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

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Abstract

The impact of maize research and extension in Tanzania's Northern Zone during the past 20 years was evaluated through a formal survey in 1995. Data were grouped into two major agroecological zones: the intermediate and the lowland sub-zones. Sample farmers were also categorized based on land preparation method. A two-step Heckman's procedure was used to simultaneously analyze factors affecting adoption of improved maize seed and inorganic fertilizer. The study found that demand for composite seed was less than that for hybrids, although the National Maize Research Program had released more composites, which can be recycled. Farming experience was the only factor that significantly influenced the probability of adopting improved maize in the intermediate zone. No factor significantly influenced intensity of adoption of improved seed. About 80% of farmers recycled improved varieties, including hybrids, contrary to recommendations. The rate of adoption of chemical fertilizers was low, influenced only by the number of livestock units. No farm characteristic influenced intensity of fertilizer adoption. Recommendations on fertilizer placement were poorly followed, which magnifies the negative impact of the poor management of crop residues in the zone. Formal credit is not available to maize farmers; with rising input prices, this dynamic will become more critical. Adoption of recommendations on land preparation, frequency and timing of weeding and fertilizer application, and plant spacing have been successfully adopted in both zones. Recommendations based on survey results include the development of additional hybrids for the Northern Zone and/or village level production of composite seed; research on the economics of recycling improved varieties (including both composites and hybrids); more research and extension effort directed toward efficient use of fertilizers (manure, chemical fertilizer, and crop residues); and encouraging measures by banks and policy makers to make credit more available to small maize farmers with a high rate of loan recovery and low cost of administration.

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ABBREVIATIONS AND ACRONYMS

CAN	Calcium Ammonium Nitrate
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo [International Maize and Wheat Improvement Center]
DRT	Department of Research and Training
FSD	Food Security Department
FSR	Farming systems research
Hh	Hand-hoe
HH	Household
ICW	Ilonga Composite White
IMR	Inverse Mills Ratio
masl	Meters above sea level
MDB	Marketing Development Bureau
MOA	Ministry of Agriculture
MSV	Maize streak virus
Mt.	Mount
NGO	Non-governmental organization
NMRP	National Maize Research Programme
N	Nitrogen
n	Sample size
No.	Number
OLS	Ordinary Least Squares
OPV	Open pollinated variety
Ox (or O)	Oxen
SA	Sulphate of Ammonia
SACCAR	Southern Africa Center for Coordination of Agricultural Research
SARI	Selian Agricultural Research Institute
SG2000	Sasakawa-Global 2000
ST	Streak resistant
SUR	Seemingly unrelated regression
TARO	Tanzania Agricultural Research Organization
TMV	Tanzania maize variety
Trac (or T)	Tractor
Tsh	Tanzanian Shillings
UCA	Ukiriguru composite A
ULVA	Ultra low volume applicators
USAID	United States Agency for International Development
WAP	Weeks after planting
yrs	Years

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The Maize Research Impact Evaluation study is the culmination of the efforts of many people and institutions. This makes the task of recognizing each contributor exeedingly difficult. We are especially grateful to the northern Tanzania maize farmers who participated as our sample subjects. Despite the difficult charge of simultaneously managing their farms and raising families, they took the time to respond to our rather lengthy questionnaire. Their time and candid responses made this study possible. We are indebted to SACCAR, CIMMYT, and the Government of Tanzania for financial support. We are grateful to Dr. Joel Ransom of CIMMYT for financial and logistical support for the survey.

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EXECUTIVE SUMMARY

Maize provides 60% of the 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. Realizing the importance of the maize crop to the lives of Tanzanians, the government has been committing human and financial resources to develop the industry. A National Maize Research Program (NMRP) was started in 1974 with the broad objective of developing cultivars suitable for major maize producing areas. The NMRP and maize extension services have made considerable impact on increasing food production.

The objective of this study was to evaluate the impact of maize research and extension for the past 20 years. It was conducted by the Department of Research and Training (DRT) in collaboration with the Southern Africa Coordination Center for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement Center (CIMMYT). To increase data validity and reliability, farmers were interviewed by researchers and experienced extension officers using a structured questionnaire. Interviews were conducted in all seven agroecological zones of the country between June and November 1995. This report covers survey findings in the Northern Zone, which includes Arusha and Kilimanjaro regions. Northern Tanzania is an important maize growing area, accounting for about 10% of the total national maize production. The zone is one of the country's maize surplus areas. Total area under maize production in the zone is 160,700 ha, of which 70% is in the Arusha region.

Data collected in the survey were grouped into two major agroecological zones: the intermediate and lowland sub-zones, the most important zones for maize production in the study area. Analysis was also undertaken after sample farmers were categorized according to their method of land preparation. A two-sample comparison between zones and among methods of land preparation was employed to investigate statistical differences. A two-step Heckman's procedure was used to simultaneously analyze factors affecting adoption of improved maize seed and inorganic fertilizer.

Results of the analysis showed that raising livestock in the zone was quite common. Of the 126 farmers sampled, 84% kept cattle, 79% kept goats, and only 40% raised sheep. Overall, each household averaged about five head of cattle, six goats, and two sheep. All sampled households had hoes equivalent to the number of family laborers available. Ox-ploughs were for land preparation and planting in Arumeru, Babati, Hanang, and Mbulu districts in the Arusha region and Hai District in the Kilimanjaro region. The decision to preparare land by hand-hoe was largely dictated by terrain. Rolling topography in the highlands makes mechanization difficult. In the intermediate zone, tractors were the major means of land preparation. The majority of farmers owning tractors were found in Arusha.

Intercropping maize with beans or pigeon peas is the most common cropping system in northern Tanzania. Sixty percent of sample farmers in the intermediate zone grew maize in association with beans and pigeon peas. Forty percent of sample farmers in the lowland zone grew maize in pure stand. Coffee in association with banana is a common cropping system on the mountain slopes where rainfall is high and temperatures are cool. About 19% of the sample farmers grew coffee in association with banana.

All sample farmers reported that they used either certified or recycled improved seed. On average, about 80% of the sample farmers recycled improved maize seed for 4 to 6 years. Recycling improved maize seed, including hybrids, has reduced the adoption of improved maize seed in the two zones. Extension agents should discourage farmers from recycling hybrids and advise them on how to recycle composites. CG4141 is the most preferred hybrid in both zones because of its yield and drought tolerance/resistance/avoidance attributes. Forty-five percent of sample farmers at one point had discontinued growing an improved variety for various reasons. The varieties that have been discontinued by most farmers in the intermediate zone are hybrids H622 and H632, and Kilima and Katumani in the lowlands. The major reason given for discontinuing hybrids was their late maturity.

Over the span of the study, there was no statistically significant difference (P=0.05) of rate of adoption of improved maize varieties among methods of land preparation except for hand-hoe versus oxen in 1990, and hand-hoe versus tractor in 1990 and 1991. Comparing the intermediate and lowland sub-zones of the Northern Zone showed that only farming experience significantly affected (P=0.05) the probability of adopting improved maize seed in the zone. An increase in one year of experience increased the probability of adopting by 1.3%. The reason other factors did not have a significant impact on probability of adoption could be the high rate of adoption of improved maize seed. Also no factor significantly influenced (P=0.05) the intensity of adoption of improved maize seed. The reason for the non-significant difference may be the narrow range of intensity of adoption (0.17-1.0 ha, with a mean of 0.89 and a standard deviation of 0.21 ha). Farmers reported that the major non-household factors affecting adoption of improved maize varieties were prices of inputs, poor marketing systems, and varietal traits.

The adoption of agronomic technologies was generally high. Farmers reported that crop planting time is dictated by the onset of rainfall. Hence, the significant difference in timing of planting (P=0.01) is a factor of location (and onset of rainfall), rather than management differences. Row planting was practiced by all but one of the 126 respondents. The average plant population was slightly lower than the recommended population of 44,444 plants/ha for the medium and longer duration varieties commonly grown in the zone.

About 89% and 60% of sample farmers in the intermediate and lowland zones, respectively, weeded their maize twice during the growing season. The difference in the proportion of farmers weeding twice between the two zones is significant at p = 0.01. It may be explained by the length of the growing season. In the lowlands, the growing season is shorter so farmers may not have time to weed twice. Only 21% of the sample farmers in the lowland weeded their maize fields once and followed the recommended time for the first weeding. Farmers in the intermediate zone did their first weeding 3.8 weeks after planting, compared to 3.6 weeks for the lowland farmers. About 80% and 92% of sample farmers in the intermediate and lowland zones, respectively, applied fertilizer. The difference in the percentage of farmers applying fertilizer between the two zones is significant at p = 0.01. Application of organic manure was more common in the Arusha region than in Kilimanjaro. About 49% and 44% of sample farmers in the intermediate and lowland zones, respectively, applied kraal manure. While 64% of the farmers in the intermediate zone applied chemical fertilizer, only 44% of sample farmers in the lowland zone used chemical fertilizer in the 1994/95 season. The difference in the proportion of farmers applying chemical fertilizer is significant at P=0.05. Up until 1994, the fertilizer application level was still less than half the recommendation for intermediate and highland areas, which averaged 80 kg N/ha. The majority of farmers reported that they top dressed fertilizer only once. Only 10% of sample farmers applied a second application of top dressing fertilizer, while only 4% applied basal chemical fertilizer at planting. On average, timing of fertilizer application was close to the recommendation. Applications ranged from 1 to 13 weeks after planting maize, with an average of 4.7 weeks. There was no significant difference (at p = 0.05) between zones on time of fertilizer application. The majority of farmers in the intermediate zone broadcast fertilizer, contrary to the recommendation of spot or furrow application and covering fertilizer with soil. In the lowland zone, the majority of farmers banded fertilizer around crops without covering it. The recommendation for fertilizer placement was followed poorly in both zones.

For both zones, units of livestock significantly influenced the probability of adopting fertilizer ($p = 0.05$). A unit increase in livestock units decreased the probability of adopting fertilizer by 1.5%. The reason may be that farmers with large herds have more manure, which they can substitute for chemical fertilizer. In addition, farmers who have large cattle herds live in areas with less rainfall, hence less soil leaching, which makes their soils more fertile and lessens the need to apply fertilizer.

For the two zones, no variable significantly influenced ($p=0.05$) the intensity of adoption of fertilizer. However, for the intermediate zone, livestock herd size significantly influenced the intensity of fertilizer adoption ($p=0.01$). The income effect of livestock herd size may have contributed to its positive influence, as opposed to its negative impact on probability to adopt fertilizer. Richer farmers, as manifested by larger livestock herds, were likely to use higher doses of fertilizer. The crop residue management recommendation is to plough it under in order to avoid soil mining for farmers who do not apply or apply only small amounts of fertilizer. However, only 11% of the farmers followed this recommendation. About 94% of the respondents from the lowland zone, compared to 71% from the intermediate zone, reported that they fed their maize stover to cattle in the field. The majority of farmers in the lowland zone do not zero graze because they have large herds of cattle. Only 14% of the farmers cut and carried stover home for feeding zero-grazed dairy cows. This results in nutrient flow from the field to other areas. Extension officers should encourage farmers who cut and carry stover and those who feed crop residue *in situ*, to apply fertilizer to their fields in order to replenish the exported nutrients.

Stalk borer (*Buseola* spp.) is one of the most important maize pests in Tanzania. As expected, a significantly higher percentage of farmers in the lowland zone have been affected by stalk borers as compared to farmers in the intermediate zone. About 58% and 20% of the farmers in the intermediate and lowland zones, respectively, used chemical control against insect pests. Due to efforts aimed at breeding for disease control, maize diseases were rarely reported by sample farmers. The major disease reported was Maize Streak Virus (MSV). No farmer reported using any measure to control the disease.

Most farmers in Kilimanjaro and the lowlands of the Arusha region store their maize using gunny bags or airtight drums. For sample farmers who used gunny bags, 80% treated maize using chemicals alone or in combination with ashes. Farmers who used drums did not use chemicals and had no grain losses. Treatment with Actellic Super powder for shelled maize was the most common chemical control. Upright cribs are used in Arusha. Farmers who used cribs normally did not shell their maize. Ninety percent of tractor users treated their shelled maize as compared to 77% of hand-hoe users.

Sixteen percent of the sample farmers in the two zones received a loan. Sasakawa-Global 2000 (SG-2000) was the major source of credit for small-scale, subsistence farmers in northern Tanzania. The major disadvantage of the SG-2000 credit service was its short-term nature (3 years) and weak credit administration that increased the loan default rate when it was extended to a large number of farmers. About 19% of sample farmers in the intermediate zone received credit once as compared to 8% of the farmers in the lowland zone. The difference in loan accessibility may be due to the fact that SG-2000 had more sites in the intermediate than in the lowland zone. Only 1 out of 3 loan recipients in the lowland zone, compared to 1 out of 13 in the intermediate zone, reported that they received a loan from a formal bank. Lack of collateral and cumbersome loan application procedures were the major obstacles that farmers from both zones faced in securing loans from formal credit institutions. The three most important sources of maize production information were extension agents, farmers, and non-governmental organizations. In both zones, extension officers were the most important sources of all agricultural production technologies, except for technologies pertaining to draft animals in the lowlands.

1.0 INTRODUCTION

1.1 Introduction to the 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. In the Northern Zone, the per capita consumption is estimated to be 130 kg 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 or about 45% of the cultivated area in Tanzania. However, most of the maize is produced in the Southern Highlands (46%), the Lake Zone, and the Northern Zone. Dar es Salaam, Lindi, Singida, Coast, and Kigoma are deficit regions. Dodoma is a surplus region in good growing years, and the region is the number one supplier of maize to Dar es Salaam in years following a plentiful rainfall season (FSD 1992; Mdadila 1995).

Maize is not only a staple crop in surplus regions, it is also a cash crop. For instance, in the Lake Zone, maize competes aggressively with cotton for land, labor, and farmers' cash. Realizing the importance of the maize crop to lives of Tanzanians, the government has been committing human and financial resources to develop the industry. Research and extension efforts in maize started in 1960. Breeding efforts in the 1960s resulted in the release of Ukiriguru composite A (UCA), and Ilonga composite White (ICW). Between 1973 and 1975 Tanzania experienced a severe food shortage due to drought and the "villagization" campaign that displaced 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 food self-sufficiency. The country also launched a maize project in 1974 with assistance from the U.S. Agency for International Development (USAID). Its objective was to promote maize production in pursuit of food self-sufficiency. On the research frontier, the National Maize Research Program (NMRP) was launched with the broad objective of developing cultivars suitable for major maize producing areas.

The NMRP and maize extension have made considerable impact on increasing food production. This study was conducted to evaluate the impact of maize research and extension during the past 20 years. Conducted by the Department of Research and Training (DRT) in collaboration with the Southern Africa Coordination Center 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 Northern Zone.

1.2 Objectives of the study

The objectives of the study were to:

- describe the maize farming systems in northern Tanzania,
- evaluate adoption of maize production technologies in the Northern Zone, and
- define the future research agenda in light of the study's findings.

1.3 Description of the study area

Northern Tanzania consists two of mainland Tanzania's twenty regions—Arusha and Kilimanjaro. The Arusha region alone covers 82,000 km^2, about 9.3% of the area of Tanzania. With a population density of 17 persons/km^2, Arusha is one of the country's most sparsely populated regions (MDB 1993). It has a diverse climate that enables it to produce a wide range of crops and it is the number one wheat producer in the country, accounting for more than 64% of national wheat production each year since 1981. The region was the second largest producer of maize and beans between 1981 and 1989 (Nkonya et al. 1991). Arusha is also endowed with the world's richest game parks that attract tourists from all over the world.

The Kilimanjaro region has an area of 13,000 km^2, which is 1.5% of mainland Tanzania. With a population density of 94 persons/km^2, Kilimanjaro is the third most densely populated region in the country after Dar es Salaam (1,849 persons/km^2) and Mwanza (97 persons/km^2) (MDB 1993). Kilimanjaro is a leading producer of arabica coffee in the country, producing about 40% of its mild arabica coffee (Nkonya et al. 1988). The Kilimanjaro region also attracts tourists drawn by the highest mountain in Africa, snow-capped Mt. Kilimanjaro, that stands at 19,840 ft (5,890 m) above sea level.

The northern Tanzania climate also allows production of temperate and tropical high value crops, specifically, flowers, snap beans, barley, garlic, pigeon peas, paddy, and onions. Excluding Dar es Salaam, northern Tanzania has the best communication system in the country. There is an international airport, about 700 km of paved road, and a railroad that connects the zone with two important ports, Tanga and Dar es Salaam.

Northern Tanzania is an important maize growing area that accounts for 10% of the total national production of the cereal (Nkonya et al. 1991) and is one of the nation's maize surplus areas. Total area under maize production in the zone was 160,700 ha, of which 70% was in the Arusha region (MDB 1993). The major maize producing districts are Mbulu, Babati, Hanang, and Arumeru; other maize producing districts of less importance are Moshi, and Rombo. Remaining districts—Mwanga, Same, Kiteto, Monduli, Ngorongoro, and Simanjiro—are maize deficit areas because of their unreliable rainfall.

The Northern Zone has three major agroecological zones:

(1) **High Rainfall Zone:** This zone receives about 1,200 - 1,500 mm of rainfall per year. Rainfall distribution is good and reliable. The zone is located on the slopes of Mt. Kilimanjaro, Meru, Hanang, Monduli, Pare, and Ngorongoro mountain ranges; Oldeani and Loolmalasin. Some areas located in the high plateaus fall into the high rainfall zone including Bashnet in Babati and Mama Isara area in Mbulu. Most areas in the high rainfall zone rise to an altitude of 1,500 meters above sea level (masl). Other areas are above 1,500 masl, but their rainfall is less than 1,200 mm per annum (these areas are always on the lee side of mountains, e.g. Olkokola in Arumeru). Major crops grown in this high rainfall zone are coffee in association with banana.

Because these areas are densely populated, with the attendant problem of land shortage, farmers grow their maize in the drier lowland areas. The rolling topography of the zone prohibits mechanization in many areas where farmers prepare their fields using only hand-hoes. Livestock in the zone are either exotic or cross breeds of exotic and local dairy cows. Stall feeding is the most common feeding system in the zone (Cunard et al. 1983; Nkonya et al. 1991). Figure 1 shows the rainfall patterns for the various stations representing three agroecological zones.

(2) **Moderate Rainfall Zone:** Rainfall in this zone ranges from 800 to 1,200 mm per annum, with moderately reliable distribution and amount. Moderate rainfall areas are located between 900 and 1,500 masl. The major crops grown in this zone are banana in association with coffee, and maize intercropped with beans or pigeon peas. Farmers in this zone also grow monocropped maize in the lowland plains. The livestock-keeping system in the zone is semi-intensive. Land is prepared mainly with ox-ploughs and tractors. Hand-hoes are used for land preparation in areas where the terrain is steep (Cunard et al. 1983; Nkonya et al. 1991). The mountain slopes and high plateau of Hanang, Mbulu, Babati, and some parts of Monduli fall in this zone, which is the most important area for the production of maize, bean, pigeon peas, and wheat.

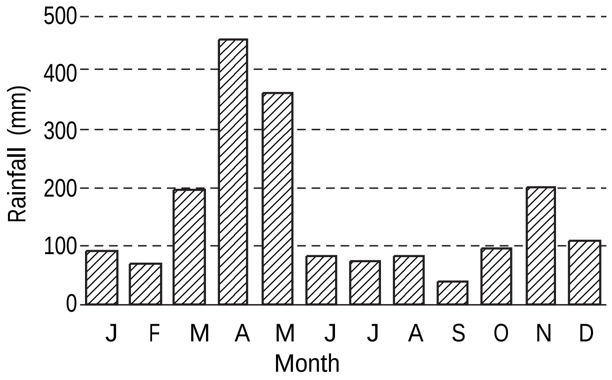

Figure 1a. Rainfall pattern for the highland zone, monthly totals (Maua Station).

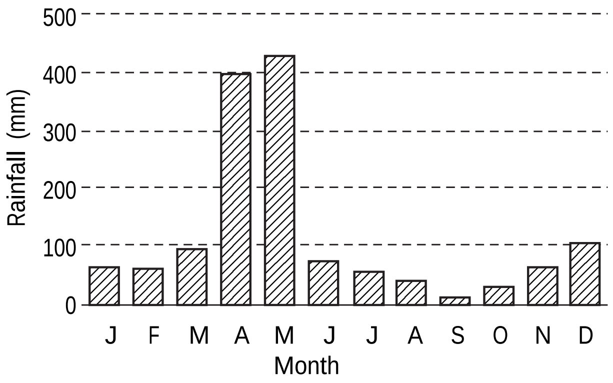

Figure 1b. Rainfall pattern for the intermediate zone, monthly totals (Lyamungu A.R.I.).

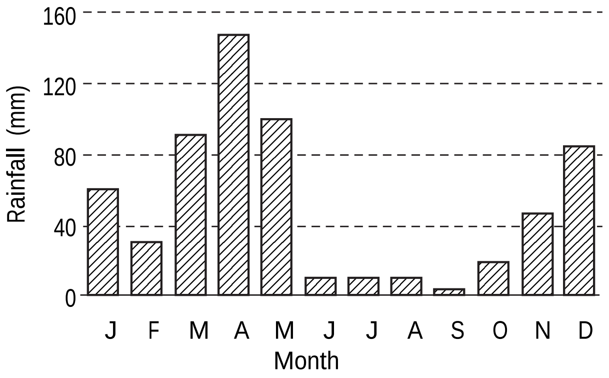

Figure 1c. Rainfall pattern for the lowland zone, monthly totals (Miwaleni Station).

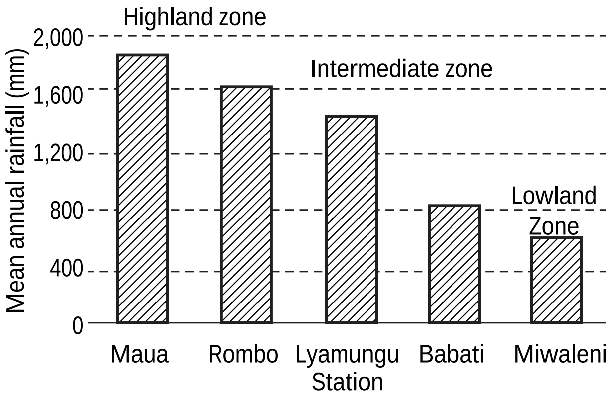

Figure 1d. Mean annual rainfall for selected stations in each zone.

(3) **Low Rainfall Zone:** This zone receives rainfall ranging from 500 to 800 mm per year with very erratic distribution. Low rainfall areas are always in the lowland plains below 900 masl. Studies show that drought occurs in one out of every four years. Because there is no land pressure in this zone, farmers in the high and moderate rainfall zones grow their maize and other annual crops in this area, the second most important area for maize production in northern Tanzania. The major cropping systems in the zone are monocropped maize, monocropped beans, and maize in association with beans. Extensive livestock-keeping prevails in the zone, which is the most important area for livestock production in northern Tanzania. Land preparation is predominantly accomplished using ox-plough and tractor (Cunard et al. 1983; Nkonya et al. 1991).

1.4 Methodology

1.4.1 Sampling procedure

This report is part of a national survey covering all agroecological zones of Tanzania. The number of farmers interviewed in each zone was determined by the importance of maize production in the area. About 1,000 maize farmers were interviewed nationwide. The Northern Zone was allocated 126 farmers, or approximately 13% of the national sample. At the zonal level, farmers were sampled from districts with significant maize production based on figures from the statistical unit of the MOA. Seven districts were purposively sampled. At the district level, villages were selected with the help of extension staff. Seven villages were purposively sampled (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, 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 returned to the respective zones for analysis and completion of the zonal reports.

1.4.2 Data analysis

Data were grouped into two major agroecological zones, the intermediate and lowland zones, which were the most important zones for maize production in the study area. Even highland zone farmers grew maize in either the intermediate or lowland zones. Sample farmers were also grouped according to the method of land preparation they used. Two-sample comparisons between zones and among methods of land preparation were made to investigate statistical differences. A two-step

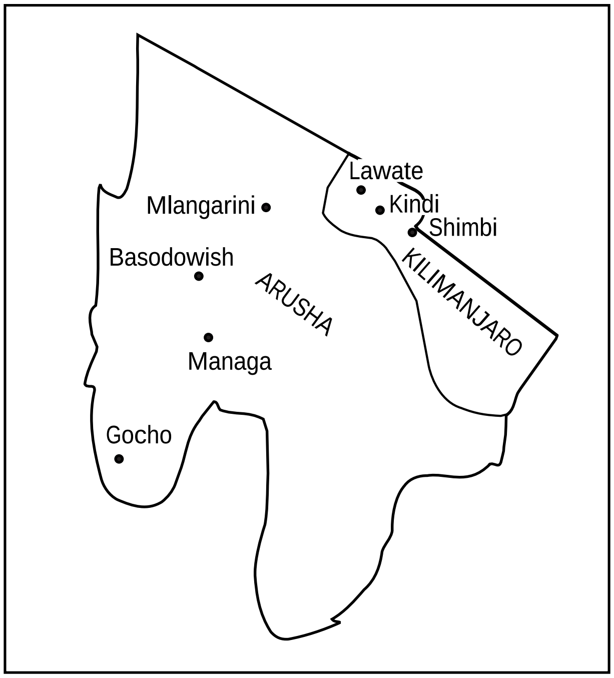

Figure 2. Northern Zone villages sampled for survey, 1995.

Heckman’s procedure was used to analyze factors affecting the probability of adopting improved maize seed and inorganic fertilizer.

This procedure was used because it addressed simultaneity problems. Farmers tend to adopt improved maize seed and fertilizer simultaneously: farmers who plant improved maize seed are likely to apply fertilizer. The converse is also true: farmers who apply fertilizer are likely to plant improved maize seed (Smale et al. 1994; Nkonya et al. 1997; Kaliba et al. 1998). Hence, when estimating the probability to adopt maize seed, inorganic fertilizer should be included as an independent variable in the model. Also, when estimating the probability of using inorganic fertilizer, improved maize seed should be included as an independent variable. When simultaneously determined variables are included as independent variables in a system of (simultaneous) equations, they are referred to as “endogenous” variables. The adoption of improved maize seed and fertilizer is estimated in a system of two simultaneous equations, one for each endogenous variable. The Heckman’s two-step procedure involves two estimation steps. In step 1, a probit equation is estimated for each of the simultaneous equations. The probit model is used because its likelihood function is well behaved as it gives consistent Maximum Likelihood Estimate (MLE) coefficients (β) and the standard error of the estimate (σ) (Maddala 1983). The estimated probit models are:

P(AS)= f(FARMS,EXP,EDUC,LUNIT,LABOR,MLP1,MLP2,MLP3,NRATE,Ui) .... (1)
P(AF) = f(FARMS,EXP,EDUC,LUNIT,LABOR,MLP1,MLP2,MLP3,ADIS,Ui)............................ (2)

where:
P = probability;
AS = 1 if farmer uses improved maize seed, 0 otherwise;
AF = 1 if farmer uses fertilizer, 0 otherwise;
FARMS = Farm size (acres);
EXP = Farming experience (years);
EDUC = Level of education of family head (years);
LUNIT = Livestock units (index where livestock numbers are aggregated using following weighting factors: cow = 0.8; goat = 0.4; sheep = 0.4);
LABOR = Family labor (index where family members are aggregated using following weighting factors: male and female adults above 16 years = 1; children 12-15 years = 0.5);
MLP1 = Hand-hoe (number);
MLP2 = Ox-plough (number);
MLP3 = Tractor (number);
MLP 4 = Other method (number);
NRATE = Rate of nitrogen (N) applied (kg/ha) (endogenous variable);
ADIS = Number of acres planted with improved maize seed (endogenous variable); and
Ui = Random error

Results of the first step show the influence of independent variables on the probability of adopting a given technology ($\partial p/\partial x$). The results are the same as any other probit model estimated as a single equation.

In step 2, the intensity of adopting fertilizer or improved maize seed is estimated as follows:

$$E(y_i \mid y_i > 0) = \beta x_i + \sigma f(\beta x_i)/F(\beta x_i) \ldots\ldots (3)$$

where y_i = intensity of adoption of a technology (area under improved maize seed or level of fertilizer), $x_{i^{th}}$ = independent variable as specified in equations 4 and 5 below.

The ratio of $f(\beta x_i)/F(\beta x_i)$ is the Inverse Mills Ratio (IMR), evaluated at each sample observation. IMR is calculated from the probit results of the first step. Using the data from adopters only, an Ordinary Least Squares (OLS) model, including the IMR as regressor, is estimated for each endogenous variable. The impacts of the same factors on intensity of adoption ($\partial ADIS/\partial X$ and $\partial NRATE/\partial X$) are estimated using a system of Seemingly Unrelated Regression (SUR) equations. In our case, the following two OLS equations will be estimated simultaneously in a system of equations:

$$ADIS = f(FARMS, EXP, EDUC, LUNIT, LABOR, MLP1, MLP2, MLP3, NRATE\ IMRS, U_i) \ldots\ldots (4)$$
$$NRATE = f(FARMS, EXP, EDUC, LUNIT, LABOR, MLP1, MLP2, MLP3, ADIS, IMRF, U_i) \ldots\ldots (5)$$

The variables are as defined earlier.

There are two advantages to using the Heckman's approach. The first is that we use SUR[1] in the second stage because only adopters are included in the second stage analysis. SUR is easy and familiar, hence available in many econometric computer packages. The second advantage is that the use of SUR purges the heteroscedasticity of the estimates obtained from the second step (Greene 1993). Some of the factors influencing adoption were either not variables across farmers or could not be collected from household surveys. Those variables were analyzed using cross tabulations.

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[1] A SUR is a system of equations whose individual equation random errors are believed to have some correlation. For instance, in our case, errors of equation estimative intensity of adoption of maize seed are believed to be correlated with errors of the equation estimating intensity of adoption of fertilizer. In this situation, the equations are estimated as a system and not individually, in order to account for the cross equation relationship of random errors.

2.0 HISTORY AND DEVELOPMENT OF MAIZE RESEARCH

2.1 Introduction

About 85% of Tanzania's total maize production 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 (over 100 ha). Between 1961-65 and 1985-95 the growth rate of maize production in Tanzania was estimated to be 4.6%, of which 2.4% and 2.2% per year were due to growth in area and yield, respectively. Despite this growth in yield, the national average is less than 1.5 t/ha, however, grain yields are higher in high potential areas such as the southern highlands (Moshi and Marandu 1988).

Maize breeding and agronomy trials have been conducted in Tanzania for more than 20 years. The improved open pollinated varieties (OPVs), namely 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.

In 1974, the NMRP was launched as a means to coordinate maize research, which included better utilization of some resources. The program is responsible for coordinating all phases of maize research, from varietal development and maize management research on station, to verification in farmers' fields. The program divided the country into three major varietal recommendation agroecological zones: (i) highland zone (elevations above 1,500 masl), with a growing period of 6-8 months; (ii) intermediate zone (900-1500 masl), which is further subdivided into 'wet' (>1,100 mm rainfall) with a 4-5 month growing period, and 'dry' (<1,100 mm rainfall) with a 3-4 month growing period; and (iii) lowland zone (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 highland zone, 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 disease, whereas Kilima was recommended for the mid-altitude zone. Kito is an early maturing variety adapted to both low and mid-altitude zones. In 1987 two OPVs, TMV1 and TMV2, were released. TMV1 is white flint, streak resistant, and has intermediate maturity. It is recommended for the lowland and mid-altitude zones. TMV2 is also white flint and is recommended for the high altitude, high-potential maize producing areas.

In 1994, the NMRP released versions of Kilima, UCA, Kito, and Katumani that are resistant to maize streak virus: Kilima-ST, UCA-ST, Kito-ST, and Katumani-ST, respectively. Around the same time two foreign seed companies, Cargill and Pannar, introduced/released seven hybrids for commercial use by the farmers. For the improvement of husbandry practices, the NMRP conducted off-station agronomic trials that resulted in the 1980 recommendations for maize production practices specific to 11 regions. The recommendations were on varieties, spacing, plant density, fertilizer rate, weeding regime, and pesticide use. Maize research work in the Northern Zone was formerly coordinated from the Lyamungu Agricultural Research Institute. Research activities focused on soil fertility, weed control, cropping systems, and variety testing. Until early 1994 these research activities were collaboratively conducted by staff from the maize section, the FSR program, and the National Bean Research Program.

In 1994 the coordination of maize research activities in the Northern Zone was moved to SARI, which is also the zonal headquarters for research and training activities. Aside from the activities they formerly coordinated at Lyamungu, the maize staff was also made responsible for:

1) Initiating maize breeding activities to cater to the mid-altitude areas of the country.
2) Collaborating with staff at Arusha Foundation Seed Farm at Ngaramtoni to maintain purity of existing maize inbred lines.
3) Initiating activities on inbred lines from the existing OPVs.
4) Performing crosses among existing inbred lines as well as among inbred lines to be extracted from existing OPVs, in order to obtain new maize hybrids for mid-altitude areas (Anandajayasekeram et al. 1992).

2.2 Maize production technology recommendations

As indicated, most maize growing areas in Tanzania are divided into three agroecological zones: the low altitude zone (less than 900 masl); the medium altitude zone (900-1,500 masl); and the high altitude zone (above 1,500 masl). Maize production recommendations were developed to fit the agroecological zones as outlined below.

2.2.1 Varieties

The choice of maize variety is determined by the farmer’s objective, the length of growing season, the elevation, and the amount of rainfall. Recommended varieties for the various ecological zones in Tanzania, including those of the Northern Zone, are shown in Table 1.

2.2.2 Planting time, method, and spacing

Generally, early sowing is the most important single factor for increased grain yield (Goodbody 1990). Lower yields and increased pest and disease attack occur with late sowing. Varieties susceptible to maize streak virus disease suffer more when sown late.

The total length of the growing season and the number of days to silking of varieties influence the decision on when and what variety to grow. If the rains come late, farmers are advised to plant early maturing varieties even in areas that are suitable for full season varieties.

In most areas of the Northern Zone maize is normally sown between mid-January and mid-March. In isolated pockets that have bimodal rainfall,—Rombo, Mwanga, and Same districts in Kilimanjaro region—farmers also sow their maize in October.

It is recommended that seed be sown directly into moist soil to protect it against rodents, birds, and drying. Normally 5-7 cm is considered an adequate sowing depth. Deeper sowing retards emergence. In dry areas, maize seed may be sown deeper and then covered with soil.

The best way to get uniform stands is to sow in regularly spaced rows and at regular intervals within the row. Row planting makes weeding and insect control easier. Generally, across all of the Northern Zone's agroecological zones plant populations range from 40,000 to 53,000 plants/ha. For small statured varieties, namely, Kito and Katumani, optimum plant density can range from 60,000 to 70,000 plants/ha (Matowo and Mgema 1990b). Taking into account unreliable seed quality, insect pests, and vermin it is advisable to sow more plants per hill. However, excess plants (if any) need to be thinned about 2-3 weeks after seedlings emerge from the soil.

Recommended spacings for full season varieties (H6302, H614, H622, Kilima/Kilima ST, UCA/UCA ST, ICW, Tuxpeño, Staha, Pannar and Cargill hybrids) are 75x30 cm or 90x25 cm with a final stand of one plant per hill. Using this spacing, a plant population of 44,444/ha is achieved. More recent results show that in areas above 1,500 masl with reliable rainfall, two plants per hill at 90x50 cm and three plants per hill at 90x75 cm gave similar results to the spacing cited above. In the drier intermediate altitude areas and the lowland and coastal zones, two plants per hill at 75x60 cm gave the same yield as one plant per hill at 75x30 cm. For small statured varieties (Kito and Katumani) a spacing of 75x40 cm with two plants per hill is recommended.

Table 1. Commercial varieties in Tanzania and their potential

Variety	Potential yield (t/ha)	Expected yield under good husbandry (t/ha)
Lowland and Coastal areas (0-900 m)		
Ilonga Composite (ICW)	6.0	4.0
Staha	6.5	4.5
Tuxpeño	5.5	4.0
Kito	5.0	3.5
Katumani	4.5	3.0
Medium-altitude (900-1,500m)		
Low rainfall (below 1,000mm)		
Kilima/Kilima ST	7.0	5.0
Staha	6.0	4.5
Katumani	5.5	4.0
Kito	6.0	3.5
High rainfall (over 1,000mm)		
UCA/UCA ST	7.5	5.0
Kilima/Kilima ST	7.5	5.4
H632	7.5	5.0
High altitude areas (over 1,500m)		
H6302	11.0	8.0
H614	10.0	7.0

Source: Anon. (1988).

2.2.3 Fertilizer type, time, and method

To provide nitrogen one can use either urea, calcium ammonium nitrate (CAN), or sulphate of ammonia (SA). Nitrogen application may be split, with 30-50% of the total requirement applied at planting. The remaining N should be applied when maize is about a meter high. Phosphorus (P_2O_5) is necessary to promote root growth, strong stems, and good grain. The entire recommended amount should be applied at sowing. Table 2 summarizes the fertilizer recommendation for northern Tanzania.

For lowland plains, 40kg N/ha is recommended. For areas receiving rainfall above 800 mm per annum, 80 to 112 kg N/ha is recommended. No response for triple super phosphate (TSP) has been observed, but for high potential areas a basal application of 0-40 kg P_2O_5 (for replenishing phosphates used up by crops) is recommended.

Fertilizer is normally placed 5 cm below the depth of the seed and about 5 cm to the side. This is accomplished by digging a single hole beside each seed and placing fertilizer in the hole and covering it with soil. Alternatively, a continuous furrow can be made along the length of the planting row. Fertilizer is then placed in the furrow and covered with soil. The seed is then planted on top of this soil and covered properly.

2.2.4 Weeding time, frequency, and method

Weed control in maize is important to reduce competition for water, soil nutrients, and light. Research results have consistently shown that late and poor weeding can result in yield reductions of 30% to 70% (Matowo and Mgema 1990a). Generally, two hand-weedings should suffice at all elevations. However, durations between the first and second weeding vary between locations. For example, for areas over 900 masl weeding should be done at 2 and 5 weeks after planting (WAP). For areas under 900 masl weeding should be done at 2 WAP and 4 WAP. Weeds may also be controlled by using various herbicides. The following herbicides have been recommended for use in monoculture maize:

1) Atrazine (Gesaprim)
2) Atrazine + metalachlor (Primagram)
3) Alachlor (Lasso/atrazine)
4) Pendimethalin (Stomp)

Table 2. Fertilizer recommendation for maize according to agroecological zones

		Fertilizer rate (kg/ha)		
Altitude (masl)	Rainfall	N	P_2O_5	Districts covered[a]
0-900	High	20-45	20	Mos Hai Arm Rom
	Low	0-20	0-20	
900-1500	High	40-112	20-40	Han Mbu Mos Hai Rom Mond Arm
	Low			
>1500	High	40-112	20-40	Mos Hai Rom Arm
	Low	20-50	20	

[a] Mos = Moshi, Arm = Arumeru, Mbu = Mbulu, Han = Hanang, Rom = Rombo, and Mond = Monduli.

Source: Haule (1988); Samki and Harrop (1984); Mowo et al. (1993).

On the other hand, in maize/bean intercropping alachlor plus linuron (Lasso/linuron) and metabromuron + metoalachlor (Galex) have been recommended.

2.2.5 Pest and disease control

Stalk borers and armyworm are the two major insect pests of maize. Stalk borers can be controlled fairly easily with endosulfan, malathion, carbaryl, and sumithion when applied at the correct time. When the plants have about seven leaves, a small amount of dust should be applied into the funnel of the leaves. About two weeks after the first dusting, a second application should be made. Armyworm outbreaks in Tanzania can be effectively controlled only with intervention by national or international organizations, as aerial insecticide applications are required in outbreak areas. Individual farmers, however, can respond to lower-scale infestations with knapsack sprayers and ultra low volume applicators (ULVA). Malathion, fenitrothion, permethrin, and endosulphan are all very effective.

There are five major maize leaf diseases: common rust caused by *Puccinia sorghi;* lowland rust caused by *Puccinia polysora*; *Helminthosporium turcicum; Helminthosporium maydis;* and maize streak virus disease (MSV). None of these diseases can be economically controlled by chemical means. Biological control through breeding for disease resistance or tolerance is the only economical control.

There are also three common cob diseases: *Gibberella* spp., *Fusarium* spp., and *Diplodia* spp. These diseases attack the grain and the cob. To break the disease cycle, all diseased cobs should be destroyed at harvest and diseased plants and insects should be burned.

3.0 SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

3.1 Demographic characteristics

Table 3 summarizes the family characteristics of households in northern Tanzania. Most respondents were middle aged (in their early forties). Farmers in the lowland zone tended to be younger than the intermediate zone respondents, however, the age difference was not significant (p = 0.05). Early crop farmers in northern Tanzania settled on the fertile slopes of Mt. Kilimanjaro, Meru, Hanang, and other mountains. Land pressure pushed younger farmers to settle in the lowlands where rainfall is unreliable (Dunford 1980). Their farming experience is about 19 years, implying that they started farming at 20 years of age. In both zones, the mean for family labor is four, 50% of which is female labor. Family labor may not be enough to accomplish all operations during peak periods of planting, weeding, and coffee picking.

About 56% of sample households hired labor for weeding and harvesting maize and beans and picking coffee. Among farmers who hired labor, 86% hired labour for weeding maize and 23% for harvesting. Eighty percent of sample farmers who grew coffee hired labor for harvesting the crop.

The level of education of the household heads was 6.5 years in the lowland zone and 5.8 years in the intermediate zone. As expected the younger farmers in the lowland zone were slightly better educated than their peers in the intermediate zone. No sample farmer was illiterate. A number of farmers did not have formal education, but had attended adult education classes. In such cases, a maximum of four years of formal education was assigned to farmers to reflect their literacy level.

3.2 Land resources and allocation patterns

Land is a limiting factor in northern Tanzania. This is especially true on the Kilimanjaro and Meru mountain slopes. The land shortage results in small plots and a large number of holdings. In the plains of almost all districts of the Arusha region, land shortage is not as acute. Since Arusha is sparsely populated, farmers in the region generally have bigger farms than in the Kilimanjaro region. Survey findings confirm this observation as farmers sampled from Arusha had bigger land areas than those from Kilimanjaro. Figures 3 and 4 show an upward trend of total farm size and maize area in both zones. The reason for this trend may be that most farmers started farming 20 years ago (the mean farming experience of sample farmers is 19.4 years with a standard deviation of 11 years). When farmers start farming, most have small holdings. They normally increase their farm size through buying, renting, and clearing land in areas with surplus land like Hanang, Babati, and some Mbulu District areas. However, maize area in the lowlands dropped in 1984. Severe drought in in that year engulfed the entire country. The lowlands experienced the most severe drought and this may have contributed to its drop in maize area.

Table 3. Demographic characteristics of sample households

Mean of:	Lowland (n=36)	Intermediate (n=90)	P-value[a]
Age of household head (yrs)	41	44	>0.50
No. of male adults	2	3	>0.50
No. of female adults	2	2	>0.50
No. of children	4	4	>0.50
Educ. household head (yrs)	6.5	5.8	>0.50

[a] Paired test comparing zones.

Comparison of farm size and maize area between zones show that the intermediate zone farms have larger areas than lowland farms (Figures 3 and 4). The difference is not significant at p = 0.05. It was expected that lowland households would have larger tracts of land than those in the intermediate zone (Cunard et al. 1983; Nkonya et al. 1991; Nkonya et al. 1992). The reason for these findings is that three of the four sample villages for the intermediate zone were drawn from Arusha districts, namely, Hanang, Babati, and Karatu; districts known to have larger tracts of land than Arumeru and Rombo, the districts representing the lowland villages (Nkonya et al. 1991).

Farmers were asked to state their future plans for maize area: fifty-three percent of the sample farmers intended to keep their maize area constant, while 34% intended to increase it. Sample farmers who planned to keep their maize area constant said that the area they had was enough for their current food and marketing requirements. At the time of survey, farmers probably did not have an incentive to grow more maize the following season because of low maize prices in 1995. The average producer price of maize in 1995 was Tsh 4,500/100 kg bag (equivalent to US$ 72.5/t). The average f.o.b price of white maize from South Africa was US$ 100/ton, i.e., US$ 10/100 kg (Kapaliswa et al. 1992). Farmers who intended to increase maize area said they wanted to do so to get more food and money.

3.3. Livestock ownership

Livestock keeping in the zone is quite common. Of the 126 farmers sampled, 84% kept cattle, 79% kept goats, and 40% raised sheep. Herd size of all domestic stock was larger in Arusha than in Kilimanjaro region. Overall, every household had about five head of cattle, six goats, and two sheep. On the slopes of Mt. Kilimanjaro and Meru, farmers keep zero-grazed cattle, mainly for milk. Table 4a shows that the livestock numbers derived from sample farmers do not differ at a statistically significant level across zones. Contrary to expectation, farmers in the intermediate zone tended to have larger herds than those in the lowland zone. This may be the result of sampling more farmers from Arusha for the intermediate zone than from Kilimanjaro. If the zones of the two regions were sampled one at a time, it would be observed that herds of livestock in the lowland zone are bigger than herds in the intermediate and highland zones. Hence, these results are due to a sampling variation.

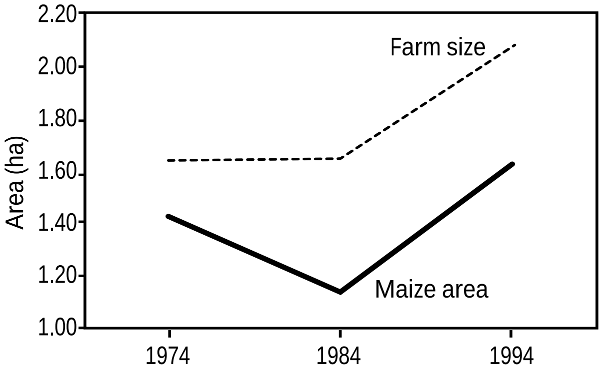

Figure 3. Farm size and maize area in the lowland zone.

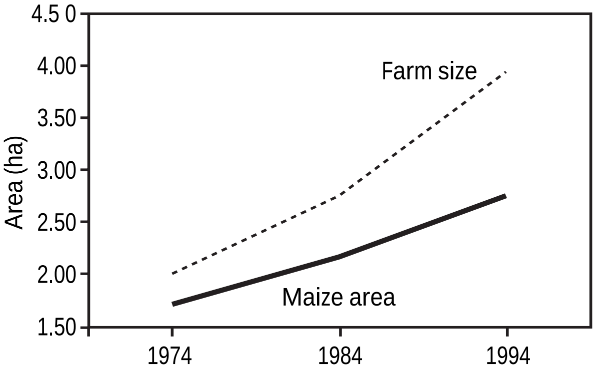

Figure 4. Farm size and maize area in the intermediate zone.

An examination of livestock ownership by method of land preparation shows that farmers who used oxen had significantly bigger herds of cattle (p = 0.01) than hand-hoe users (Table 4b). Tractor users also had significantly bigger herds of cattle than hand-hoe users (p = 0.10). Herds of small ruminants did not differ significantly (p = 0.10) by method of land preparation or zone.

Table 4a. Livestock ownership on zonal basis

Mean of:	Lowland	Intermediate	P-value[a]
No. of cattle	3	6	>0.50
No. of goat	6	6	1.0
No. of sheep	1	2	>0.50
No. other livestock	5	8	>0.50

[a] Paired test comparing zones.

Table 4b. Livestock herd size by land preparation

	Cattle	Goats	Sheep
Land prep. method	———	Mean heads	———
Hand-hoe (n=27)	2.7	4.9	1.5
Oxen (n=24)	6.2	4.7	1.8
Tractor (n=54)	4.5	7.1	2.2
P-value[a]: Hand-hoe vs. oxen	0.01	0.80	0.65
Hand-hoe vs. tractor	0.07	0.18	0.33
Oxen vs. tractor	0.80	0.57	0.89

[a] Paired test comparing methods of land preparation.

3.4 Farm mechanization

All sampled households had hoes equivalent to the number of available family laborers. That is, if a family had two people working on-farm, then that household would have two hoes. Almost all families sampled also had cutting tools such as machetes, axes, and knives for different farm operations.

Table 5 presents the number of ox-ploughs, ox-carts, trailers, and tractors owned and used by sample farmers in the two zones. Ox-ploughs are used for land preparation and planting in Arumeru, Babati, Hanang, and Mbulu districts in Arusha region and Hai District in the Kilimanjaro region. Comparison of ownership across zones shows that there is no significant difference between the mean number of implements owned by sample farmers (p = 0.05). However, comparing the ownership of farm implements and machinery across the method of land preparation shows a very distinct difference (p = 0.01). As expected farmers who use hand-hoes for land preparation have the lowest mean number of ox-ploughs, carts/trailers, and tractors. Their decision to prepare land by hand may be dictated by the terrain or by lack of resources to buy or hire farm machinery. The rolling topography in the highlands makes mechanization difficult, forcing farmers to prepare land by hand.

For the intermediate zone, the major means of land preparation is hiring a tractor from rich farmers (Table 6). A higher proportion of farmers (p=0.05) in the intermediate zone used a tractor for land preparation than farmers in the

Table 5. Number of farm implements owned

Mean of:	Lowland	Intermediate	P-value[a]
No. of ox-ploughs	0.50	0.66	0.15
No. of carts	0.05	0.49	0.42
No. of tractors	0.05	0.37	0.34

Mean of:	Hand-hoe	Oxen	Tractor	P-value[a]		
	Mean No.owned			Hh/Ox	Hh/Tra	Ox/Trac
No. of ox-plough	0.12	1.08	0.61	0.001	0.00	0.00
No. of carts	0.04	0.87	0.40	0.00	0.00	0.00
No. of tractors	0.04	0.60	0.30	0.00	0.00	0.00

[a] Paired test comparing zones and methods of land preparation.

Table 6. Method of land preparation in each zone

	Intermediate (n=87)	Lowland (n=36)	
Method	Proportion		P-value[a]
Hand-hoe	0.16	0.36	0.01
Oxen	0.20	0.31	0.20
Tractor	0.55	0.33	0.02
Hand-hoe+oxen	0.07	0.00	0.10
Zero tillage	0.023	0.00	0.30

[a] Paired test comparing zones.

lowland zone. There were five tractors for each 100 sample farmers in the lowland zone as compared to 37 tractors per 100 respondents in the intermediate zone (Table 5). The majority of farmers owning tractors were found in Arusha. The major reason for this may be that Arusha farmers residing in the high plateaus of Hanang, Babati, Mbulu, and Monduli have bigger tracts of land that justify owning a tractor. Farmers in Kilimanjaro with small parcels of land have little incentive to own tractors—they would rather hire than own tractors. Oxen are the second most important means of land preparation in all zones. Land preparation by oxen is mainly used in the lowland and intermediate zones. The highland zone has difficult terrain that hardly allows mechanization. As opposed to *a priori* expectations, Table 6 shows that the lowland zone has a significantly higher proportion (36%) of farmers using hand-hoe for land preparation than farmers in the intermediate zone. The difference was significant ($p = 0.01$). Most hand-hoe users were sampled from Shimbi village (Rombo), which is not typical of the lowlands. Other studies show that the use of hand-hoes is common in the high rainfall, high altitude zone (Cunard et al. 1985; Nkonya et al. 1991). The high rainfall, high altitude zone was not adequately sampled in this study due to its low area and production of maize. The proportion of farmers using oxen in both zones was not significantly different ($p=0.10$).

4.0 MAIZE PRODUCTION PRACTICES AND ADOPTION OF RECOMMENDATIONS

4.1 Crops and cropping systems

Intercropping maize with beans or pigeon peas is the most common cropping system in northern Tanzania. Sixty percent of sample farmers in the intermediate zone grew maize in association with beans and pigeon peas (Table 7). Pigeon peas are usually planted in Babati and the Karatu area in Mbulu. It is an up-and-coming crop in Arumeru. Pigeon pea is considered a commercial crop as less than 10% of production is consumed at home. Beans are widely grown in all districts growing maize.

As expected, more sample farmers in the lowlands grew maize in pure stands (40%) than in the intermediate zone (Table 7). Moisture stress may be one reason for planting maize in pure stand. Another reason may be that farmers in the lowlands do not have an acute land shortage, making monocropping possible. The major reason cited by farmers for intercropping maize with legumes was land scarcity. About 30% of farmers intercropped because of land shortage. Eighteen percent said that they intercropped maize with legumes to get more money, while only 6% intercropped to diversify production and spread price risks. Only 3% reported that they intercropped to save labor. One of the most compelling reasons for intercropping is that it spreads risk. Many farmers did not cite this reason because they regard production risks as beyond their control.

Coffee in association with banana is a common cropping system on the mountain slopes where rainfall is high and temperatures are cool. About 19% of the sample farmers grew coffee in association with banana. Tuber crops were not commonly grown in the zone. Only 1% of sample farmers grew tuber crops, i.e., cassava or sweet potatoes.

4.2 Cropping calendar

The Northern Zone has a diverse climate ranging from temperate zones on mountain slopes to semi-deserts in the lowland plains and the Maasai plateau. In most areas, the cropping season begins in October and ends in September. Rainfall is generally bimodal (Figure 1). Short rains (*vuli*) are not utilized for maize production in most areas. Rombo, Pare, and the Mwanga eastern highlands are on the windward side of the Mt Kilimanjaro and Pare mountain ranges, however, and they capture moisture-rich air from the ocean and use these *vuli* rains for maize production. For instance, the Rombo season commences in July and ends in April. Figure 5 shows the cropping calendar for the two zones.

About 21% of sample farmers in the intermediate zone prepare their land in November, 32% in December, and 29% in January. The commencement of land preparation in the lowland zone is more variable as it captures two major seasons: the long season

Table 7. Cropping systems in the two zones

	Maize/legume	Sole maize
Zone	%	
Intermediate (n=90)	85.2	14.8
Lowland (n = 36)	60.0	40.0
P-value[a]	0.00	0.04

[a] Paired test comparing zones.

in Arumeru (Mlangarini village), and the short season in Rombo District (Shimbi village). Fifty-three percent of the sample farmers prepared their land between July and September. Most of the farmers who prepared their land during this period were sampled from Shimbi Rombo District. It should be noted that although the *vuli* season rain is not commonly used for maize production in the typical lowland zone, Rombo is an atypical case. In the highland and intermediate zones, the *vuli* season is normally used for vegetable production. Lowland farmers use irrigation for crop production in the *vuli* season.

Farmers were asked why they chose to prepare land and plant when they did. More than 95% of sample farmers in both zones said that the onset of rains determined their cropping calendar. Farmers start land preparation well before the onset of rains. Both dry and wet planting are common. The most common practice is to plant after effective rains have fallen because farmers

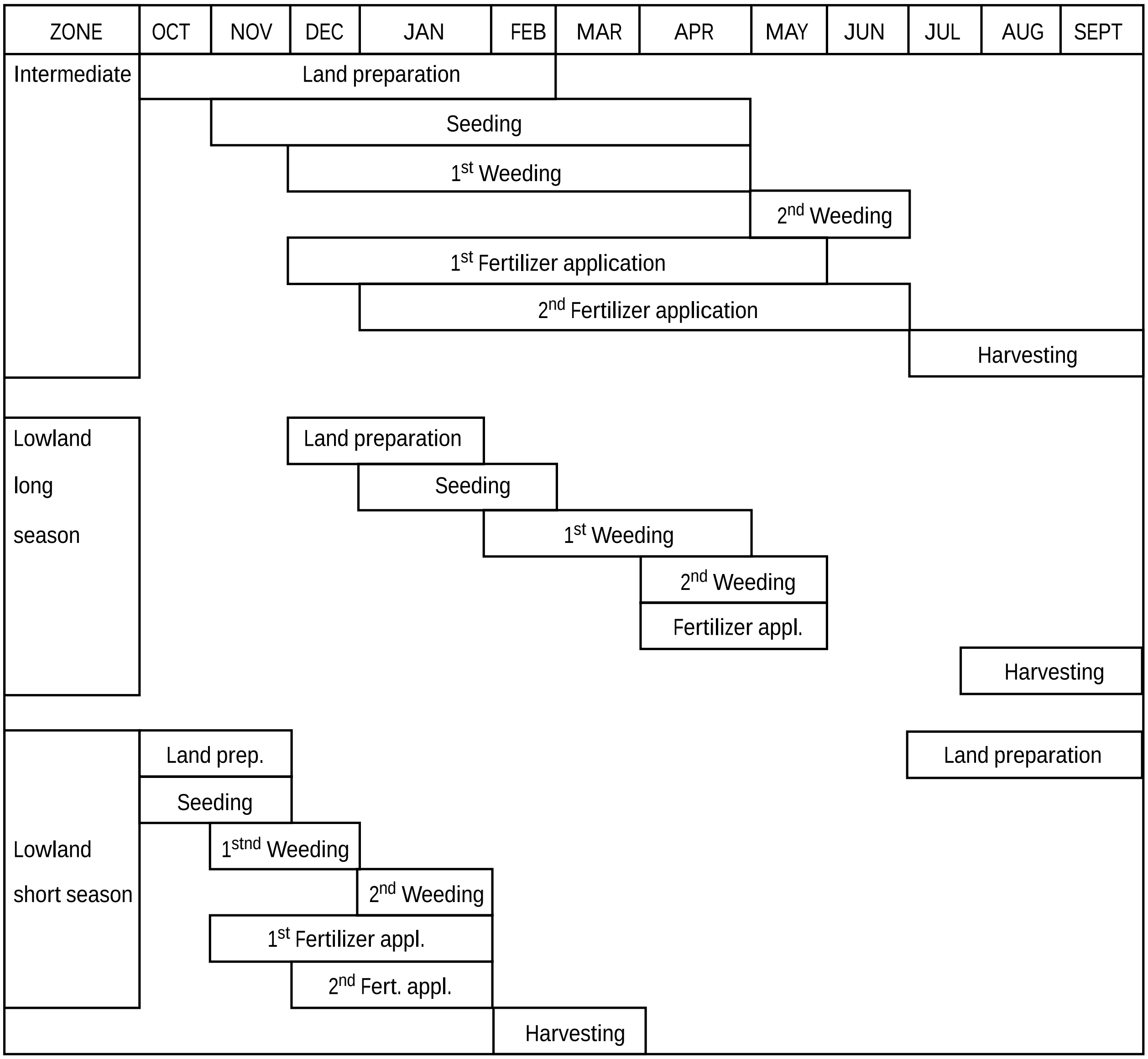

Figure 5. Maize cropping calendar for agroecological zones in northern Tanzania.

are then sure that there is enough moisture in the soil. The cropping season begins in Rombo, then moves to Arusha and finishes in Moshi and Hai. The labor bottleneck occurs during planting and weeding. So for Arusha, the labor bottleneck occurs in January through March while in Moshia the labor shortage is experienced in February through April.

4.3 Rate and intensity of adoption of improved maize varieties

4.3.1 Definitions

Feder et al. (1985) defined adoption as the degree of use of a new innovation in long-run equilibrium when a farmer has full information about the new technology and its potential. If the innovation is modified periodically, however, the equilibrium level of adoption will not be achieved. As the new technology is introduced, some farmers will experiment with it before adopting. The rate of adoption is defined as the percentage of farmers who have adopted a new technology or the area under a new technology. 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 receiving fertilizer are measures of the intensity of adoption of improved maize seed.

4.3.2 Current varieties grown

According to Table 8, all sample farmers grew locally bred or imported cultivars. Some farmers maintained that they grew ‘local’ varieties, which they did not have local names for. Actually these ‘local’ varieties were improved varieties that have been recycled for so many years that they have lost their identities.

Some farmers in the eastern zone of Mbulu District, however, grew local maize varieties called ‘*bhor*,’ which means ‘black.’ The *bhor* variety is flint, with mixed white and black grains, tall, and late maturing (Nkonya et al. 1992). CG4141 is the most common variety grown in both zones and with various methods of land preparation. With the exception of Katumani, there is an insignificant difference ($p = 0.05$) in the proportion of farmers planting other varieties between the two zones. Among the methods of land preparation, the proportion of farmers who used ox-plough planted significantly ($p = 0.05$) more H632/H622 than the respondents who used other means of land preparation. H632/H622 are mostly planted in Babati, Mbulu, and Hanang districts, which use ox-plough for land preparation and planting. Use of CG4141 and all composites was not significantly different ($p = 0.05$) among farmers classified by method of land preparation (Table 12).

4.3.3. Trend of adoption of maize varieties

Figures 6 and 7 show the trend of adoption of all improved maize varieties for the past 20 years. Comparison of adoption across zones indicates that there was no significant difference ($p=0.05$) in trends of adoption over all the years. It was expected that lowland farmers would lag behind the intermediate zone farmers but this was not the case. Figure 6 shows that before 1992, farmers in the intermediate zone had adopted improved maize varieties more than those in the lowlands. After 1992, the adoption rate of lowland farmers surpassed the intermediate zone level. However, the difference in the rate of adoption between the two zones continued to be insignificant ($p = 0.05$).

Comparison of the rate of adoption across the method of land preparation shows that hand-hoe users lagged behind oxen and tractor users between 1985 and 1992. After 1992, hand-hoe users caught up with the oxen and tractor users. The adoption patterns of oxen and tractor users tended to move together throughout (Figure 7). The paired test shows that the difference in the rate of adoption by method of land preparation is not significant ($p = 0.05$) for all the years and between any two methods, except hand-hoe versus oxen in 1990, and hand-hoe versus tractor in 1990 and 1991.

As more farmers adopted improved varieties, maize yield increased over time (Figures 8 and 9). The yield increase probably resulted from farmers gaining experience in management of the new technology. The yield trend for 'local varieties' does not show pronounced changes for either zone or methods of land preparation. This implies that those varieties have attained their maximum potential.

4.4 Factors affecting adoption of improved maize varieties

4.4.1 Household characteristics

Researchers and extensionists want to know the factors that affect both the rate and intensity of adoption of new technologies. To a researcher, this is important for designing technologies that

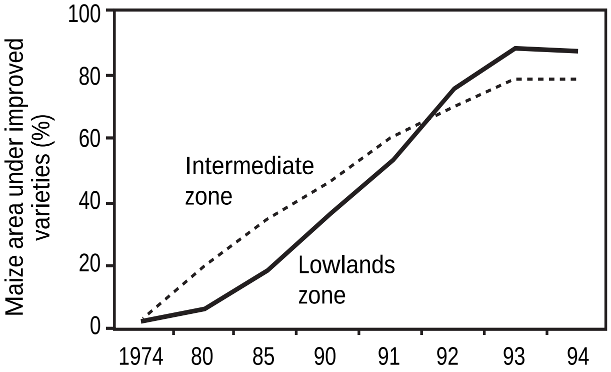

Figure 6. Adoption of maize varieties by agroecological zone, 1974-94.

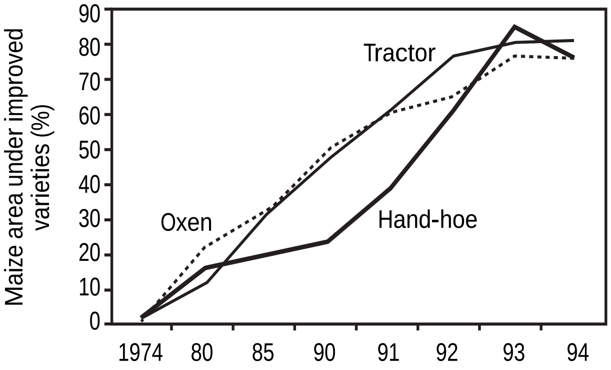

Figure 7. Adoption of maize varieties by land preparation method.

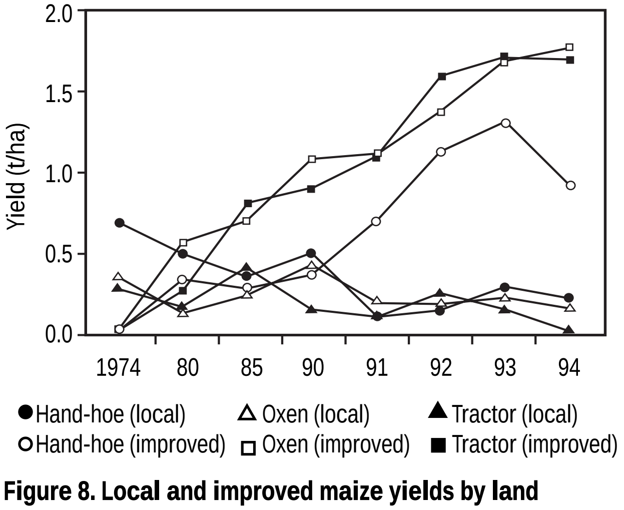

Figure 8. Local and improved maize yields by land preparation method.

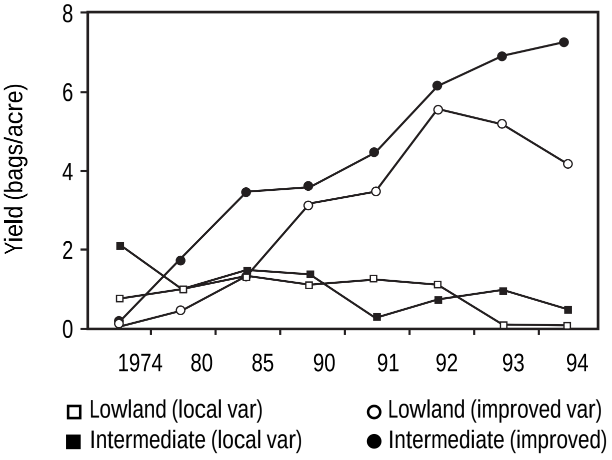

Figure 9. Local and improved maize yield by zone.

address the factors that influence adoption. For an extension officer the knowledge helps in designing extension messages that respond to the identified factors. To check for an annual variance of intensity of adoption, a three-year average of acres under improved maize seed or fertilizer for each sample farmer was used instead of a single year level of adoption. The factors that were thought to influence adoption of both improved maize seed and fertilizer were: farm size, farming experience, education of household head, livestock units, family labor, methods of land preparation (hand-hoe, ox-plough, tractor, and other), rate of nitrogen application, and area under improved maize seed.

A two-step Heckman's procedure was used to analyze the adoption of inorganic fertilizer and improved maize seed. In the first step of Heckman's procedure, the coefficients of factors that influence the probability to adopt a technology ($\partial P/\partial x$) are estimated using a probit model. In the second stage, the impacts of the same factors on intensity of adoption ($\partial ADIS/\partial x$ and $\partial NRATE/\partial x$) are estimated using a system of Seemingly Unrelated Regression (SUR) equations. In this study, two equations, one for ADIS and another for NRATE as dependent variables, are estimated simultaneously in a system of equations. Tables 8 and 9 show the Heckman's first stage results for the two zones separately and jointly.

In the lowland zone, 4 out of the 36 sample farmers did not use improved maize seed compared to 7 out of the 90 sample farmers in the intermediate zone. This high rate of adoption in both zones reduced the variability of the dependent variable, making the influence of almost all regressors not significant ($p=0.05$). As Table 8 shows, there was no factor that significantly affected ($p=0.05$) the probability to adopt improved maize seed in the lowland zone. The same observation was made when both zones were considered jointly (Table 9).

Table 8. Heckman's first stage procedure results estimating factors affecting adoption of improved maize seed for the intermediate and lowland zones

	Intermediate zone (n = 90)			**Lowland zone (n = 36)**		
Variable	**MLE**	**$\partial P/\partial x$**	**P-value**	**MLE**	**$\partial P/\partial x$**	**P-value**
Constant	3.79	0.550	>0.50	2.21	0.42	>0.50
Farm Size	-0.01	-0.001	>0.50	-0.06	-0.01	0.25
Farming Experience	0.09	0.013	0.05	0.11	0.02	0.17
Education of HH[1] Head	0.16	0.023	0.25	0.30	0.06	0.49
Livestock Units[2]	-0.03	-0.004	0.38	-0.03	-0.01	>0.50
Family Labor	0.35	0.052	0.13	0.47	0.09	0.25
MLP[3]: Hand-hoe	-7.57	-1.105	>0.50	-7.70	-1.46	>0.50
Ox-Plough	-5.19	-0.757	>0.50	-5.11	-0.97	>0.50
Tractor	-5.58	-0.815	>0.50	-5.20	-0.98	>0.50
Nitrogen Fertilizer rate	0.01	0.001	>0.50	0.13	0.03	0.22

LLF = -16.43 cdf = 0.92, pdf = 0.146 LRT[4] (df = 9) = 16.34 LLF = -7.88 cdf = 0.89, pdf = .189 LRT (df=9) = 9.36

McFadden $R^2 = 0.33$ McFadden $R^2 = 0.37$ LRT=9.36

χ^2 (df=9,p=0.05) =16.92

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[1] Household

[2] Livestock Units: Cow = 0.8; Goat = 0.4; Sheep = 0.4

[3] MLP = Method of Land Preparation.

[4] LRT = Likelihood Ratio Test

The problem of analyzing factors affecting adoption in the lowland zone is that since almost all farmers recycled improved maize seed, it was not easy to sample farmers who used ‘local’ varieties. In a study by Nkonya et al. (1997), improved maize seed was defined as certified seed planted by sample farmers. Hence, farmers who recycled seed were not counted as adopters, so the rate of adoption was 52% as opposed to the 94% observed in this study. The factors that significantly affected adoption of improved maize seed in the study by Nkonya et al. (1997) were level of education of household head, farm size, and number of extension visits. This implies that future adoption studies in northern Tanzania should distinguish between improved variety seeds that are certified and those are not certified (recycled).

In the intermediate zone, however, farming experience positively influenced the probability to adopt improved maize seed (Table 8). An increase in one year of experience increased the probability to adopt ($\partial P/\partial x$) by 1.3%. If farming experience entails accumulation of knowledge, then it augments technology use, as observed in the intermediate zone. Experienced farmers must have had the opportunity to experiment with new varieties and observe their superiority over local varieties. This argument is supported by Figure 8, which shows upward yield trends of improved maize over time. However, if experience is equated with the aging process, it may then have a negative impact on technology adoption as old farmers are set in their ways and tend to stick to old technologies. The two antagonistic influences might have acted simultaneously, with the technology augmenting force prevailing in the intermediate zone. Overall, the three models (summarized in Tables 8 and 9) for estimating factors influencing probability to adopt improved maize seed are not signficant ($p = 0.05$).

Table 10 reports the Heckman’s second stage SUR system results for the intermediate zone and for all zones. The SUR system for the lowland zone was not estimated because a very small sample

Table 9. Heckman’s first stage procedure results estimating factors affecting adoption of improved maize seed and fertilizer for the two zones

	Intermediate zone (n = 90)			Lowland zone (n = 36)		
Variable	**MLE**	**$\partial P/\partial x$**	**P-value**	**MLE**	**$\partial P/\partial x$**	**P-value**
Constant	5.201	0.590	>0.50	0.153	0.043	0.85
Farm Size	-0.012	-0.001	>0.50	0.007	0.002	0.71
Farming Experience	0.033	0.004	0.18	0.010	0.003	0.40
Education of HH[1] Head	0.104	0.012	0.31	0.021	0.006	0.72
Livestock Units[2]	-0.018	-0.002	0.47	-0.054	-0.015	0.02
Family Labor	0.158	0.018	0.26	0.024	0.007	0.54
MLP[3]: Hand-hoe	-5.828	-0.650	>0.50	-0.350	-0.098	0.19
Ox-Plough	-4.899	-0.554	>0.50	-0.741	-0.206	0.90
Tractor	-5.211	-0.589	>0.50	-0.068	-0.019	0.53
Nitrogen fertilizer rate	0.005	0.001	>0.50	0.258	0.072	0.85

LLF = -22.75   cdf = 0.944, pdf = 0.113   LRT[4] (df = 9) = 8.58   LLF = -77.34   cdf = 0.587, pdf =0.278   LRT (df=9) = 16.13

McFadden $R^2 = 0.159$ McFadden $R^2 = 0.09$ LRT=16.13

χ^2 (df=9,p=0.05) =16.92

[1] Household

[2] Livestock Units: Cow = 0.8; Goat = 0.4; Sheep = 0.4

[3] MLP = Method of Land Preparation.

[4] LRT = Likelihood Ratio Test

remained after omitting the non-adopters of both technologies (only 11 observations were adopters of both improved maize seed and fertilizer). Consequently, the system ran out of degrees of freedom because the total number of independent variables (10 for ADIS and 10 for NRATE) was more than the number of remaining observations. In the intermediate zone, no independent variable (other than the constant) significantly affected intensity of adoption of improved maize seed ($p = 0.05$). The reason for the non-significant results may be the narrow range of intensity of adoption (0.17 to 1.0 ha, with a mean of 0.89 and a standard deviation of 0.21 ha). The low variability may be due to the use of the three-year average, which tended to smooth over the variability of adoption among farmers.

With the lack of significance of the independent variables, we need to look at other sample and non-sample variables that influence intensity of adoption. Such variables could not be included in the Heckman's procedure because they were either non-sample information (e.g., seed marketing problems and maize seed variety characteristics), or they were farmers' responses/observations when asked why they adopted/disadopted technologies and/or why they preferred some varieties over others. The discussion of market and institutional factors affecting adoption of maize technologies and reasons for varietal preference and disadoption follows in the next section.

Table 10. Heckman's second stage procedure SUR results estimating factors affecting intensity of adoption of improved maize seed and fertilizer for intermediate zone and for the two zones

	Intermediate zone			Both zones		
Variable	**Coefficients**	**Std error**	**P-value**	**Coefficients**	**Std error**	**P-value**
First equation of SUR (intensity of adoption of improved maize seed)						
Constant	0.674	0.212	0.00	0.836	0.197	0.00
Farm size	-0.001	0.004	>0.50	0.002	0.004	>0.50
Farming experience	0.002	0.004	>0.50	0.001	0.004	>0.50
Education of HH head	0.002	0.016	0.15	0.007	0.015	>0.50
Livestock units	-0.006	0.008	0.47	-0.003	0.007	>0.50
Family labor	0.009	0.011	0.42	-0.001	0.010	>0.50
MLP: hand-hoe	-0.019	0.180	>0.50	0.029	0.158	>0.50
Ox-plough	0.008	0.135	>0.50	0.030	0.127	>0.50
Tractor	-0.064	0.117	>0.50	-0.016	0.116	>0.50
Nitrogen fertilizer rate	0.001	0.001	0.40	0.001	0.001	0.34
IMRS[1]	0.431	0.374	0.25	-0.256	0.472	>0.50
Second equation of SUR (intensity of adoption of fertilizer)						
Constant	194.76	125.10	0.13	73.61	137.10	>0.50
Farm size	-0.847	0.662	0.20	-1.038	0.992	0.29
Farming experience	-2.778	1.459	0.06	-1.141	1.162	0.33
Education of HH head	-1.506	2.937	>0.50	-0.566	3.338	>0.50
Livestock units	9.817	6.018	0.10	4.887	6.131	0.42
Family labor	-0.771	1.976	>0.50	-0.390	3.273	>0.50
MLP: hand-hoe	39.998	22.663	0.08	46.427	40.148	0.25
Ox-plough	29.341	33.316	0.38	50.362	87.399	>0.50
Tractor	17.296	18.149	0.34	25.311	19.116	0.19
Nitrogen fertilizer rate	-56.561	50.721	0.27	13.524	31.831	>0.50
IMRF[2]	-216.96	144.62	0.13	-122.390	190.080	>0.50

System $R^2 = 0.283$; Observations above limit (OAL) = 54 System $R^2 = 0.178$ OAL=71

[1] Inverse Mills Ratio for seed.

[2] Inverse Mills Ratio for fertilizer.

4.4.2 Market and institutional factors

Farmers reported that the major factors affecting adoption of improved maize varieties are input prices, the marketing system, and varietal traits. The discussion below examines the maize seed industry in northern Tanzania and varietal traits that farmers prefer or dislike that affect adoption/ disadoption of some varieties.

4.4.3 The maize seed industry in Tanzania

CG4141 is multiplied and distributed by Cargill Hybrid Seed Ltd. based in Arusha. The locally bred hybrids H622 and H632 are grown mainly by farmers in the intermediate zone. Only 6% of sample farmers in the lowland grew the locally bred hybrids. This is because the hybrids are late maturing. Locally bred cultivars are flint with good pounding and storage qualities, and as high yielding as CG4141. They are marketed mainly by the Tanzania Seed Company (TANSEED) which has not fared well in the competitive seed industry. This has contributed to the low adoption of locally bred hybrids. Before input liberalization in 1990, locally bred varieties were nearly the only improved maize planted in Tanzania. Now, the demand for (adoption of) locally bred cultivars in northern Tanzania is low.

After input liberalization private companies have engaged in seed multiplication and also conducted trials that evaluate the adaptability of imported varieties to the local environment. The varieties are subsequently released to farmers. CG4141 is competing aggressively with the locally bred cultivars that are multiplied and sold by TANSEED. Pannar, meanwhile, started production and marketing of maize seed in 1995. The new companies recruit a chain of stockists who sell their seed in villages and towns. TANSEED has followed suit. Farmers also indicate that seed sold by the private companies is purer, more uniform, and higher yielding than TANSEED seed. This has reduced the demand for TANSEED seed.

The biggest drawbacks of the new varieties sold by Cargill and Pannar are their high price, poor storability, pounding quality, and 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 renewed importation by the Tanganyika Farmers Association (TFA) of the once-famous hybrid H511 from Kenya. H511 is a flint maize and is as high yielding and as early maturing as CG4141. Its advantage over CG4141 is its flinty grain.

The 1994/95 price for Cargill (CG4141) and Pannar (PAN 6481) seed was 650 Tanzanian shillings (Tsh) /kg, while Kilima, a composite, sold at Tsh 450/kg. The high prices of maize seed have forced many farmers to recycle hybrids. No sample farmer reported growing Staha, TMV1, or Tuxpeño. Demand for composites is generally low, despite their possessing a distinct advantage: with proper selection in the field, composites can be recycled for at least three years without substantial loss of vigor. This concerns the local breeders who have strived to produce composite varieties for the Northern Zone (Moshi et al. 1990).

It is not clear whether the low demand for composite varieties is due to a low standard of seed multiplication resulting in poor seed quality or farmers' lack of information about the advantage of recycling OPVs with less yield loss than recycling hybrids. Marketing efforts by the TANSEED company, which sells the locally bred cultivars, are much less than those of Cargill and other companies selling imported seed. This obviously contributes to the low adoption of the local improved seed. Another possible reason for the low demand for composites is that the seed industry does not make substantial profits on OPVs, because farmers normally recycle OPV seed for three years, during which time the seed dealers would experience low seed demand. This is the major reason why Cargill Hybrid Seed Ltd. does not sell very much OPV seed (Banfield, Director Cargill Hybrid (T) Ltd., personal communication). OPVs also have a low yield potential relative to hybrids during good seasons, yet another possible explanation for the low demand for OPVs.

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 since they depended on borrowed money for buying inputs. This led to delayed input supply and chronic shortages that served as a disincentive to farmers (Mbiha 1993; Nkonya 1994). Input liberalization has led to a rapid increase in the number of private businesses that engage in input marketing. Farmers could obtain inputs, in a timely manner, from village stockists who are much closer to them than prior to 1990. As expected, the price of inputs has increased sharply, wiping out the shortages that existed before.

4.4.4 High price of inputs coupled with low price of maize produce

All sample farmers who recycled improved varieties said that the rising certified seed and fertilizer prices coupled with falling maize output price was the major reason for recycling improved maize seed. Table 11 shows the price ratios of maize produce to the price of fertilizer and maize certified seed. The ratios give the amount of N (or certified maize seed) that 1 unit of maize produce can buy given their market prices. This represents the actual purchasing power of the farmers.

$$[\text{Tsh}/(\text{kg of Maize})]/[\text{Tsh}/(\text{kg of N})] = (\text{kg of N})/(\text{kg of Maize})$$

The purchasing power of maize produce has fallen from its highest level in 1984 to its lowest level in 1995. For instance, the purchasing power of maize produce fell from 0.011 kg to 0.002 kg of N per kg of maize produce between 1984 and 1995.

Trade liberalization in Tanzania was initiated in 1984 and this caused a considerable fall in the market price, hence the fall in terms of trade for maize farmers as compared to input dealers (Missiaen and Lindert 1993). The trend of the purchasing power of maize produce in relation to maize seed stayed nearly constant between 1988 and 1990, and it rose between 1990 to 1991 as this period

Table 11. Trend of maize produce price to input price ratio in Tanzania

Year	N	H632/H622	OPVs
1980	0.003	0.123	0.167
1981	0.004	0.139	0.188
1982	0.012	0.333	0.455
1983	0.024	0.915	1.204
1984	0.011	0.442	0.543
1985	0.009	0.282	0.372
1986	0.008	0.188	0.261
1987	0.007	0.137	0.169
1988	0.008	0.106	0.147
1989	0.010	0.133	0.152
1990	0.010	0.109	0.122
1991	0.006	0.205	0.242
1992	0.006	0.207	0.229
1993	0.006	0.108	0.144
1994	0.004	0.072	0.102
1995	0.002	0.039	0.070

followed a poor harvest in 1990/91. It fell steadily between 1986 and 1995. Fertilizer price increased rapidly during 1990-1994 when the government continued to withdraw its subsidy from the peak level of more than 50% that prevailed in the early 1980's, to 0% in 1993 (MOA 1993b). The 1994/95 price of Cargil maize seed varieties (CG4141) and Pannar (PAN 6481) was Tanzanian shillings (Tsh) 650/kg, while Kilima, a composite, sold at Tsh 450/kg.

4.4.5 Varietal traits preferred by farmers

As suggested by the results of Table 12, Table 13 also shows that CG4141 was the most preferred variety in both zones. However, the proportion of farmers preferring CG4141 and Katumani in the lowlands is significantly higher (p=0.05) than the proportion in the intermediate zone. The probable reason for this is that Katumani and CG4141 mature earlier than the locally bred hybrids, so lowland farmers with less reliable rainfall would naturally choose the early maturing varieties. Farmers in the intermediate zone could opt for varieties other than CG4141 and Katumani because the moisture limitation is less acute than in the lowlands.

In both zones, high yield is the major reason for preferring varieties. CG4141 again was identified as the most high yielding in both zones. Drought tolerance/resistance/avoidance was the second major criterion for preferring a variety and CG4141 once again was selected for that reason (Table 14).

Table 12. Maize varieties planted in the 1994/95 season

	Intermediate zone (n=88)	Lowland zone (n=18)		Hand-hoe (n=26)	Oxen (n=28)	Tractor (n=55)	P-values[b]		
Variety	% Planting[c]		P- value[a]	% Planting[c]			Hh/Ox	Hh/T	Ox/T
CG4141	55.7	61.1	>0.50	73.0	64.0	80.0	0.50	0.10	0.10
H632/H622	23.9	5.6	0.01	8.0	29.0	9.0	0.02	0.01	0.02
Kilima	16.0	28	0.29	19.0	7.0	7.0	0.20	>0.50	>0.50
UCA	3.4	0.0	0.08	1.0	1.0	1.0	1.00	1.00	1.00
Katumani	0.0	5.6	0.30	0.02	0.04	0.0	>0.50	0.20	0.15
Staha	1.1	0.0	0.32	1.0	0.0	0.0	>0.50	1.00	1.00

[a] Paired test comparing zones.

[b] Paired test comparing methods of land preparation. Each two methods of land preparation are compared using a paired t-test. The results are reported in the last three columns of Table 8. The pairs of land preparation compared are: Hh/Ox = hand-hoe/oxen; Hh/T = hand-hoe/tractor; Ox/T = oxen/tractor.

[c] Percentages may add to more than 100% because some sample farmers plant more than one variety and/or use more than one method of land preparation.

Table 13. Most preferred maize varieties

	Intermediate (n=83)	Lowland (n=36)	
Variety	%		P-value[a]
CG4141	54.2	77.8	0.02
H622/632	22.9	0.0	0.00
Kilima	16.0	6.0	0.15
Katumani	0.0	17.0	0.00

[a] Paired test comparing the two zones.

Table 14. Reasons for varietal preference

		% Reporting reason			
Zone	Variety	High yield	Drought	Sweet	Other
Intermediate (n=83)	CG4141	31.3	20.5	2.4	0.0
	H622/632	18.1	3.6	0.0	3.6
	Kilima	4.8	6.0	3.6	0.0
Lowland (n=36)	CG4141	52.8	19.4	0.0	5.6
	Katumani	0.0	5.6	5.6	5.6
	Kilima	5.6	0.0	0.0	0.0

4.4.6 Factors contributing to disadoption of improved varieties

Forty-five percent of sample farmers had at one point discontinued growing an improved variety for various reasons. The varieties discontinued by most farmers in the intermediate zone were hybrids H622 and H632, and in the lowland zone, Kilima and Katumani (Table 15). The major reason given for discontinuing hybrids was their late maturity. Given that most maize is produced in the intermediate and lowland zones, moisture may be limiting in some poor years, so farmers would prefer medium to short season varieties. H632 and H622 reach physiological maturity after 150-160 days. CG4141 and other imported varieties were disadopted by 28%, mainly because they were no longer available. Importation of SR52 variety from Zimbabwe was discontinued in 1988. This was also the case for the MH41 (CG4141) that was not available until Cargill Hybrid Seed Ltd. started multiplying and distributing the variety in 1990. Other varieties were disadopted for being low yielders.

4.5 Seedbed type, planting configuration, and weeding

4.5.1 Seedbed type

The common seedbed type in northern Tanzania in both zones is the flat bed (Table 16). All farmers said that they use a flat seedbed because it is easy to work. Seedbed types are important for water harvesting in semi-arid areas. For instance, tie ridging has been shown to conserve more moisture than a flat bed. However, seedbeds are also determined by the method of land preparation. Most of the tractors owned by medium-scale farmers in northern Tanzania do not have ridgers. This forces farmers who hire them to prepare a flat bed.

4.5.2 Spacing

Row planting was practiced by 99% of respondents. Only one farmer (from Rombo) out of 126 respondents broadcast seed. The major reason given for row planting is that it is easy to work. The average row-to-row and hill-to-hill spacings are shown in Table 17. The average plant population as reported by farmers was slightly lower than the recommended population of 44,444 plants/ha for the medium and long maturing varieties commonly grown in the zone. Farmers in Arusha who normally plant using ox-plough usually attain the recommended level.

Table 16. Percentage of farmers planting on flat beds or ridges in each zone

Zone	Flat	Ridges
Intermediate (n=88)	100	0.0
Lowland (n=36)	97	2.8

Table 15. Discontinued varieties

	%			%			P-values[b]		
Variety	Intermediate n=43	Lowland n=8	P-value[a]	Hand-hoe n=10	Oxen n=11	Tractor n=31	Hh/O	Hh/T	O/T
H622/632	48.8	12.5	0.01	20.0	37.0	48.0	0.40	0.50	>0.50
CG4141	25.6	12.5	0.33	30.0	9.0	35.0	0.25	0.10	0.10
Kilima	9.4	25.0	0.33	0.0	27.0	1.0	0.05	0.08	0.15
Katumani	2.3	25.0	0.14	20.0	9.0	3.0	0.50	0.40	0.40

[a] Paired test comparing the two zones.

[b] Paired test comparing methods of land preparation methods

Sometimes farmers exceed the recommended population because they drop seed in furrows made by the ox-plough during harrowing. Occasionally farmers drop too much seed and later thin (Nkonya et al. 1991). This is always the case when the seed is the progeny of improved varieties. When fresh improved seed is used farmers tend to stick to the recommendation.

The plant spacing for monocropped maize and maize in association with legumes does not differ for cases where maize is the major crop in the intercrop. However, farmers in Arumeru, Moshi, Rombo, Babati, and Hai plant beans in association with maize in strips. In this case, bean is the major crop and maize is a companion crop; more than two rows of beans are planted between two rows of maize.

4.5.3 Weeding

Table 18 shows that the majority of farmers weed twice. In the intermediate zone, 89% of respondents weeded twice, compared to 60% of respondents in the lowlands. The difference of proportion of farmers weeding twice between the two zones is significant (p=0.01). The difference in the frequency of weeding between the two zones may be determined by the length of the growing season. In the lowlands, the growing season is shorter, hence farmers may not have time to weed twice. Only 21% of the sample farmers in the lowlands weeded their maize fields once (Table 18).

Table 19 shows the timing of planting, first weeding, and fertilizer application. On average, sample farmers in the intermediate zone did their first weeding 3.8 weeks after planting compared to 3.6 weeks for the lowland farmers.

Assuming that emergence of planted maize takes place a week after planting, the first weeding is done two and a half weeks after emergence. This is within the recommendation. Matowo and Mgema (1990a) observed that highest grain maize yield was obtained when the first weeding was done 2-3 weeks after

Table 17. Spacing for monocropped maize and maize/ legume intercrop

			%	
Spacing (cm), row x hill	**Seeds/ hill**	**Population (plants/ha)**	**Intermediate (n=87)**	**Lowland (n=22)**
90 x 50	2	44,444	35.0	27.3
90 x 30	1	37,037	13.0	18.2
100 x 30	2	66,666	3.4	9.6
75 x 60	2	44,444	10.0	4.5
80 x 50	2	50,000	4.4	4.5
Broadcast			0.0	9.1
Other			39.7	27.6
Overall	1.8	44,408		

Table 18. Frequency of weeding

Weeding frequency	**Intermediate (n=85)**	**Lowland (n=33)**	**P-value**[a]
	% of farmers		
Once	3.5	21.2	0.02
Twice	89.0	63.6	0.00
Thrice	7.1	15.2	0.24

[a] Paired test comparing the two zones.

Table 19. Time of planting, weeding, and fertilizer application

	Lowland zone	**Intermediate zone**	
Operation	**Mean weeks after planting**		**P-value**[a]
Time of planting[b]	9.5 (n=36)	6.9 (n=85)	0.00
Time of 1st weeding	3.8 (n=31)	3.6 (n=78)	>0.50
2nd weeding	5.7 (n=18)	5.8 (n=32)	>0.50
1st top dress	4.8 (n=10)	4.7 (n=36)	>0.50
2nd top dress	5.8 (n=31)	5.5 (n=16)	>0.50

[a] Paired test comparing the two zones.
[b] Weeks after land preparation.

emergence. On average, the second weeding is done 5.8 weeks after planting. This timing is within the recommendation of performing both weedings within 6 weeks after emergence. Overall, Northern Zone farmers closely followed the recommendation on weeding schedules. Herbicide use was reported by only 7% of respondents.

Farmers reported that crop planting is dictated by the onset of rains. Therefore, the significant difference in timing of planting (p=0.01) is a factor of location and the onset of rains, rather than management differences. The number of weeks (after planting) to first and second weeding and fertilizer application in both zones was not statistically different (p=0.05). This implies that after the onset of the rains, farmers in both zones follow more or less the same cropping calendar.

4.6 Fertility management

4.6.1 Adoption of fertility management technologies

Table 20 shows that 80% and 92% of sample farmers in the intermediate and lowland zones, respectively, apply some form of fertilizer. The difference in the percentage of farmers applying some form of fertilizer between the two zones is significant (p=0.01). Sixty-four percent of respondents in the intermediate zone applied chemical fertilizer compared to 44% of sample farmers in the lowland zone in the 1994/95 season. The difference in the proportion applying chemical fertilizer is significant at the 5% level. This result was anticipated because the intermediate zone farmers receive more rain and their terrain is hilly, so leaching and erosion make their soils poor. Adoption of chemical fertilizer is far less than adoption of improved maize varieties, which is almost 100%. This may be explained by the stepwise adoption of technologies, i.e., farmers decide to adopt seed technology first because it is easily implemented, and adopt fertilizer later. Seed technologies are normally adopted spontaneously while fertilizer requires a higher level of knowledge before farmers decide to use it.

Application of organic manure is more common in the Arusha region than in Kilimanjaro. About 49% of sample farmers in the intermediate zone and 44% of respondents in the lowland zone applied kraal manure (Table 20). Use of kraal manure and crop residue between the two zones revealed no statistical differenences (p=0.05). These findings were unexpected, as it was anticipated that farmers in the lowland zone would use more kraal manure and crop residue because they have more cattle and they do not stall feed their animals. The reason behind these findings may be that the three villages sampled in the intermediate zone were from the livestock-rich region of Arusha. This is reflected in Table 4a, which shows that the intermediate zone farmers had more cattle than those in the lowland zone. Green manuring was uncommon as only 4% of sample farmers reported practicing it.

Table 20. Adoption of fertilizer use in the 1994/95 season

	Intermediate (n=86)	Lowland (n=36)	
Type of fertilizer	% of farmers applying		P-value[a]
Any form	80	92	0.00
Chemical	64	44	0.04
Kraal manure	49	44	>0.50
Crop residue	41	44	>0.50

[a] Paired test comparing the two zones.

4.6.2 Fallowing and crop rotation

Due to land shortage, only 3% of sample farmers in the intermediate zone fallowed their farms compared to 13% in the lowland zone. This means that the most feasible method for replenishing fertility in this zone is through the application of fertilizer. Crop rotation was reported by 11% of the intermediate zone respondents and by 22% of sample farmers in the lowland zone. This may be caused by land shortage that acts as a constraint on growing a variety of crops (Table 21).

4.6.3 Chemical fertilizer application trends

Figures 10 and 11 depict the trend in the application of chemical fertilizer, indicating an increase in the amount of N applied. The major N-carriers used are SA, CAN, and urea. In both zones, a dramatic increase of N fertilizer application occurred after 1992. As was the case with improved maize seed, this may be a reflection of improved extension services and input marketing. Maize yields have increased accordingly as depicted by Figures 8 and 9. The increase in yield may be due to adoption of improved varieties and application of fertilizer. With the exception of 1994, the intermediate zone respondents applied more N fertilizer than those in the lowland zone. The difference in the amount of N applied between the two zones, however, is not significant (p=0.05) for all years studied. The lowland zone farmers increased N application much faster from 1985 to 1994 when they caught up with those in the intermediate zone. The reason for the dramatic increase in N application in the lowland zone may be that crop production started later than in the intermediate zone (Dunford 1980). In the past, fertility in the lowland zone may have been higher than in the intermediate zone, hence the farmers may have had good production without applying much N fertilizer. Under continuous cultivation, fertility in the marginal lowland zone may have declined, thus requiring N applications commensurate with those in the intermediate zone.

Table 21. Fallowing and crop rotation

	Fallow	Crop rotation
	%	%
Intermediate (n = 90)	3.1	13.2
Lowland (n = 36)	11.0	22.0
P-value[a]	0.15	0.26

[a] Paired test comparing two zones.

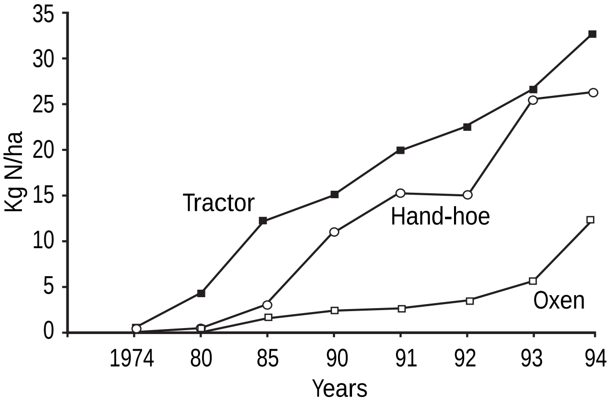

Figure 10. Fertilizer application by land preparation method.

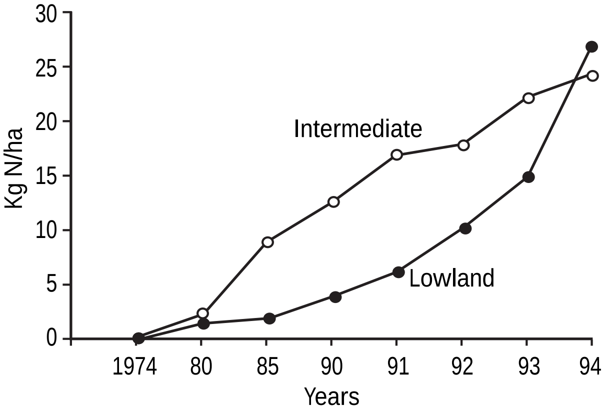

Figure 11. Fertilizer application by agroecological zone.

Evaluating the level of N applied by method of land preparation presents interesting results. Table 22 shows that, for the years of the study, there was no significant difference in the level of N applied between farmers who used hand-hoes and those who used oxen for land preparation. There was also no statistically significant difference in the level of N applied by farmers using hand-hoe and those using tractors. A highly significant difference was found (p=0.01) in the level of N applied by farmers who used tractors and those who used oxen. Farmers using oxen applied the lowest amount of N. It was expected that farmers who used hand-hoes were the poorest and so they were expected to apply the lowest level of N. Farmers who used oxen applied the lowest amount of N, probably because they applied more kraal manure to their fields. The amount of kraal manure applied may be determined by the number of livestock owned (Nyaki et al. 1991). Farmers who used oxen for land preparation had a significantly higher number of cattle (Table 4b) (p = 0.07) than the tractor and hand-hoe users, hence they were likely to apply more kraal manure than hand-hoe users. Farmers who use tractors may be wealthier and more able to afford chemical fertilizer. They may also have smaller herds of cattle that cannot supply enough kraal manure.

Until 1994, N application levels were still less than half of the recommendation for intermediate and highland areas, which average 80 kg N/ha. The recommendation for the high rainfall area with an altitude less than 900 masl was to apply 20-45 kg N/ha (Mowo et al. 1992; Samki et al. 1984). Since farmers applied an average of 27 kg N/ha in 1994 (Figure 10), a large gap was evident between recommendation and farmer practice. The majority of the farmers reported that they top dress fertilizer only once. Only 10% of sample farmers applied a second top dressing of fertilizer, while only 4% applied basal chemical fertilizer at planting.

4.6.4 Timing of fertilizer application

Timing of fertilizer application was close to the recommendation. There was no significant difference (p=0.05) between zones in timing of fertilizer application. The maximum and minimum number of weeks the sample farmers top-dressed fertilizer after planting maize was 13 and 1, respectively. The first top dress was at about 4.7 weeks after planting for both zones (Table 19). This was also within the recommendation of top dressing when maize is about one meter high.

Table 22. Trend of fertilizer application

	Intermediate (n=31)	Lowland (n=14)		Hand-hoe (n=27)	Oxen (n=29)	Tractor (n=61)	P-values[b]		
Year	Mean N/ha		P-value[a]	Mean N/ha			Hh/O	Hh/T	O/T
1974	0.32	0.0	0.52	0.0	0.0	0.5	1.00	0.50	0.00
1980	2.42	1.6	0.70	0.5	0.0	4.3	0.00	0.19	0.00
1985	8.87	1.9	0.10	3.1	1.4	12.2	0.83	0.12	0.00
1990	12.7	4.0	0.12	10.7	2.3	14.9	0.61	0.57	0.00
1991	16.9	6.2	0.08	15.2	2.7	19.5	0.34	0.60	0.00
1992	17.9	10.2	0.26	14.9	3.4	22.2	0.32	0.42	0.00
1993	22.1	15.0	0.32	25.4	5.4	26.2	0.14	0.93	0.00
1994	24.2	26.7	0.75	26.3	12.4	32.7	0.29	0.52	0.00

[a] Paired test comparing the two zones.

[b] Paired test comparing methods of land preparation for the two zones.

4.6.5 Methods of fertilizer application

The majority of respondents in the intermediate zone broadcast fertilizer, contrary to the recommendation for spot or furrow application and covering fertilizer with soil. In the lowland zone, the majority of farmers banded fertilizer around crops without covering (Table 23). This means the recommendation for fertilizer placement has been poorly followed in the intermediate zone where nutrient application is more important. The difference in the methods of placement between the two zones is significantly different (p=0.05) for all the methods except furrow application, which was not practiced by any of the sample farmers.

4.6.6 Factors affecting adoption of fertilizers

As was the case for adoption of improved maize seed, impacts of some variables on intensity of adoption fertilizer were analyzed using the two-step Heckman's procedure. Table 13 summarizes the influence of selected variables on probability of adopting fertilizer for the two zones. Only livestock units significantly influenced the probability of adopting fertilizer (p = 0.05). A unit increase in LUNIT decreases the probability of adopting fertilizer by 1.5%. It was expected that, with large herd size, farmers have more wealth and can therefore afford to buy chemical fertilizer, so LUNIT was expected show positive indicators. Nkonya et al. (1997) also observed that herd size was negatively related to the probability of adopting chemical fertilizer. The reason for this unexpected result may be explained by the fact that farmers with large herds have more manure that is used to replace chemical fertilizer. It is also true that farmers who have large herds of cattle live in areas with lower rainfall that are less subject to soil leaching. This keeps their soils more fertile and reduces the need for fertilizer.

The second part of Table 10 summarizes the influence of the selected variables on intensity of adoption for the intermediate zone and for the two zones taken together. For the two zones, no variable significantly influenced NRATE (p=0.05). For the intermediate zone, however, LUNIT significantly influenced NRATE (p=0.1). LUNIT has a positive impact on the probability of adopting fertilizer for the two zones.[2] This means that among adopters, LUNIT exerts a positive influence on NRATE via its income effect, i.e., richer farmers (as indicated by bigger LUNIT) were likely to apply more N.

4.6.7 Crop residue management

The recommendation for crop residue management for farmers who apply only low levels of fertilizer or none at all has has been to plough under in order to avoid soil mining. About 94% of the respondents from the lowland zone compared to 71% from the intermediate zone reported that they fed their maize stover to cattle *in situ*, i.e., in the field (Table 24). The

Table 23. Methods of placing top dress fertilizer

Application method	Intermediate (n=31)	Lowland (n=14)	
	% of farmers		P-value[a]
Broadcast	74.2	28.6	0.00
Spot (hole)	16.1	0.0	0.01
Banding	3.1	71.4	0.00
Furrow	0.0	0.0	1.00

[a] Paired test comparing the two zones.

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[2] It should also be noted that the opposing results are not surprising as they were obtained from two separate sub-samples, one consisting of non-adopters and the other adopters only. The negative impact of LUNIT on probability to adopt was on non-adopters and its positive impact was on the intensity of adoption among adopters.

majority of farmers in the lowland zone did not zero-graze because they had large herds of cattle; the herds are fed on stover after harvest. Only 14% cut and carried stover home to feed zero-grazed dairy cows, resulting in a nutrient flow from the field to other areas. Some districts have bylaws that restrict feeding crop residues *in situ*. Restrictions on grazing stover in the field help minimize soil erosion because such grazing leaves the fields bare and the animals pulverize the soil, making it susceptible to wind and sheet erosion. Extension officers should encourage farmers who cut and carry stover, and those who feed crop residues *in situ*, to apply fertilizer to their fields in order to replenish the exported nutrients. Sample farmers who ploughed under crop residues were 11% of all the respondents.

Table 24. Management of crop residues

	Intermediate (n=70)	Lowland (n=18)	Hand-hoe (n=26)	Oxen (n=14)	Tractor (n=44)
Management			**Proportion practicing**		
Plough under	0.13	0.00	0.12	0.00	0.10
Burn	0.014	0.00	0.00	0.00	0.02
Feed cattle	0.71	0.94	0.65	0.93	0.75
Stallfeed	0.14	0.06	0.23	0.07	0.10

4.7 Pest and disease control

4.7.1 Most serious pests and diseases

Insect pests are a significant production constraint for maize in Tanzania. Stalk borer (*Buseola* spp.), one of the nation's most serious pests (Nyambo and Kabissa 1990), is prevalent during dry spells or in areas with hot weather and marginal rainfall. Cultural and chemical control measures of the pest have been recommended (Nyambo and Kabissa 1990). As expected, a significantly higher percentage of farmers in the lowland zone (with hotter climate) reported being affected by stalk borers compared to respondents from the cooler intermediate zone (Table 25). About 58% of farmers in the intermediate zone who reported being affected by insect pests used chemical control compared to 20% in the lowland zone. Other farmers did not use any control measures, probably because the economic threshold of damage was not attained.

Table 25. Common maize pests reported by sample farmers.

		Stalk borer	Armyworm	Cutworms
Zone/MLP[a]			**%**	
Intermediate	(n=88)	53.0	42.0	5.70
Lowland	(n=34)	77.0	19.0	4.00
P-value [b]	(Zones)	0.00	0.00	>0.50
Hand-hoe	(n=25)	68.0	28.0	4.00
Oxen	(n=25)	80.0	16.0	4.00
Tractor	(n=54)	48.0	44.0	8.00
P-value[b] :	(Hh/Ox)	0.30	0.30	1.00
	(Hh/Trac)	0.10	0.20	>0.50
	(Ox/Trac)	0.01	0.01	>0.50

[a] MLP = method of land preparation.

[b] Paired test comparing the two zones and methods of land preparation.

Armyworms occur occasionally. At such times, the government takes responsibility for controlling the outbreaks through the department of pest control. Occurrence of cutworms is spotty; it was reported by only 5.7% of the respondents in the intermediate zone and 4% of sample farmers in the lowland zone.

Thanks to varieties bred for disease resistance and tolerance, maize diseases were rarely reported by sample farmers. The major disease reported was MSV. No farmer reported having controlled the disease. Its control includes roguing and seed dressing using carbofuran (Mduruma et al. 1990). Only two farmers in the lowland zone reported MSV as a problem.

4.8 Transportation, storage, and post-harvest technology

4.8.1 Transportation

As shown in Table 26, head loads are the commonest means of transporting maize from the fields to homes for both zones and for all methods of land preparation.

Ox-carts and trailers were the second most important means of transportation for the two zones and methods of land preparation. Use of donkeys was not reported by farmers, but other studies have reported that the animals are used by many farmers in Mbulu, Arumeru, Hanang, Babati, Simanjiro, Monduli, and Kiteto (Nkonya et al. 1992; Cunard et al. 1983).

4.8.2 Storage

The major maize storage pests in northern Tanzania are *Sitophilus* spp., *Prostephanus truncatus* (Larger grain borer, LGB), *Tribolium* spp., *Rhizopertha dominica, ephestia* spp., *Sitotroga cerealla, and Oryzaephilus* spp. Storage losses of maize of up to 70% have been recorded in the lowland zone as a result of LGB (Uronu 1990). Storage losses caused by other pests are substantial if stored maize is not treated.

Farmers used different methods of preserving their maize crop (Table 27). Most farmers in Kilimanjaro stored their maize using gunny bags and airtight drums. Upright cribs were common in Arusha, where 60% of intermediate zone respondents were sampled. Farmers who used cribs normally did not shell their maize. Storage is accomplished by tying two cobs of maize together using the husks and hanging them on upright cribs. When farmers need to mill maize, they shell the amount needed at that time. This method allows farmers to forego treating their maize.

Table 27. Methods of grain storage across zones

Method	Intermediate	Lowland
	%	
On cribs[a]	56.7	2.8
Gunny bag	22.2	88.9
Air tightdrums	21.1	5.6
Kihenge[b]	1.3	2.8
Shelled no treatment	14.1	2.8

[a] Unshelled and untreated.

[b] Maize is shelled and treated with ash or other local material and then stored in local containers called ‘kihenge’.

Use of gunny bags is the most common practice in the lowland zone (Table 27). Of sample

Table 26. Transportation of maize from field to homestead

Method	Intermediate (n = 70)	Lowland (n = 18)	Hand-hoe (n = 26)	Oxen (n=14)	Tractor (n=44)
			%		
Head loads	42.5	57.6	55.0	39.0	48.0
Carts	41.4	21.2	22.0	44.0	33.0
Pick-up	16.1	12.1	11.0	17.0	19.0
Bicycles	0.0	9.1	11.0	0.0	0.0

farmers who used gunny bags, 80% treated maize using chemicals alone or in combination with ashes. Farmers who used drums did not use any chemicals and reported that they did not experience grain losses. Treatment with actellic super dust for shelled maize was the most common chemical control. Ninety percent of tractor users treated their shelled maize compared to 77% of hand-hoe users.

4.9 Seed selection

4.9.1 Seed selection criteria

In both zones, the majority of farmers selected their seed for the next season from their harvest (recycling). The criteria used for selection are summarized in Table 28.

A big cob was the most common selection criterion in both zones. However, size of the cob does not necessarily reflect the genetic yield potential; cob size may be a result of the environment in which the plant grew. For instance, a maize plant growing on border rows or on ant-hill soil may be larger than others, even if it has lower yield potential. Therefore, farmers need to be educated about effective seed selection practices.

4.9.2 Recycling improved maize varieties

Recycling the seed of improved varieties is a common practice in northern Tanzania. On average, about 80% of sample farmers recycled improved varieties for 4 to 6 years. The type of varieties planted between the two zones differed as expected. No sample farmer in the lowland zone reported recycling the full season hybrid H622 or H632. Contrary to expectation, recycling of composites was limited, probably because fewer farmers grew OPVs compared to imported and locally bred hybrids. Only 18 farmers in the intermediate zone and two farmers in the lowland zone reported recycling a composite variety (Table 29). The research recommendation is to recycle composites for a maximum of three years. Hybrids are not recommended for recycling. The recycling procedure is to select seed from the middle of the field when maize cobs have dried; those cobs have been exposed to minimal cross-pollination from neighboring fields. Contrary to this recommendation, farmers selected their seeds at home after harvesting the entire field.

In the intermediate zone alone, hybrids were recycled for a longer period than OPVs. On average, hybrids were recycled for about 6.7 years compared to 3.9 years for OPVs. Imported varieties, such as CG4141, were recycled for about 4 years in the intermediate zone and 2.5 years in the lowland zone (Table 29).

Table 28. Seed selection criteria

	Big cob	Mature cob
	%	
Intermediate (N=79)	98.7	1.3
Lowland (N=13)	100.0	0.0
P-value[a]	0.31	0.31

[a] Paired test comparing the two zones.

Table 29. Mean number of years of recycling improved cultivars

Variety	Lowland	Intermediate	P - value[a]
Composites	8.5 (n=2)	3.9 (n=18)	0.15
H622/H632	0.0 (n=0)	6.7 (n=33)	NA
CG4141	2.5 (n=8)	4.3 (n=21)	0.24

[a] Paired test comparing the two zones.

Recycling is a result of high seed prices. Extension agents should discourage farmers from recycling hybrids and advise farmers on how to recycle composites. Researchers should study the economics of recycling improved varieties.

Farmers were also asked to state where they obtained their maize seed. About 77% said they obtained seed from their own farms, while 11% got seeds from their neighbors. Twelve percent bought seed from the market. This demonstrates that farmers are careful in obtaining seeds because the majority of them obtained seed from their own fields to ensure that they knew what they were planting.

5.0 CREDIT AND EXTENSION SERVICES

5.1 Credit availability

If small farmers are to be given a loan, such loans should be small to enable them to manage the funds and repay the loan. Small loans to individual farmers, however, involve high administrative costs that render them impractical. Commercial banks also require collateral that small farmers do not have. Group loans are one alternative that has been suggested (Miller 1974). Banking institutions in Tanzania have been giving loans to small farmers through their cooperatives (Due 1980). These loans have been used to buy inputs that are then sold to individual farmers. Farmers growing export crops like coffee and tobacco have been given such inputs on loan. It was possible to make these farmers repay their loans because they were obliged to sell their produce to the same cooperatives. Until 1993 the cooperatives were the sole buyers of export crops. For food farmers in Tanzania, there have not been any formal credit facilities other than NGOs. This is the case in many developing countries. Miller (1975) observed that the major source of credit for small maize and rice farmers in Nigeria was informal lenders like friends and relatives. Such loans were small and their main use was for paying school fees and casual labor. Rarely were they used to buy inputs. Anderson and Dillon (1992) note that these informal credit institutions play a vital role in low income countries, but they are poorly documented.

Cooperatives often experienced liquidity problems that led to delays in input delivery and shortages of inputs. Now export crop marketing has been liberalized, so farmers are not forced to sell their produce to cooperative societies. This will probably make loan recovery difficult, resulting in a termination of cooperative loans to small export crop farmers. The prevision of credit to small farmers remains elusive, especially after the market reforms implemented by the government of Tanzania. Commercial banks and other credit institutions have no plans for providing loans to small farmers, especially small food crop farmers. Government intervention to make loans available by forcing banks to waive collateral requirements (and other conditions) and make credit available at below-market interest rates leads to inefficient and costly use of funds. Corruption has also plagued such interventions; soft loans often wind up being more available to the rich than the poor (Anderson and Dillon 1992).

SG-2000 has been the major source of credit for small food crop farmers in northern Tanzania. The major drawback of credit from SG-2000 has been its short-term nature (three years) and weak credit administration, which increased the number of loan defaulters when credit was extended to a large number of farmers (Nkonya 1994). Nevertheless, SG-2000 is the foremost NGO addressing the issue of credit for small food crop farmers in Tanzania. However, the program would benefit by emulating the Grameen Bank in Bangladesh, which has been successful in giving loans to small farmers on a sustainable basis. In recognition of the bank's success, its founder, Yunus Mohammed received the 1994 World Food Prize (IPS 1994).

Sample farmers who received loans in the two zones represented 16% of the 126 respondents. Table 30 shows that 19% of intermediate zone respondents received credit at least once compared to 8% of respondents from the lowland zone. The difference in loan accessibility may be that the SG-2000 project had more sites in the intermediate zone than in the lowland zone. The major source of credit reported was NGOs, especially SG-2000. Only 1 out of 3 loan recipients in the lowland zone reported receiving a loan from a formal bank. In the intermediate zone, 3 out of 17 loan recipients obtained a loan from a formal bank.

Farmers did not report receiving any loans from informal money lenders, probably because they thought that a ‘loan’ comes from a formal institution such as a bank or NGO. There was no significant difference in the source of the loan between the two zones (p=0.05). Table 30 shows some of the problems farmers encountered in trying to obtain loans.

Lack of collateral was the major problem farmers faced in trying to get loans from formal credit institutions in both zones. Cumbersome loan procedures were cited as the second major problem. Problems encountered in obtaining loans across the two zones were not statistically significant (p = 0.05). Table 30 should be interpreted with care because it involves a very small sample for the lowland zone.

5.2 Sources of information

There is a need to investigate farmers' sources of information about new technology in order to assess the effectiveness of such sources in delivering technologies to farmers. Farmers were asked whether they had received information on maize production technologies from various sources and if they had adopted such technologies. Tables 31 and 32 summarize farmers’ responses to these questions. The three most important sources of production information cited were extension agents, other farmers, and NGOs. In both zones, extension officers led in imparting knowledge to farmers for all technologies, except draft animals in the lowland zone. The NGOs that have been active in agricultural extension in northern Tanzania include: Sasakawa Global 2000 (SG2000), Farm Africa, Heifer Project International (HPI), and religious organizations (e.g. ADDO), among others.

Table 30. Credit availability, credit sources, and problems of getting loans

	Lowland	Intermediate	P - value[a]
	%		
Received credit? (% yes)	8.0 (n=36)	19.0 (n=90)	0.07
Source of credit: NGO	67.0 (n=3)	82.0 (n=17)	>0.50
Bank	33.0 (n=3)	18.0 (n=17)	>0.50
Problems of getting a loan:			
No collateral	75.0 (n=32)	84.0 (n=74)	0.30
Cumbersome procedure	25.0 (n=32)	14.0 (n=74)	0.20
Other	0.0 (n=32)	3.0 (n=74)	0.13

[a] Paired test comparing the two zones.

The responses on sources of technology information were, however, biased against other farmers as a source. A farmer may forget to report that he or she received production technology information from another farmer because the two live together as peers, so the sharing of information sometimes goes unnoticed. Notwithstanding this bias, 'other farmers' ranked as the second most important source of production information for all technologies in the intermediate zone (Table 32). Use of draft animals was learned at a tender age from parents, so it is not surprising that other farmers were the most important source of information on use of draft animals in the lowland zones. Extension efforts have been directed mainly toward improved varieties, chemical fertilizer use, and planting configuration, which explains why over 80% of sample farmers in the intermediate zone and all respondents in the lowland zone reported that they had received maize production information on these technologies. Information on herbicide use had been received by only 7% of sample farmers, implying that this technology was still new to the majority of farmers.

Technology on draft power was also poorly extended to farmers as only 14% of respondents in the lowland zone and 41% of sample farmers in the intermediate zone had received information on this technology. Draft animal technology is important because farmers experience labor bottlenecks during planting and weeding. Using draft animal power could ease the bottlenecks and release labor for other gainful activities. Ox-weeding technologies were practiced in some parts of Arumeru districts for pure stand maize (Nkonya et al. 1991; Cunard, et al. 1983), however, this technology was rarely practiced by farmers in other districts. Extension agents need to direct their efforts to advising farmers on how to weed pure stand maize using oxen.

Table 31. Sources of maize production technology information for the lowland zone

Technology		Received info? (% yes)	Sources of information			
			Extension	Other farmers	NGO	Other
Improved variety	(n=18)	100	44	11	17	28
Planting method	(n=21)	100	89	0	11	0
Fertilizer	(n=16)	100	29	21	21	29
Weed management	(n=14)	100	31	0	23	46
Pest/disease control	(n=10)	100	56	33	0	11
Storage methods	(n=14)	100	61	15	8	15
Animal draft	(n=21)	14	0	67	0	33

Table 32. Sources of maize production technology information for the intermediate zone

Technology		Received info? (% yes)	Sources of information			
			Extension	Other farmers	NGO	Other
Improved variety	(n=72)	85	66	18	3	13
Planting method	(n=69)	85	76	8	8	8
Fertilizer	(n=65)	80	69	21	4	6
Weed management	(n=64)	73	68	11	2	19
Pest/disease control	(n=65)	74	79	11	4	6
Storage methods	(n=61)	75	56	15	9	20
Animal draft	(n=61)	41	48	24	24	4

6.0 CONCLUSIONS

Maize is the major staple crop in northern Tanzania. The NMRP has directed considerable efforts toward generating technologies suitable for specified target zones. Northern Tanzania is categorized by NMRP as an intermediate altitude zone, hence most of the varieties bred for the zone are OPVs (Kilima, Staha, TMV1, UCA, and Tuxpeño). Two hybrids, H632 and H622, are also recommended for the zone. This study observed that most farmers in the intermediate and lowland zones grew imported hybrids, especially CG4141. The variety was preferred mostly because of its high yield and early maturity, despite its poor pounding, storage, and taste characteristics. In the intermediate zone, hybrids H632 and H622 were the second most preferred varieties followed by Kilima. In the lowland zone, Kilima and Katumani were the second and third most preferred varieties, respectively. This means the demand is lower for composites than for hybrids. However, the NMRP has released more composites than hybrids for this zone. Maize seed production and marketing institution inefficiency may be responsible for the low demand for composites, which are suitable for recycling. More effort needs to be expended on breeding hybrids targeted for the Northern Zone. Another strategy is to promote composite seed production at the village level to overcome seed marketing problems.

The two-step Heckman analysis of factors affecting adoption showed that farming experience was the only household characteristic variable that significantly influenced the probability to adopt improved maize seed in the intermediate zone. The probable reason why other factors were not detected was the high rate of adoption of improved maize seed. No factor influenced significantly the intensity of adoption of improved maize seed. The probable reason for this may be the narrow range of the level of adoption, i.e., the 1992-1994 average maize area under improved maize seed ranged from 0.17 to 1.00 ha with a mean of 0.89 and a standard deviation of 0.21 ha.

All farmers in the two zones grew improved maize varieties in the 1994/95 season. The proportion of area under improved varieties was 76% of total area under maize for both zones and methods of land preparation in the same season. The average rate of adoption of improved maize seed between 1992 and 1994 was 94%. The rate of adoption increased dramatically between 1990 and 1994, probably because of an improved input delivery system under liberalized markets and increased extension efforts. However, about 80% of sample farmers recycled improved varieties, including hybrids. In the intermediate zone, locally bred hybrids were recycled for a longer period than composites. This is contrary to expectations and recommendations. Farmers in the lowland zone did not usually grow the locally bred hybrids. Seed selection was performed at home instead of from the middle of the field as recommended. There is a need to research the losses farmers incur when they recycle hybrids and composites, as well as the economics of recycling improved varieties. The extension services should also direct more effort to advising farmers on the best methods of recycling composites and discourage them from recycling hybrids.

The rate of adoption of chemical fertilizer was still low. About 64% of intermediate zone and 44% of lowland zone sample farmers applied chemical fertilizer. About 49% of intermediate zone respondents used kraal manure in the 1994/95 season compared to 44% of sample farmers from the lowland zone. The average rate of adoption of fertilizer application for the period 1992 to 1994 was 59%. The only farm characteristic that influenced adoption of fertilizer was livestock units. A unit increase in livestock reduced the probability of adopting fertilizer by 1.5%. No household characteristic significantly influenced the intensity of adoption of fertilizer.

Recommendations on fertilizer placement were poorly followed. The majority of farmers broadcast or banded chemical fertilizer without covering it. More extension efforts should be directed toward fertilizer technologies, as a majority of farmers use inefficient practices. Also, studies on the economics of fertilizer use should be undertaken, especially now that input and output markets have been liberalized.

Crop residues are still poorly used by farmers in northern Tanzania. The majority of farmers fed crop residues *in situ*, and a few in the intermediate zone cut and carried stover to feed zero-grazed cows. This magnifies the importance of using chemical fertilizers. Rising fertilizer prices, however, have forced farmers to use kraal manure and crop residues. Extension efforts advising farmers to use organic manure to supplement chemical fertilizers should be increased. More research effort should be directed to soil mining, supplementation of chemical fertilizers with different sources of organic manure, crop residue management, and soil conservation. Additional fertility research will be particulalry relevant because use of chemical fertilizer is likely to remain low in the foreseeable future due to its increasing price.

Adoption of other recommendations, namely land preparation methods, frequency and time of weeding and fertilizer application, and crop spacing have been readily and successfully adopted in both zones. Hence, research and extension in those areas should be given low priority.

Formal credit is not available to maize farmers. With rising input prices, credit to farmers becomes increasingly important. Therefore, policy makers and bankers should direct more effort toward providing loans to small maize farmers in ways that will ensure a high rate of loan recovery and low cost of credit administration. The experience of the Grameen bank of Bangladesh should be emulated.

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