46, and 43 years, respectively, with 20 years of farming experience. Farmers' level of education was low, averaging about 4.5 years in the low and intermediate rainfall zones and 7 years in the high rainfall zone. Households averaged about 14, 13, and 11 persons for the intermediate, low, and high rainfall zones, respectively. The number of female adults and children was higher in the intermediate rainfall zone. The average farm size was highest in the intermediate rainfall zone (46 acres) compared to the low (20 acres) and high (6.5 acres) rainfall zones. The number of cattle was significantly higher in the intermediate rainfall zone (48) ($p=0.05$) than in the low (24) and high rainfall zones (5.6).

The timing of land preparation, planting, and harvesting depended on the rainfall pattern. Land preparation started mostly in September–October in the low and intermediate rainfall zones, whereas it started in November–January in the high rainfall zone. Planting was done between October and November in the low and intermediate rainfall zones and between January and March in the high rainfall zone. Farmers in the high rainfall zone used less space between rows and hills compared to farmers in the low and intermediate zones. Most farmers weeded their maize plot twice, with the time of the first and second weeding depending on the rainfall pattern and time of planting. However, most farmers weeded after the first two weeks of planting and weeded the second time depending on the emergence of weeds. Most farmers in the high rainfall zone weeded between March and June, while farmers in the low and intermediate rainfall zones weeded mostly between November and January. Maize was harvested between April and July in the low and intermediate rainfall zones, while farmers in the high rainfall zone harvested between August and September.

The use of fertilizer for maize production was constrained by its high price and farmers' lack of knowledge about the technology. Farmers mainly applied urea and CAN, and the average amount of fertilizer used was higher in the high rainfall zone (20 kg/ha) compared to the low (13 kg/ha) and intermediate rainfall zones (17.5 kg/ha). To increase soil fertility, farmers plowed crop residues back into the soil, mainly in the low and high rainfall zones. Farmers in the intermediate zone (58.1%) used crop residues to feed cattle. More farmers in the low (76.1%) and high (83.3%) rainfall zones rotated crops compared to farmers in the intermediate rainfall zone (60.4%). In all zones, the important field pests and diseases were stalkborers and MSV.

A large number of farmers recycled seed for more than 10 years (52.4% of farmers in the low ranfall zone and 78.6% in the intermediate rainfall zones). In the high rainfall zone, 75% of farmers recycled seed every 2 years. Farmers selected seed from the previous harvest based on the size of the cob and lack of pests/diseases. Selection was done mainly at the homestead after the harvest. Seed maize was stored separately from the main crop, usually in cribs, and maize for consumption was shelled and stored in gunny bags, cribs, or a *kihenge*. Most farmers in the low (94%) and intermediate rainfall zones (88.6%) treated stored maize with industrial chemicals to control storage pests, while only 22% of the farmers in the high rainfall zone treated their maize.

The main maize varieties grown during the 1994/95 farming season in the high rainfall zone were local varieties and H625 (imported from Kenya). In the low rainfall zone, the main varieties grown in the 1994/95 farming season were local varieties, Kilima, H614, Tuxpeño, Katumani, and H625. The improved maize variety preferred by farmers in the high rainfall zone was H625. In the intermediate rainfall zone, farmers mainly grew local varieties, Kilima, and H625. Varieties were preferred for their yield potential, resistance to drought, and resistance to field pests. About 29%, 25%, and 56% of the farmers in the low, intermediate, and high rainfall zones, respectively, disadopted improved maize varieties. Farmers in the high rainfall zone mainly disadopted H625 and Katumani, and farmers in the low rainfall zone mainly disadopted Tuxpeño. Farmers in the intermediate rainfall zone disadopted mostly Katumani and Tuxpeño.

Very few farmers used credit (3% of farmers in the low rainfall zone, 2% of farmers in the intermediate zone, and no farmers in the high rainfall zone). The only credit institutions were the cooperative unions. Most farmers reported that credit was difficult to obtain (all farmers in the high rainfall zone, 62.5% of farmers in the intermediate rainfall zone, and 82.4% of farmers in the low rainfall zone). Lack of knowledge (information) and credit facilities were the main constraints to obtaining credit in all zones.

Most farmers had received information on all of the agronomic practices, except for disease and weed control (herbicides). The most important sources of information were research and extension.

The tobit analysis showed that education, farmer's experience, farm size, family labor, extension, livestock units, and hand hoe use were significant factors affecting the proportion of land allocated to improved maize varieties. Education and extension increased the probability that a farmer would allocate land to improved maize at the means by about 1.8% and 12%, respectively. The farmer's experience and farm size increased the probability of allocating land at the means by about 0.5% and 0.7%, respectively. Family labor and livestock units decreased the probability of allocating land at the means by about 1.9% and 0.6%, respectively. Farmers using hand hoes were less likely to allocate land to improved maize varieties and their probability decreased by about 13%. The odds in favor of adopting fertilizer increased by a factor of 6.2 if a farmer received an extension visit.

7.2 Recommendations

The characteristics of the innovation and external influences are the major factors affecting the adoption of improved maize practices. Field pests limit maize production, and flexible integrated management packages that combine a drought tolerant variety with improved cultural practices could increase yields. Low-cost technologies for controlling stalkborer and MSV 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. The use of fertilizer is constrained by high price and farmers' lack of knowledge about the technology, however. An efficient marketing system for inputs and outputs would benefit farmers by offering higher prices for maize and reducing the cost of fertilizer. Such a system cannot be established without policy support from the government. Studies on the economics of fertilizer use should be undertaken, especially now that input and output markets have been liberalized.

The use of improved varieties was low in the study area, especially in the low and intermediate rainfall zones. Farmers in the high rainfall zone mainly grew improved maize hybrids imported from Kenya (H625). Furthermore, most farmers in the low and intermediate rainfall zones recycled seed for more than 10 years. These findings would seem to indicate that suitable maize varieties should be developed for the study area, especially for the low and intermediate rainfall zones. More suitable hybrids should be developed for farmers in the high rainfall zone.

Extension efforts need to be strengthened to increase the flow of information to farmers. More effort should be directed toward fertilizer technologies, as a majority of farmers use inefficient practices. Advice to farmers to use organic manure to supplement chemical fertilizer should be increased. Furthermore, extension efforts should be directed towards promoting the adoption of improved varieties, weeding, and management of field and storage pests and diseases. Farmers in the high rainfall zone need to be encouraged to treat their stored maize.

Formal credit is not available to most of the 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 procedures. The formation of farmer groups should be encouraged as well, because lending to groups tends to reduce transaction costs and ensures a high rate of loan recovery.

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