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SACCAR
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Abstract: This report of the adoption of maize production technologies in the Southern Highlands of Tanzania forms part of a larger study to evaluate the impact of maize research and extension throughout Tanzania over the past 20 years. Using a structured questionnaire, researchers and extension officers interviewed farmers in June–November 1995. Survey data were grouped by agroecological zone: the intermediate zone and highlands. A tobit analysis was used to analyze factors affecting the adoption of land allocated to improved maize varieties and the amount of inorganic fertilizer used. The tobit analysis showed that the proportion of land allocated to improved maize varieties was significantly influenced by zone (intermediate), extension, and numbers of livestock units. The tobit analysis also showed that farm size, hand hoe use, and farmers' experience were significant factors affecting the amount of fertilizer used. Future maize research should address the problem of stalk borers, cutworms, and maize streak virus by developing tolerant varieties, and these new varieties should be developed and promoted through participatory on-farm research. Extension services should increase their educational contacts with farmers, especially on topics such as herbicide and oxen use, because appropriate technologies could reduce the labor bottlenecks confronting farmers during land preparation and weeding. With rising input prices, it becomes increasingly important to ensure that farmers have access to credit, and policy makers and bankers should seek ways of providing loans to small-scale maize farmers in ways that will ensure a high rate of loan recovery and low cost of credit. More information should be provided to farmers about credit schemes, and the requirements for collateral should be reviewed. Finally, policy makers should continue to encourage and support the private sector to invest in input acquisition and distribution so that inputs are available when farmers need them.

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Acronyms and Abbreviations

CAN	Calcium ammonium nitrate
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DALDO	District Agricultural and Livestock Development Officer
DAP	Di-ammonium phosphate
DRT	Department of Research and Training
FSR	Farming systems research
FYM	Farm yard manure
ICW	Ilonga Composite White
MARTI	Ministry of Agriculture Research and Training Institute
MASL	Meters above sea level
MIP	Maize Improvement Programme
MOA	Ministry of Agriculture
MSV	Maize streak virus
NAFCO	National Agricultural and Food Cooperation
NGO	Non-governmental organization
NMRP	National Maize Research Programme
NPK	Nitrogen, phosphorus, and potassium
RALDO	Regional Agricultural and Livestock Development Officer
SA	Sulfate of ammonium
SACCAR	Southern African Centre for Coordination of Agricultural and Natural Resources Research and Training
SARI	Selian Agricultural Research Institute
TANSEED	Tanzania Seed Company
TFA	Tanganyika Farmers' Association
TMV1	Tanzania Maize Variety-1
Tsh	Tanzanian Shilling
TSP	Triple super phosphate
UCA-St	Ukiriguru Composite A-Streak resistant
URT	United Republic of Tanzania
VEO	Village Extension Officer

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Executive Summary

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

This report forms part of a larger study to evaluate the impact of maize research and extension in Tanzania over the past 20 years. The Department of Research and Training (DRT) conducted the study in collaboration with the Southern Africa Coordination Centre for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement Center (CIMMYT). To increase data validity and reliability, researchers and experienced extension officers using a structured questionnaire for interviewing farmers. Interviews were conducted in all seven agroecological zones of the country between June and November 1995. This report covers survey findings in the Southern Highlands, which includes Iringa, Mbeya, Rukwa, and Ruvuma regions. Data collected in the survey were grouped into two agroecological zones, the intermediate zone and the highlands. These are the most important zones for maize production and therefore the most important categories for analysis. A tobit analysis was used to analyze factors affecting the adoption of land allocated to improved maize varieties and the amount of inorganic fertilizer used.

Maize research activities in the Southern Highlands Zone are undertaken at the Ministry of Agriculture Research and Training Institute (MARTI), Uyole. The major varieties released and developed in collaboration with national and international research centers were H614, H632, H6302, and TMV2 for the highlands and Ukiriguru Composite A (UCA), Kilima, and TMV1 for the intermediate zone. Kito was released for the lowlands.

The mean age of household heads was 44 years in the intermediate zone and 41 years in the highlands. The educational level of the household head averaged five years of formal training for both zones. Sample households had about nine and eight family members comprising at least two male and female adults and five (four) children in the intermediate zone and highlands, respectively. Land is mainly a constraint in the highlands, where the average farm size (8.0 acres) was lower compared to the intermediate zone (9.2 acres). Livestock ownership is more common in the intermediate zone. Farmers owned an average of 8.5 cattle in the intermediate zone compared to the highlands (4.3). The hand hoe was the major farm tool used in both zones.

Maize is the chief food and cash crop in the study area. Intercropping of maize with beans or sunflower was common in both zones. Maize monocropping, however, was the strategy most preferred by farmers (83% in the intermediate zone and 58% in the highlands). Land preparation depended on the onset of the rains in each zone. The hand hoe was the major tool used in land preparation. Maize was mostly planted in rows and most farmers used the recommended spacing. Maize plots were weeded at least twice. The first and second weeding depended on date of sowing and onset of the rains. Sixty-five percent of the farmers in the intermediate zone and 79% in the highlands reported using inorganic fertilizer. Fertilizer use was constrained by lack of cash. Virtually all farmers in both zones (96%) used organic fertilizer. Other soil fertility management activities were also carried out. About 42% of the farmers in the intermediate zone and 50% in the highlands fallowed their land, while crops were rotated, mainly with legumes, by about 68% of farmers in the intermediate zone and 53% in the highlands.

Stalk borers were the most serious field pests of maize for 93% and 99% of the farmers in the intermediate and highland zones, respectively, and most farmers used chemical control methods. Maize streak virus (MSV) was the most important disease for 94% and 78% of the farmers in the intermediate and highland zones, respectively. Most farmers used roguing to control for diseases.

Most maize was harvested in June/July in the intermediate zone (84.7%) and from August to September in the highlands (66.2%). In the intermediate zone most farmers (62.5%) used ox-carts to transport maize, and in the highlands most farmers (62.8%) used head loads. Most farmers in both zones stored their food maize in a *kihenge* and selected their seed maize at home (about 69% of intermediate zone farmers and 75% percent of highland zone farmers). A big cob was the most important seed selection criterion for most farmers. About 97% and 90% of the farmers in the intermediate and highland zones, respectively, purchased seed every year.

In the 1994/95 cropping season, about 36% of the farmers in the intermediate zone and 51% of those in the highlands grew improved maize. H614 was the preferred variety in the intermediate zone (75%) and highlands (60%), mainly because of its high yield. In both zones, farmers had stopped growing H6302 and H614, mainly because seed was unavailable or too costly, or because the varieties were susceptible to diseases and yielded poorly.

About 20% of the farmers in both zones obtained credit, and the main source of credit was non-governmental organizations (NGOs) (60%). Lack of knowledge and lack of collateral were the major constraints to obtaining credit. Most farmers had received information on improved maize practices such as improved seed, weeding, use of fertilizer, planting dates, pest management, and storage methods. Less information was disseminated about herbicides, ox-drawn implements, and disease control methods. Extension was farmers' most important source of information.

The tobit analysis showed that the proportion of land allocated to improved maize varieties was significantly influenced by zone (intermediate), extension, and numbers of livestock units. Extension increased the probability of growing improved maize at the means by 10%. Farmers in the intermediate zone were less likely to allocate land to improved maize varieties (the probability decreased by about 4%). An increase in livestock numbers by two units increased the probability of using improved maize varieties by 1%.

The tobit analysis also showed that farm size, hand hoe use, and farmers' experience were significant factors affecting the amount of fertilizer used. An increase of farm size by 5 acres decreased the probability of adopting fertilizer by 1%, and a ten-year increase in farming experience decreased the probability of adopting fertilizer by 1%. The use of the hand hoe as a land preparation method increased fertilizer adoption by 1%.

New varieties should be developed and promoted through participatory on-farm research. Research should address the problem of stalk borers, cutworms, and MSV by developing tolerant varieties. TMV1 variety, which resists MSV, has been developed, but this variety has not yet reached the farmers. Similar efforts should be concentrated on developing tolerant varieties for stalk borer and cutworm.

Extension services should increase their educational contacts with farmers, especially on topics such as herbicide and oxen use, because appropriate technologies could reduce the labor bottlenecks confronting farmers during land preparation and weeding. Only 10.5% of the farmers in the intermediate zone and 27.6% in the highlands have received information on using herbicides and oxen; only 19.6% in the intermediate zone and 36.4% in the highlands use these new technologies. Maize streak virus is a serious disease, yet only 33.3% and 24.7% of the farmers in the intermediate and highland zones, respectively, have received information on how to control maize diseases. Extension should continue to extend messages through farmer groups and on-farm demonstrations to reach more farmers quickly and at a relatively low cost.

The formal credit market is hardly involved in supplying credit to farmers, but rising input prices make it increasingly important to ensure that farmers have access to credit. Policy makers and bankers should direct more effort to providing loans to small-scale maize farmers in ways that will ensure a high rate of loan recovery and low cost of credit. More information should be provided to farmers about credit schemes, and the requirements for collateral should be reviewed.

Policy makers should continue to encourage and support the private sector to invest in input acquisition and distribution so that inputs are available when farmers need them. Credit and efficient import regulations should be provided to private traders to avoid unnecessary delays in the importation of inputs. Also, farmers who plant during the dry season should receive inputs during that time of the year. Finally, government policy should strengthen the input delivery system if the smallholder sector, which produces more than 85% of Tanzania’s maize, is to maintain its productivity.

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1.0. Introduction

1.1. Motivation and Objectives for This Study

Maize is the major cereal in Tanzania. Annual per capita consumption of maize in Tanzania is estimated at 112.5 kg, and national maize consumption is estimated to reach three million tons per year. Maize accounts for 60% of the dietary calories of Tanzanian consumers (FSD 1996) and more than 50% of utilizable protein, whereas beans contribute 38% (Due 1986).

Recognizing the importance of the maize crop to the lives of Tanzanians, the government has committed human and financial resources to developing the industry. Maize research and extension efforts began in 1960, and breeding during the 1960s resulted in the release of Ukiriguru Composite A (UCA) and Ilonga Composite White (ICW). A National Maize Research Programme (NMRP) was started in 1974 with the broad objective of developing cultivars suitable for major maize-producing areas.

Maize is an important food and cash crop in the Southern Highlands of Tanzania. The zone comprises four regions, namely Iringa, Mbeya, Rukwa, and Ruvuma (Figure 1) and produces about 46% of national maize production. Furthermore, the Southern Highlands account for nearly 90% of the maize purchased for the National Food Security Granary (Mussei and Shiyumbi 1992; Moshi and Nnko 1989). Over 80% of the maize produced in the region is grown by smallholders under a wide range of management practices, climatic conditions, and socioeconomic circumstances.

Previous studies have shown that maize production in the Southern Highlands Zone started early this century in Iringa. In the 1950s it expanded to other regions, especially Mbeya and Ruvuma, and in the 1970s to Rukwa (Mussei and Shiyumbi 1992). Maize has completely replaced traditional coarse grains such as finger millet and sorghum, which were the dominant food crops.

Maize research in the Southern Highlands started during the 1970/71 cropping season at the Ministry of Agriculture Research and Training Institute (MARTI), Uyole. In collaboration with national and international research institutes and technology transfer agents, a number of improved technologies were tested, adapted, and released to suit various agroecological zones of the Southern Highlands. Although these recommendations have been used for the past 20 years, there is still a wide gap between farmers' yields (1.5 t/ha) and potential yields for most of the hybrids that are available (7 t/ha) (Lyimo and Temu 1992). In part to determine the reasons for this yield gap, the Department of Research and training (DRT), in collaboration with the Southern Africa Coordination Centre for Agricultural Research (SACCAR) and the International Maize and Wheat Improvement

Center (CIMMYT) conducted a national survey to evaluate the impact of maize research and extension. The study was conducted between June and November 1995. This report covers the survey findings from the Southern Highlands. Specifically, the study was undertaken to describe the maize farming systems of the Southern Highlands, evaluate the adoption of improved maize production technologies in the region, and define future research needs in light of the findings of the study.

1.2. The Study Area

The Southern Highlands are located between latitudes 7° and 11.5°S and longitudes 30° and 38°E (Figure 1) (URT 1985). The population is about 4.1 million (1988 census), of which about 90% engage in agriculture. The Southern Highlands cover an area of about 250,000 km^2 (28% of the mainland area of Tanzania), and elevation ranges between 400 and 3,000 masl. The climate varies from tropical to temperate in areas higher than 2,000 masl. Temperatures are warm in the lowlands and cool in the highlands. The mean annual rainfall ranges from 750 to 3,500 mm. The rainfall pattern is usually unimodal, from November to May. The soils are highly weathered and leached, frequently acidic and of relatively low fertility. This range of climatic and other conditions explains the diversity of agroecological zones in the Southern Highlands, which have been classified into ten agroecological zones (Figure 2). More than 70 crops, including fruits and vegetables, are grown, and smallholder farmers keep several different livestock species. The major farming systems include the maize-based farming system, the rice-based farming system, agropastoral farming systems, and coffee/banana-based farming systems.

Figure 1. Southern Highlands, Tanzania.

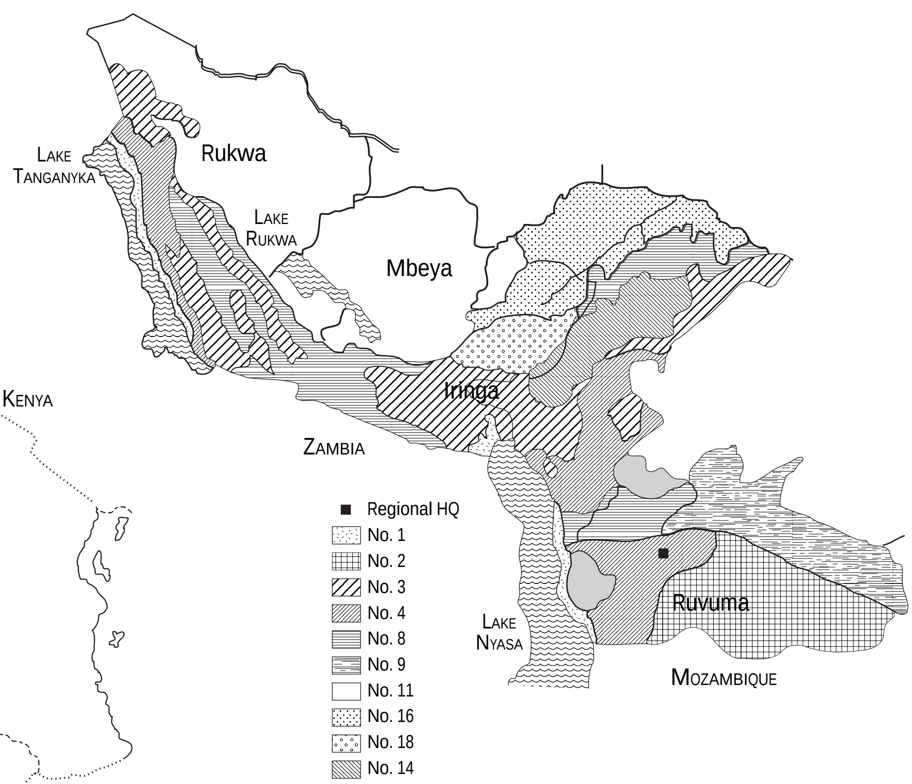

Figure 2. Agroecological zones of the Southern Highlands, Tanzania .

The **maize-based farming system** is found in all regions, at elevations ranging from 700 to 2,900 masl. Under normal climatic conditions, maize is planted from the second week of November and the second week of December and harvested between June and July, depending on the weather and the variety grown. Other crops grown in these areas include beans, sunflower, potatoes, finger millet, and assorted vegetables.

The **rice-based farming system** is found in isolated areas of the zone where the altitude is between 400 and 700 masl, such as Kyela, Usangu, Pawaga, Mbinga (along Lake Nyasa), Kirando, Karema, and Lake Rukwa Valleys, all of which are found in the great East African Rift Valley. Also a substantial amount of rice is produced in Tunduru District. With the exception of Usangu, where both small- and large-scale irrigation and rainfed farming are practiced, in all other areas rice is produced under rainfed conditions. Other crops in these areas include cassava, maize, groundnuts, bananas, nuts, and legumes.

Agropastoral farming systems are relatively new in the zone. The migrant Wasukuma have introduced it from the Lake Zone during the last 20 years. These migrants, who own large herds of cattle, settled in Usangu and Lake Rukwa Valleys and Chunya in search of pasture for their animals. In addition to keeping cattle, goats, and sheep, these people produce crops such as maize, sorghum, sweet potatoes, pulses, and pumpkins. In the drier eastern part of Iringa District, the migrant Maasai practice both crop and livestock production as well.

The **coffee/banana-based farming system** is important for cash crop production. It is found in Rungwe and Mbozi Districts in Mbeya region and in Mbinga District in Ruvuma region, where the climate is cool and rainfall reliable. Other crops in these areas include legumes, maize, and horticultural crops. In Rungwe District, tea is also produced in the same system. Other areas where tea is produced (mainly on a large scale) are Mufindi and Njombe Districts in Iringa region. One important characteristic of the coffee/banana-based farming system is land scarcity, which is the result of population pressure arising when land is taken for coffee and banana production.

1.3. Methodology

1.3.1. Sampling procedure

As mentioned previously, this report is part of a national survey covering all research 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 Southern Highlands were allocated 396 farmers or approximately 40% of the national sample. Farmers were sampled from the districts in the zone that are important in maize production. Production figures from the statistical unit of the Ministry of Agriculture (MOA) were used to establish each district's importance for maize production. Eleven districts were purposively sampled. At the district level, villages that are important in maize production were selected with the help of extension staff. Multistage, purposive sampling procedures were used to select 22 villages for this study. 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, economists from CIMMYT and SACCAR, and national maize breeders and agronomists. As noted earlier, farmers were interviewed 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.

1.3.2. Analytical framework

Factors influencing the adoption of new agricultural technologies can be divided into three major categories: farm and farmers' associated attributes; attributes associated with the technology (Adesina et al. 1992; Misra et al. 1993); and the farming objective (CIMMYT 1988). Factors in the first category include a farmer's education, age, or family and farm size. The second category depends on the type of technology (e.g., the kind of characteristics a farmer likes in an improved maize variety). The third category assesses how different strategies used by the farmer, such as commercial versus subsistence farming, influence the adoption of technologies. For this study, a tobit model was used to test the factors affecting the allocation of land to improved maize varieties and amount of fertilizer used in kg N/ha (intensity of adoption). The tobit (Maddala 1983) model that tests the factors affecting incidence and intensity of adoption can be specified as follows (Shakya 1985):

$$E(Y \mid I) = I * F(I \mid \sigma) + \sigma * f(I \mid \sigma),$$

where:

$E(Y \mid I)$ = expected amount (e.g., of fertilizer use or land allocated to improved maize varieties) at a given stimulus level I;

σ = standard error of estimate;

$I \mid \sigma$ = standardized index level;

$F(I \mid \sigma)$ = tobit probability of choosing the event, calculated from the cumulative normal distribution (Z-tables);

$f(I \mid \sigma)$ = normal density function of the index at $Z = (I \mid \sigma)$.

I is the index reflecting the combined effect of X independent variables that prevent or promote adoption. The index level I can be specified as (Shakya 1985):

$$I_i = b_0 + b_1 X_1 + \ldots + b_n X_n + \varepsilon i$$

where:

I_1 = ADIS (amount of land allocated to improved maize varieties in acres);

I_2 = NRATE (rate of nitrogen applied, kg/acre);

b_0 = constant;

X_1 = FARMS (farm size, in acres);

X_2 = EXP (household head's experience of farming, in years);

X_3 = EDUC (education level of household head, in years);

X_4 = LUNIT (livestock units; index where livestock numbers are aggregated using following weighing factors: cow=0.8; goat=0.4; sheep=0.4);

X_5 = IVAR (farmer received information on improved maize varieties; IVAR=1 if farmer received information; 0 otherwise); or FERTR (farmer received information on the use of fertilizer; FERTR=1 if farmer received information; 0 otherwise);

X_6 = LABOR (family labor; index where family members are aggregated using following weighing factors: male and female adults above 16 years=1; children between 12-15 years=0.5);

X_7 = MLP1 (method of land preparation, MLP1=1 if farmers uses hand hoe; 0 otherwise);

X_8 = MLP2 (method of land preparation, MLP2=1 if farmers uses ox-plow; 0 otherwise);

X_9 = AEZ1 (AEZ1=1 if the farmer is in the intermediate zone, 0 otherwise); the highlands zone (AEZ2) was not included in the model to avoid multicollinearity (Griffiths et al. 1993; Green 1993);

X_{10} = HLAB (hired labor: HLAB=1 if farmer used hired labor, 0 otherwise);

X_{11} = CREDIT (farmer used credit; CREDIT=1 if farmer used credit; 0 otherwise); and

ε = error term.

The dependent variable is either the amount of land allocated to maize varieties or the quantity of fertilizer used. The model was estimated using the maximum likelihood method of Shazam Version 7.0.

Formation of the model was influenced by a number of working hypotheses. It is hypothesized that a farmer's decision to adopt or reject new technologies at any time is influenced by the combined effect of a number of factors related to the farmer's objectives and constraints (CIMMYT 1993). Several variables were hypothesized to influence the adoption of improved maize varieties and fertilizer. **Farm size** is an indicator of wealth and perhaps a proxy for social status and influence within a community. It is expected to be positively associated with the decision to adopt improved maize technology. Farm size can also encourage farmers to intensify their production, then larger farm size will be negatively related to adopting improved maize technology. The **experience** of farmers can generate or erode confidence; in other words, with more experience, a farmer can become more or less risk-averse to new technology and thus this variable can have a positive or negative effect on a farmer's decision to adopt improved maize technology. Exposure to **education** will increase a farmer's ability to obtain, process, and use information relevant to the adoption of improved maize technology. Education thus is thought to increase the probability that a farmer will adopt an improved maize technology. **Ownership of livestock** is hypothesized to be positively related to adoption of improved maize technologies. **Agricultural extension services** provided by the MOA are the major source of agricultural information in the study area. It is hypothesized that contact with extension workers will increase farmers' likelihood of adopting improved maize technologies. Large households will be able to provide the labor that might be required by improved maize technologies. Thus, **household size** would be expected to increase the probability of adopting improved maize technologies. The use of the **hand hoe** or **ox-plow** as a method of land preparation can influence adoption either positively or negatively. Farmers in the intermediate zone have less **access to input sources**, which is expected to have a negative impact on adoption. **Hiring labor** is hypothesized to be positively related to the adoption of improved maize technologies. Farmers who have **access to credit** can relax their financial constraints, and in some cases, access to credit is tied to a particular technological package. It is expected that access to credit will increase the probability of adoption.

2.0. Maize Research and Development in Tanzania and the Study Area

2.1. Maize Research in Tanzania

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

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

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

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

To date, several breeding populations have been developed and are being improved through recurrent selection for specific traits. Since 1974, two hybrids and six OPVs have been released. In 1976, Tuxpeño was released for the lowland areas. Hybrids H6302 and H614, suitable for the highlands, were released in 1977 and 1978, respectively. In November 1983, three OPVs were released: Kito, Kilima, and Staha. Staha is characterized by its tolerance to maize streak virus (MSV) disease, whereas Kilima was recommended for the midaltitude zone. Kito is an early maturing variety adapted to both lowland and midaltitude zones. In 1987 two OPVs, TMV1 and TMV2, were released. TMV1 is a white flint, streak resistant variety with intermediate maturity. It is recommended for the lowland and midaltitude zones. TMV2 is also white flint and is recommended for the high-altitude and high-potential maize-producing areas.

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

2.2. Maize Research in the Southern Highlands

Maize research in the Southern Highlands started during the 1970/71 cropping season at MARTI, Uyole under the Tanzania-NORDIC Agricultural Project. Before 1974 research on maize was limited and uncoordinated. Following the initiation of the NMRP in 1974, research at Uyole widened tremendously, especially in village trials, which facilitated the verification of agronomic packages under farmers' conditions while serving as demonstration plots (Lyimo and Temu 1992).

In 1985 maize research at Uyole expanded under the Southern Highlands Maize Improvement Programme (MIP). Essentially the objectives of the MIP were to (Marandu et al. 1989):

- develop varieties suitable for the environment and farming conditions of the Southern Highlands;
- maintain and improve parental lines of all current commercial hybrids used in the country;
- develop agronomic practices suitable for all agroecological zones and farming systems in the Southern Highlands; and
- monitor pest and disease problems affecting maize production and recommend control measures.

2.3. The Maize Seed Industry in Tanzania

The hybrid CG4141 is multiplied and distributed by Cargill Hybrid Seed Ltd., which is based in Arusha. Farmers in the Southern Highlands mainly grow the locally bred hybrids, H614 and H6302. Locally bred cultivars have flint grain, good pounding and storage qualities, and yield as well as CG4141. They are marketed mainly by the Tanzania Seed Company (TANSEED), which has not done well in the newly competitive seed industry. This has contributed to reduced adoption of locally bred hybrids, mainly in the other agroecological zones of Tanzania. Before input markets were liberalized in 1990, locally bred varieties were almost the only improved maize seed planted in Tanzania.

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

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

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

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

3.0. Maize Production Technology Recommendations

3.1. Varieties

The choice of variety is determined by a farmer's objectives, the length of the growing season, elevation, and amount of rainfall. Table 1 shows characteristics of some commercial varieties, some of which were developed through the combined efforts of Uyole and other national and international research institutes and adapted to the Southern Highlands.

3.2. Planting Recommendations

In the Southern Highlands there are two planting seasons. Most maize is planted during the wet season, although farmers in high-altitude areas can plant during the dry season utilizing residual moisture. Information was available for time of planting in the wet season only. For the wet season, maize should be planted immediately after the rains begin, which is normally after 15 November in most parts of the Southern Highlands, and not later than 15 December. However, for the past four years the rainfall pattern has shifted, affecting the time of planting. Rains start during the second half of December, and this is when farmers should start planting. It is estimated that timely planting and weeding can raise yields from 700 kg/ha to 1,200 kg/ha (Lyimo and Temu 1992). Studies in Kenya showed that 70 kg of grain/ha/day were lost when planting was delayed for two days (Cooper and Law 1976). In the Southern Highlands of Tanzania, the grain yield loss from late planting of recommended hybrids was 62 kg/ha for a delay of one day after the first rains (Lyimo and Temu 1992). Row planting is recommended to achieve the recommended plant population, facilitate weeding, and—most important—to achieve optimum yield. In fertile soils, the optimum plant population is about 45,000 plants/ha, whereas in soils with low fertility the population ranges between 22,000 and 33,000 plants/ha. Plant population is also determined by spacing and seeding rate. Table 2 shows the recommended spacing and seed rates.

Table 1. Characteristics of improved varieties for the Southern Highlands

Variety	Year released	Yield potential (t/ha)	Altitude	Maturity time (days)
H614[1]	1977/79	7.0	High	180-200
H6302	1977	8.0	High	180
H632	1965	6.0	Intermediate/high	170-180
UCA	1966	4.5	Intermediate	140
Kilima	1983	4.8	Intermediate	140
Kito[2]	1983	3.5	Low	90-100
TMV1[3]	1987	3.7	Low/intermediate	130
TMV2	1987	7.0	High	170

Source: N. Lyimo, Maize Breeder, MARTI-Uyole (pers. comm.).

1 Released twice (in 1977, using EC 573 C5 as the male parent in the final cross, and in 1979, using EC 573 C5 as the male parent).

2 Recommended for areas of dry-low to intermediate elevation, such as some parts of Ileje District in Mbeya region.

3 Resistant to maize streak virus.

Table 2. Recommended spacing and seeding rates

Spacing (cm)	Seeds/hill	Method suitable for:
75 cm x 30 cm	1-1-1-1	Using a planter
75 cm x 60 cm	2-2-2-2	Using a hand hoe
75 cm x 90 cm	3-3-3-3	Using a hand hoe
90 cm x 25 cm	1-1-1-1	Using a planter
90 cm x 50 cm	2-2-2-2	Using a hand hoe

Source: Temu (1991).

3.3. Fertilizer Type and Time and Method of Application

Nitrogen (N) and phosphorus (P) are the major limiting nutrients for maize production in the Southern Highlands. Studies have shown that improved varieties require substantial quantities of mineral nutrients for their vegetative and grain development. For instance, a crop that produces 5-6 t/ha will have removed 100-150 kg of N and 40-60 kg of $P_2 0_5$/ha from the soil by harvest (Prasad 1978). The use of both inorganic and organic fertilizers can lead to high yield. Research conducted at Uyole showed that 7.1 t/ha were realized using 20 t/ha farm yard manure (FYM) supplemented with 40 kg/ha N and 20 kg/ha P, compared to 4.03 t/ha when the same rates of N and P were applied alone and 5.12 t/ha when FYM was applied alone at 20 t/ha (Lyimo and Temu 1992). Fertilizer recommendations are based on soil type and nutrient deficiency. For basal application, P at a rate of 20-40 kg/ha is recommended. For top dressing, N at a rate of 50-60 kg/ha is recommended.

3.4. Weed Control

Weed control in maize is important to reduce competition for water, soil nutrients, and light. It has a positive effect on yield performance (Table 3). Studies in Ethiopia showed that yield losses caused by weeds ranged between 30% and 88% of potential yield (Sidorov et al. 1985). In Zambia weed trials have shown yield reductions of up to 63% (Nkhoma 1985), while in the Southern Highlands Zone of Tanzania yields were reduced between 50% and 100% of potential yields (Croon et al. 1984; UAC 1992, 1993). Similar trials at Ilonga in the Eastern Zone recorded a yield loss of 25% when the first weeding was delayed until four weeks after planting, while in the Lake Zone, delaying weeding for six weeks resulted in a 65% yield reduction (Matowo et al. 1988). It is recommended to weed at least twice using either hand hoes, cultivators, or herbicides. The first weeding should be done two to three weeks after emergence, and the second should be done when plants are at waist height (90-100 cm). Crop rotation can also control some weeds, especially *Striga* spp. The following herbicides are recommended for pre-emergence application: Gesaprim, Atrazine, Atrazine Metalachlor, Lasso-atrazine, Alachlor, and 2-4D amine.

3.5. Pest and Disease Control

Major insect pests in maize in the Southern Highlands are cut worms and stalk borers. Diseases are head smut, MSV, and blights. Troublesome vermin include birds, rats, and monkeys. Like weeds, insect pests and diseases can cause severe yield losses. In Malawi diseases have been reported to cause up to 10% yield loss (Ngwira 1989); and in Kenya the yield loss can range between 13% and 70% (Ochor et al. 1989). In Zimbabwe, MSV causes serious yield losses of up to 43% (Mguni 1989). In Tanzania, Mduruma et al. (1988) observed that plants

Table 3. Effect of different weeding regimes on maize grain yield

Weeding regime	Yield (t/ha)	Increase over control (%)
No weeding	2.29	100
One weeding at 10 cm stage	4.17	183
One weeding at 30 cm stage	3.88	170
One weeding at 50 cm stage	4.09	179
Two weedings at 10 and 50 cm stages	5.32	233
Two weedings at 30 and 70 cm stages	5.41	237
Three weedings at 10, 50, and 90 cm stages	5.42	238

Source: Lyimo and Temu (1992).

infected with MSV less than a week after germination produced no yield, and when infection occurred at three weeks, only half the potential yield was realized. Infection at eight weeks after germination, however, resulted in little yield reduction. Yield losses thus depended on the age of the plant at infestation. As for pests, especially stalk borers, the damage may be as high as 20% (Lyimo and Temu 1992). The recommended method of control is to apply Thiodan-EC35, Cypermethrin, or Sumicombi against stalk borers and cutworms. A local herb called "Utupa" (*Tephrosia vogelii*) is also recommended. Timely planting and crop rotation can reduce the damage caused by pests and diseases. Scaring and trapping are effective control methods for birds and vermin.

3.6. Suggested Sequence of Maize Production Technology Innovations

Table 4 summarizes various management practices and their respective impacts on yield. If all recommended practices are followed, a maximum yield of 7.2 t/ha can be attained. Table 5 shows the potential yield of high and intermediate altitude maize varieties in the Southern Highlands.

Table 4. Suggested sequence of innovations

Management practice	Characteristic	Estimated yield (kg/ha)
Zero management	Extremely low	300
One timely weeding	2-3 weeks after planting	700
Timely planting	At optimum time (2 weeks after rains)	1,200
Fertility improvement	20 kg/ha P + 40-50 kg N/ha (basal application)	2,100*
Optimum plant population	75 x 60 cm, 2 plants per hill	2,700
Improved seed	Hybrid/composite	3,800
Further fertility improvement	50kg N/ha + second weeding	6,000
Pest control	Control of stalk borers	7,200

Source: Lyimo and Temu (1992).
a Assumes soil fertility is low.

Table 5. Potential yield (t/ha) of high- and midaltitude maize varieties in the Southern Highlands

High altitude (>1,500 masl)			Midaltitude (1,000-1,500 masl)		
Variety	10 year mean	1990/91 season	Variety	5 year mean	1990/91 season
H6302	7.6	8.3	H632	3.9	3.7
H614	7.4	8.5	Kilima	4.6	4.2
TMV2[1]	6.7	9.5	TMV1	4.5	5.4
			UCA	4.2	5.3

Source: Lyimo and Temu (1992).
[1] Mean based on six years' results.

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

4.1. Demographic Characteristics

Table 6 shows the family characteristics of households in the Southern Highlands. The average age of household heads in the intermediate zone was about 44 years, significantly older than farmers in the highland zone (41 years). The farming experience in the intermediate and highland zones was 19.3 and 18 years, respectively. This difference was not statistically significant.

The level of education among the sampled farmers was generally low, but 29 farmers had received 8-13 years of schooling. Farmers went to school for an average of 5.0 years in the intermediate zone and 5.3 year in the highlands.

Mean household size was between eight and nine persons. The numbers of men and of children were significantly higher in the intermediate zone than the highlands. About 75% of the farmers in the highlands and 70% in the intermediate zone used hired labor, mainly for land preparation and weeding (Table 7). About 74% of the male household heads in the highlands hired labor, compared to 83% of their female counterparts. In the intermediate zone, about 71% and 61% of male and female household heads, respectively, hired labor for various farm operations.

Table 6. Demographic characteristics of sample households

	Intermediate zone		Highlands		
Characteristic	Mean	Standard deviation	Mean	Standard deviation	t-value
Age of household head (yr)	43.8	11.8	41.1	10.7	2.1**
Number of male adults	1.9	1.4	1.7	1.0	1.7***
Number of female adults	2.0	1.4	2.0	1.3	0.2 (NS)
Number of children	4.7	2.8	4.0	2.5	2.3**
Education of household head (yr)	5.0	2.6	5.3	2.5	1.2 (NS)

Note: NS = not significant; *** = significant at 10% level; ** = significant at 5% level.

Table 7. Percentage of farmers hiring labor for various farm operations, by zone

	Intermediate zone		Highlands	
Activity	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Hire labor	149	69.6	134	74.9
Prepare land for maize	77	35.8	77	42.8
Plant maize	16	7.4	5	2.8
Weed maize	101	47.0	104	57.8
Harvest maize	40	18.5	3	1.7
Process maize	15	6.9	48	26.7
Other	17	7.9	2	1.1

4.2. Land Resources and Allocation

Land is the most important resource among farm households. Each of the surveyed households owned land, though in differing amounts. Land is usually allotted by the village government or by household heads who redistribute family land to other family members who need it. Land may also be acquired by renting, buying, inheriting, or as a gift. Village governments usually allot land free of charge, whereas land acquired in other ways may be acquired under certain conditions, such as payment in kind. Land sales are uncommon in the Southern Highlands.

Farmers owned about three plots of land covering 10 acres, of which 6.6 acres were cultivated. A total of 2,245 acres were owned by sampled farmers in the intermediate zone, of which 1,588 were cultivated. Farmers owned 1,716 acres in the highlands and cultivated 1,058 acres. A comparison of farm size and maize area between zones showed that farmers in the intermediate zone had larger maize areas than those in the highlands (Figures 3 and 4), although the difference is not significant. Land has become increasingly scarce in the highlands because of population pressure. Farmers were asked about their future plans for their maize area. About 38% of farmers in both zones intended to keep their maize area constant, while about 34% of the farmers in the highlands and 47% in the intermediate zone intended to increase their maize area. Farmers' major reasons for changing maize area were changes in the demand for food or the need to earn more money.

4.3. Livestock Ownership

Different types of livestock are kept in all regions of the study area (Table 8). Farmers keep goats (44.2%), sheep (11%), and cattle (46.7 %), along with lesser numbers of poultry, swine, donkeys, and petty animals. Donkeys are largely kept in Rukwa region, where they are used for transportation. The average number of cattle was 8.4 in the intermediate zone and 4.3 in the highlands (significant at P = 0.01). Low numbers of cattle at higher elevations might be the result of land pressure.

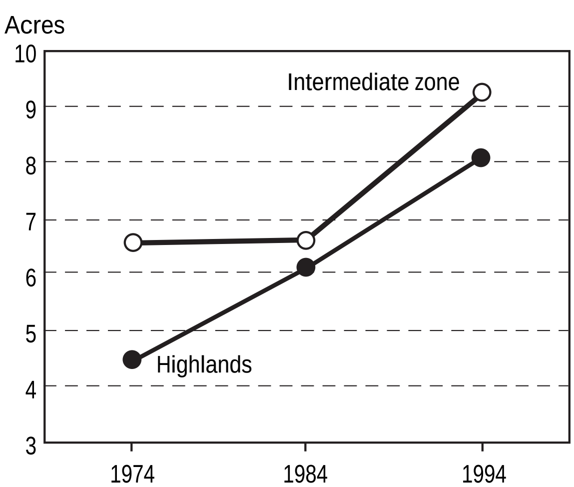

Figure 3. Trends in farm size, intermediate zone and highlands, Southern Highlands, Tanzania.

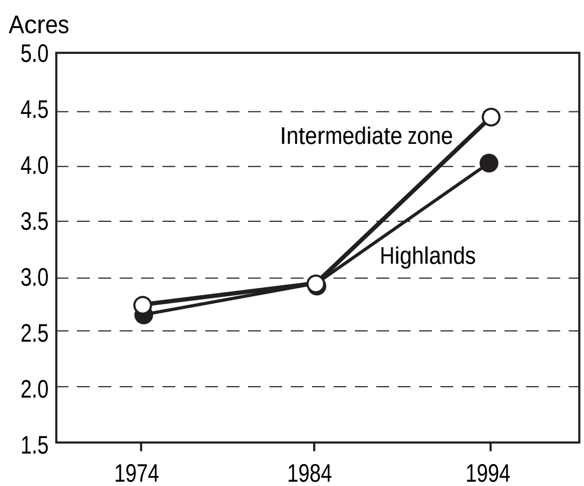

Figure 4. Trends in maize area, intermediate zone and highlands, Southern Highlands, Tanzania.

Farmers could be compelled to keep fewer animals, which are either tethered or zero grazed. Farmers in Mbeya region had the smallest mean number of cattle (3.8), while Iringa farmers had the highest (8.9).

4.4. Farm Mechanization

Table 9 shows the number of farm implements owned by sample farmers. All sampled farmers used hand hoes to perform one or more farm operations. The average number of hand hoes owned by households was about five, which was an average of 2.5 hand hoes for each full-time farm worker for both zones. The second most important farm implement was an ox-plow. Most farmers who owned plows (71.2%) were in the intermediate zone, while only 34 (18.9%) farmers in the highlands owned ox-plows. The low number of ox-plows in the highland zone might be related to the hilly terrain. About 32% of farmers in the intermediate zone and 26% in the highlands hired implements.

The average rate of hiring ox-plows was about Tsh 5,587 and Tsh 4,628 per acre in the intermediate and highland zones, respectively. This difference was significant at P = 0.01. In Rukwa region, farmers hired ox-plows and paid in kind, and for a long time oxen have been used for various farm operations. The average number of plows owned per household in Rukwa region was two, while in all other regions it was one. Other implements owned included cutting tools such as machetes, sickles, and axes. The mean number of these tools was two in Rukwa and Mbeya regions and three in Iringa and Ruvuma regions. Only 19 farmers in the highlands hired tractors, at a rate of about Tsh 6,158/acre.

Table 8. Livestock ownership by zone, Southern Highlands, Tanzania

	Intermediate zone		Highlands		
Type of livestock	Mean	Standard deviation	Mean	Standard deviation	t-value
Goats	4.2	2.8	4.5	3.1	0.66 (NS)
Cattle	8.5	12.3	4.3	5.5	3.1*
Sheep	3.3	3.4	4.9	5.2	1.19 (NS)
Other	10.2	11.0	7.6	6.4	2.0**

Note: NS = not significant; ** = significant at 5% level;
* =significant at 1% level.

Table 9. Number of farm implements owned, Southern Highlands, Tanzania

	Intermediate zone		Highlands		
Type of implement	Mean	Standard deviation	Mean	Standard deviation	t-value
Hand hoe	4.7	2.3	4.6	2.6	0.41 (NS)
Cutting tools	2.8	1.8	3.1	2.7	0.62 (NS)
Ox-plow	1.6	1.0	1.3	0.6	1.35 (NS)
Tractor[a]	—	—	1.0	—	—
Carts[a]	1.0	—	1.0	—	—

Note: NS = not significant.
[a] = only a few farmers.

5.0. Maize Production, Crop Practices, and Marketing in the Southern Highlands

5.1. Crops and Cropping Systems

Nearly all crops produced in other parts of Tanzania are found in the Southern Highlands. Maize is the most important food crop and is produced in all regions and districts of the zone. All sampled farmers were full-time maize producers, and for most people maize served as both a food and cash crop. Other crops produced in the zone include beans, coffee, bananas, tea, peas, finger millet, sorghum, groundnuts, and sunflower, as well as cocoa, tobacco, cassava, rounds and sweet potatoes, wheat, paddy, pyrethrum, and a wide variety of horticultural crops. Crop allocation on different plots is determined by the relative importance of the crop in each farming system. Table 10 shows which crops are allocated to the first four plots cropped by farmers in the zone.

Both monocropping and intercropping are practiced. About 83% of the sampled farmers in the intermediate zone and 58% in the highlands grew maize in pure stand, while about 17% in the intermediate zone and 40% in the highlands intercropped maize, mainly with beans and sunflower. The major reason for intercropping in the highlands was land scarcity (42%), while the major reason in the intermediate zone was that it was the traditional way of cropping (38%). Other reasons included soil fertility management, food security, and risk avoidance.

5.2. Maize Crop Management Practices

5.2.1. Land preparation

In the Southern Highlands there are two planting seasons and consequently two land preparation seasons. In higher areas such as Rungwe and Mbeya Districts, maize is planted during the dry season (i.e., from June) on residual moisture. One of the survey sites was purposively chosen in Rungwe District so as to capture data on dry-season maize. In all other districts surveyed, maize was planted during the wet season (i.e., in November-December), depending on the onset of the rains. Table 11 shows the time and methods of land preparation.

About 56% and 45% of the farmers in the intermediate and highland zones, respectively, prepared land between August and October, whereas about 43% of the farmers in both zones prepared land between November to December. Most farmers prepared land at the recommended time. Farmers

Table 10. Farmers' crop allocation by plot, Southern Highlands, Tanzania

	Plot 1		Plot 2		Plot 3		Plot 4	
Crop	No. farmers	% farmers	No. farmers	% farmers	No. farmers	% farmers	No. farmers	% farmers
Bean-maize intercrop	103	26.0	54	13.6	27	6.9	9	2.3
Maize monocrop	260	65.7	118	29.8	63	15.9	22	5.5
Bean monocrop	5	1.3	69	24.2	51	12.9	30	7.6
Coffee/banana intercrop	10	2.6	24	6.1	24	6.1	25	6.3
Tubers	—	—	18	4.5	13	3.3	7	1.8

who did not follow the recommendation mentioned labor constraints and late rains as their reasons for preparing land at a different time.

All farmers who planted maize during the dry season performed land preparation between July and August; only two farmers prepared their land in June. Again this is an appropriate time for these areas. The reasons for preparing land during this season were that if maize is planted during the wet season it will mature when there are heavy rains and the whole crop will suffer from cob rot. Also, dry season planting is a mechanism to avoid labor competition with other farm activities.

Land was mainly prepared using hand hoes in the intermediate zone (48.1%) and the highland zone (63.1%); fewer farmers used ox plows (38.8% in the intermediate zone and 24.4% in the highlands). None of the sampled farmers in the mountainous coffee/banana-based farming systems used oxen or tractors. In the less mountainous areas of Rukwa region, nearly all sampled households used oxen to prepare land.

5.2.2. Seedbed type, planting pattern, and weeding

Table 12 shows farmers' major agronomic practices. About 73% of the farmers in the intermediate zone and 76% in the highlands used a flat seedbed. Other types of seedbeds included ridges (24% of farmers in the intermediate zone, 18% in the highlands). One farmer in Rukwa region used mounds. Eighteen farmers in Mbinga district planted maize in Matengo pits (*ngoro*). Mounds and Matengo pits are indigenous seedbed types used by the Wafipa and Wamatengo groups in Sumbawanga and Mbinga Districts, respectively. Pits and mounds are said to be effective for maintaining soil fertility and controlling soil erosion. Eleven of the 18 farmers who planted maize in pits were from Miyau Village, while seven were from Mbangalla Village in Mbinga District. A study by Temu and Bisanda (1996) showed that Matengo pits are dug by nearly 90% of the farmers in central parts of Mbinga where Miyau Village is located. Farmers in the eastern part of the district where Mbangalla Village is located are slowly abandoning the pits in favor of ridges, because the area is less steep. Matengo pits are dug along the steep slopes of mountains to control soil erosion and water run-off while maintaining soil fertility. Ridges, on the other hand, are a traditional practice in Ruvuma region, and

Table 11. Time and methods of land preparation, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Time of land preparation				
August–October	120	56.1	81	45.0
November–December	92	42.8	77	42.9
January–March	2	1.1	22	12.1
Method of land preparation				
Hand hoe	103	48.1	111	63.1
Ox-plow	83	38.8	43	24.4
Tractor	2	0.9	5	2.8
Hand hoe + oxen	23	10.7	13	7.4
Zero tillage	1	0.5	1	0.6
Other	2	0.9	3	1.7

most farmers who planted maize on ridges were from Songea and Mbinga Districts, all of which are in Ruvuma region.

Farmers in the Tukuyu highlands generally plant dry-season maize, sowing the crop between June and August. About 95% of the farmers in the intermediate zone and 89% in the highlands planted maize between November and December at the recommended time. Most farmers planted at that time because it was during the onset of rains or the recommended time of planting in their areas. As noted earlier, the rains have started later than usual during the last three or four years, and some farmers who planted during the first and second weeks of November were compelled to replant their maize to cope with the effects of late rains. Maize was planted in rows by all farmers in both zones, because it eased management of the field. Row planting in the Southern Highlands has a long history; the first farmers adopted row planting in 1960.

About 44% of the farmers in the intermediate zone and 45% in the highlands used a spacing of 90 cm between rows; a 30 cm spacing between hills was favored by about 82% and 90% of the farmers in the intermediate and highland zones, respectively. The average number of seeds per hill was 1.7 in the intermediate zone and 1.4 in the highlands. This difference was significant at $p = 0.01$.

Table 12. Farmers' major agronomic practices, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	**Percentage of farmers**	**Number of farmers**	**Percentage of farmers**
Agronomic practice				
June–October	5	2.4	19	10.6
November–December	205	94.9	160	88.8
January	6	2.8	1	0.6
Planting method				
Row	197	100.0	156	100.0
Spacing between row				
60 cm	33	17.4	32	21.2
75 cm	40	21.1	38	25.2
90 cm	84	44.2	68	45.0
Other	33	17.3	13	8.6
Spacing between hills				
30 cm	160	81.6	140	89.7
60 cm	20	10.2	8	5.1
Other	16	8.2	8	5.2
Time of weeding				
First weeding				
August–November	4	1.9	19	10.2
December–January	151	82.3	134	74.9
February–March	34	15.8	26	14.9
Second weeding				
October–November	—	—	17	11.4
December–January	38	22.8	12	8.1
February–March	128	77.1	119	80.5
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
Number of seeds per hill	1.7	0.6	1.4	0.5
Number of weedings	2.0	0.6	2.1	0.7

Most of the farmers in both zones weeded at least twice. The first weeding was done in December and January by about 82% of farmers in the intermediate zone and 75% in the highlands. The second weeding was mainly done between February and March. Hand hoes were the most important weeding implements in both the intermediate zone (97.7%) and highlands (100%). About 3% of the farmers in the intermediate zone used either ox-drawn weeders or ox-drawn weeders together with hand hoes. None of the sampled farmers used herbicides during the first weeding.

Besides hand hoes, 37 farmers in the intermediate zone (17%) and 2 in the highlands (1.1%) used herbicides for the second weeding. Six farmers in the two zones used hand weeding while six farmers from intermediate altitudes used ox-drawn weeders. Very few farmers carried out three weedings.

5.2.3. Type of fertilizer, method of application, and quantity

Soil nutrient depletion in the Southern Highlands is high because of high rainfall, leaching, and continuous maize cultivation. About 100-150 kg/ha N and 40-60 kg/ha P_2O_5 is lost at a yield level of 5-6 t/ha (Prasad 1978). Nutrient supplementation is needed to maintain maize production. Farmers apply organic and inorganic fertilizers, rotate crops, fallow, and intercrop to restore declining fertility. Farmers in both the intermediate zone (65%) and highlands (79%) used inorganic fertilizer (Table 13) (in order of importance: urea, sulfate of ammonium, and calcium ammonium nitrate). The major reason that farmers did not use fertilizer was the lack of cash to purchase it. Nearly all farmers (about 97% in the intermediate zone and 95% in the highlands) used organic fertilizer, however; farmers who did not use organic fertilizer generally had no livestock.

Most farmers received information about organic fertilizer from neighboring farmers (reported by 62% of the farmers in the intermediate zone and 89% in the highlands). Most farmers used FYM. A few farmers in the intermediate zone used a green manure crop, such as a legume. About 49% of the farmers in the intermediate zone and 86% in the highlands obtained FYM from other farmers.

Table 13. Fertilizer use by sample households, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Use inorganic fertilizer (IF)	141	65.3	143	79.4
Use organic fertilizer (OF)	37	97.4	37	94.9
Reason for not using IF				
No money	84	94.4	37	90.2
Not available	1	1.1	4	9.8
Other	4	4.5	—	—
Reason for not using OF				
No livestock	65	56.5	106	85.5
Never received message	19	16.5	7	5.6
Bulky	9	7.8	7	5.6
Other	22	19.2	4	3.7

Almost all farmers in the sample applied basal fertilizer (average 55 kg/ha) from November to January. The average price of basal fertilizer during the 1993/94 cropping season was about Tsh 8,700/50 kg in the intermediate zone and Tsh 7,700/50 kg in the highlands. This difference was not significant at p = 0.1. Most farmers used triple super phosphate (TSP) or di-ammonium phosphate (DAP) as basal fertilizers and almost all farmers made holes in the soil to apply basal fertilizer. Just over half of the farmers in the intermediate zone (around 52%) and nearly one-third of the farmers in the highlands (30%) bought fertilizer at the stockist, while 40% and 61% in the intermediate zone and highlands, respectively, bought it from the cooperative society.

About 14% percent of highland farmers applied the first top-dressing between October and December. The remaining 86% applied the first top-dressing between January and March, which is when all of the farmers in the intermediate zone applied it. About 29% of the farmers in the intermediate zone and 51% in the highlands used urea, whereas calcium ammonium nitrate (CAN) was used by 25% and 18%, respectively. The first top-dressing averaged about 60 kg/ha for both zones. The second top-dressing was mainly applied between February and March by about 90% of the farmers in both zones. Forty-one percent of intermediate zone farmers and 65% of highland farmers used urea, whereas 35% and 30%, respectively, used CAN. The second top-dressing averaged 58 kg/ha in the intermediate zone and 60 kg/ha in the highlands. The major reason that some farmers did not apply a second top-dressing was lack of cash.

Eighty-five percent of intermediate zone farmers and 95% of highland farmers said that fertilizers were available on time. The only constraint was their high price, which is the result of the gradual removal of subsidies on agricultural inputs. Fertilizers are usually sold by private stockists, the Tanzania Farmer's Association (TFA), and primary cooperative societies that have taken up the role of stockists. Farmers did not travel long distances to purchase fertilizers sold by cooperative societies, in contrast to fertilizers sold by private traders and the TFA; most TFA shops and private traders are stationed in urban centers. A study by Bisanda and Mwangi (1996) in Mbeya region revealed that 39% of the sampled farmers traveled over 4 km to purchase fertilizers in urban centers, while only 12% traveled less than 1 km to where cooperative societies have taken up the role of stockists (that is, within the village).

Table 14. Fallowing and crop rotation practices of sampled farmers, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Fallow maize	90	41.9	90	50.0
Reason for fallowing				
Replenishes soil fertility	88	96.7	88	98.9
Other	3	3.3	1	1.1
Crop rotation	145	67.8	95	52.8
Reason for crop rotation				
Replenishes soil fertility	136	99.3	89	97.8
Other	1	0.7	2	2.2

5.2.4. Fallowing and crop rotation

Land was fallowed by about 42% of intermediate zone farmers (4 years) and 50% of highland farmers (3 years) (Table 14). The difference in the time of the fallow in each zone was significant at P = 0.05. Almost all farmers fallowed their land to replenish soil fertility. After fallow, about 66% of intermediate zone farmers and 49% of highland farmers grew legumes, reportedly because the legumes need less fertilizer after fallow. Land scarcity was farmers' main reason for not fallowing. About 68% of intermediate zone farmers and 53% of highland farmers rotated their crops, largely to replenish soil fertility. Maize was rotated with legumes by about 87% of intermediate zone farmers and 57% of highland farmers. In the intermediate zone, 32.8% of the farmers did not practice crop rotations because they were not aware of the benefits, while about 19% reported that they intercropped or had fertile soils. In the highlands, about 37% reporting intercropping, although 35% said they did not have enough land to do so.

5.2.5. Crop residue management

The recommended management practice for crop residues is to plow them under to avoid soil mining. Table 15 shows that more than half of the farmers in both zones burn their crop residues, however, while 41% of intermediate zone farmers and 26% of highland farmers feed the residues to cattle. Only 5% and 18% of the farmers in the intermediate zone and highlands, respectively, followed the recommendation.

5.2.6. Pest and disease control

Pests and diseases (listed in Table 16) are serious production constraints. Nearly all farmers in the sample rated stalk borers as the most serious field pest. The second most important field pest was cutworms. Farmers mainly used chemical means to control these pests. Intermediate zone farmers used Thiodan (12.4%) and DDT (37.3%); highland farmers used Thiodan (32.6%), Sumithion (18.5%), DDT (16.3%), and Novathion (8.9 %). On average, farmers in the intermediate zone applied 1.3 L/acre of chemicals; their counterparts in the highlands applied 1.5 L/acre. DDT is prohibited in Tanzania and it was not established whether what farmers called "DDT" was truly DDT or some other chemical. Farmers paid Tsh 1,790 per unit of chemical in the highlands and Tsh 2,390 in the highlands (this difference was significant at p = 0.05). Ash or local control methods were favored by about 30% of intermediate zone farmers and 10% of highland farmers. Chemicals were usually readily available and the extension services in the MOA were farmers' main source of information about them.

Table 15. Management of crop residues by sampled farmers, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Plow under	11	5.1	32	17.8
Burn	110	50.9	101	56.2
Feed cattle	88	40.7	46	25.6
Other	7	3.2	1	0.6

Maize streak virus was the most important disease for about 94% of farmers in the intermediate zone and 78% in the highlands. Cob rot was a problem for 20% of the farmers in the highlands.

Vermin were controlled by scaring or trapping.

In a study conducted in one of the high-altitude areas of Mbeya region, Nalitolela (1990) reported cob rot as a major problem, especially among hybrid maize varieties. In the intermediate zone, about 28% of the farmers did not use any form of disease control. Chemicals were used by only 3% of intermediate zone farmers and 6% of highland farmers, whereas 69% and 94% of the farmers, respectively, simply uprooted the infected plants, especially for MSV and head smut.

5.3. Maize Harvesting, Transportation, and Storage

Because there are two planting seasons in the survey area, there are two different harvesting seasons. Maize planted in the dry season was harvested between February and April (Table 17). Farmers in the highlands harvested their maize later compared to farmers in the intermediate zone, perhaps because differences in rainfall and temperature regimes delay physiological maturity of highland maize.

The most common method of harvesting maize was to remove the ears and carry them home for processing. Most farmers in the intermediate zone transported maize to the homestead using an ox-cart (62.5%), while about 63% percent of highland farmers used head loads. The most common storage method for maize was to shell it and store it in a *kihenge*. About 89% of the farmers in both

Table 16. Major pests and diseases and their control, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Field pests				
None	2	1.0	1	0.6
Stalk borers	189	93.1	168	98.8
Cutworms and termites	9	4.4	—	—
Vermin	3	1.5	1	0.6
Method of control				
Thiodan	19	12.4	44	32.6
DDT	57	37.3	22	16.3
Ash/local method	46	30.1	14	10.4
Sumithion	6	3.9	25	18.5
Novathion	16	10.5	12	8.9
Other	9	5.8	18	13.3
Field diseases				
Maize streak virus	74	93.7	47	78.3
Cob rot	4	5.1	12	20.0
Other	1	1.3	1	1.7
Method of control				
None	8	27.6	—	—
Rogue	20	69.0	31	93.9
Other	1	3.4	2	6.1

zones used a chemical treatment on their stored maize; if they did not do so, it was because they lacked cash or thought seed treatment was not needed.

5.4. Maize Seed Availability, Selection, and Recycling

When farmers selected seed for the next cycle, they mostly selected it at the homestead (69% of intermediate zone farmers and 75% of highland farmers), although some (30.8% and 25.2%, respectively) selected seed in the field. Seed was usually selected right after the harvest, and a big cob was the most important seed selection criterion (mentioned by 96% of farmers) (Table 18). When farmers purchased seed for the next cycle, they mainly acquired it from stockists (76.4% of intermediate zone farmers and 97.2% of highland farmers). The great majority of farmers purchased seed every year (97% in the intermediate zones, 90% in the highlands), and all reported that seed

Table 17. Maize harvesting, transportation, and storage

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Months of harvest				
June-July	183	84.7	44	24.4
August-October	32	15.3	119	66.2
February-April	—	—	17	9.5
Method of transportation				
Head load	72	33.3	113	62.8
Bicycle	6	2.8	1	0.6
Ox-cart	135	62.5	66	36.7
Pick-up	3	1.4	—	—
Maize storage				
Shell and store in *kihenge*	191	89.7	129	72.1
On cribs	6	2.8	14	7.8
Gunny bags	5	2.3	15	8.4
Other	11	5.2	21	11.7

Table 18. Seed selection criteria, seed storage methods, and seed sources of sampled farmers, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Selection criterion				
Big cob	126	96.2	102	96.2
Mature grain	5	3.8	4	3.8
Method of seed storage				
Shelled with chemical in bags	73	56.2	68	63.0
Kihenge	35	26.9	30	27.8
Other	6	16.9	8	9.2
Source of seed				
Cooperative union	10	11.2	2	2.8
Stockist	68	76.4	70	97.2
Other	11	12.3	—	—

was readily available. Farmers in the Southern Highlands are the largest consumers of commercial maize seed in Tanzania. In 1981/82, the zone accounted for 41% of all seed distributed through formal systems, while in 1989/90 it consumed 44% of total maize seed distributed in Tanzania (URT 1992). The average price of seed during the survey season was about Tsh 580/kg in the intermediate zone and Tsh 553/kg in the highlands.

5.5. Maize Marketing

Most smallholders grow maize for food and cash. Each year, farmers set aside a certain amount of the maize harvest for household food security and sell the remainder. In places where there are no other cash crops, such as Sumbawanga, Nkansi, Iringa, Songea, Mufindi, and Njombe Districts, maize is the most dependable source of cash.

Farmers were asked to provide information regarding the amount of local and improved maize that was sold and/or retained for home consumption. However, many farmers did not keep such records, and it was difficult for some farmers to recall these details of their harvests. In some places farmers did not provide this information at all, whereas in other places, where maize is stored without shelling, it was difficult to estimate actual yields. Another factor was that some farmers sold or consumed small quantities of maize whenever they needed cash or food. Under such circumstances, it was difficult to estimate total maize sold or consumed. Consumption patterns of sampled farmers are shown Table 19.

Table 19 shows that farmers sold more maize than they retained for household food security and kept more improved varieties than local varieties for home consumption. Also, farmers tend to sell more improved varieties than local ones to obtain household income. Given the mean household size of eight persons, households retained 175 kg of maize per person per year, which is relatively sufficient to sustain each individual through the year. In 1994, the total production of improved maize varieties was about 35 bags/ha for the intermediate zone and 26 bags/ha for the highlands. This difference was significant at P = 0.05. Total production of local varieties was about 24 bags/ha in the intermediate zone and 18 bags/ha in the highlands, a difference that was also significant at P = 0.05.

Table 19. Average amount of maize (in 100 kg bags) sold or consumed, 1974-94, Southern Highlands, Tanzania

	1974	1980	1985	1990	1991	1992	1993	1994
Local maize sold								
Intermediate zone	13.0	13.5	15.9	17.8	16.7	16.0	15.7	15.4
Highlands	15.2	17.7	17.2	15.5	16.9	14.6	16.3	20.2
Local maize retained for food								
Intermediate zone	10.2	11.7	9.8	12.8	13.0	12.8	12.3	13.0
Highlands	10.6	13.4	10.9	12.2	13.0	12.3	12.2	12.7
Improved maize sold								
Intermediate zone	18.6	20.0	14.7	22.0	18.8	19.2	19.4	24.8
Highlands	—	—	23.8	27.2	19.5	23.0	18.8	20.3
Improved maize retained for food								
Intermediate zone	14.2	15.9	12.8	14.4	15.0	15.4	14.6	15.2
Highlands	—	13.7	13.9	12.7	11.6	13.3	13.5	12.9

6.0. Farmers' Adoption/Disadoption of Improved Maize

6.1. Varieties Currently Grown

Both local and improved maize was grown in the zone. Local varieties were known only as local or traditional varieties, but improved varieties were identified by their actual names or origins. For instance, some hybrids (probably H614 or H6302) were known as "Njombe" or "Kenya," referring to their supposed place of origin. Similarly, another improved variety (probably SR52) was called "Malawi" or "Zimbabwe." Other improved varieties known in the zone included H632, UCA, Katumani, CG4141, CG4142, TMV2, and TMV1. The CG materials are multiplied and distributed by Cargill, while all other materials were developed either nationally, locally, and/or through collaboration with international research institutes, and multiplied and distributed by seed farms and seed companies or their agents. In the 1994/95 cropping season, about 64% of farmers in the intermediate zone and 49% in the highlands grew local varieties (Table 20). However, recent studies in the zone indicated that it was very difficult to find pure local varieties in the field (Nalitolela 1990; Bisanda and Mwangi 1996). The maize varieties that farmers regard as local varieties are improved varieties that have deteriorated after several years of seed recycling. Recycled hybrid maize seed loses its purity and ceases to preserve some of its original traits, most notably its yielding ability.

About 36% of intermediate zone farmers and 51% of highland farmers grew improved varieties. In both zones H614 was the most popular improved maize variety. As mentioned earlier, farmers obtained improved seed from stockists such as TFA, traders, TANSEED, or cooperative societies. About 41% of the sampled farmers said that following market liberalization seed was readily available, though prices were high.

6.2. Preferred Improved Maize Materials and Reasons for Farmers' Preferences

The preferred improved maize materials are shown in Table 21. H614 tops the list, which confirms earlier reports (Bisanda and Mwangi 1996) of a high preference of H614 in Mbeya region. Farmers in both zones valued H614 and H6302 for their high yield, while UCA was preferred for its drought resistance (Table 22).

Table 20. Maize varieties planted in the 1994/95 season, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
Variety	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Local variety	138	63.9	88	48.9
H6302	6	2.8	23	12.8
H614	54	25.0	46	26.2
UCA	7	3.2	17	9.4
TMV2	—	—	1	0.6
CG4141/4142	5	2.3	2	1.1
H632	6	2.8	2	1.1

Table 21. Preferred improved maize materials, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
Variety	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
H6302	14	9.7	38	29.9
H614	108	75.0	63	49.6
UCA	8	5.6	20	15.7
TMV	—	—	1	0.8
CG4141	4	2.8	2	1.6
SR52	1	0.7	1	0.8
H632	9	6.3	2	1.6

6.3. Farmers' Disadoption of Improved Maize

More than half of the farmers in each zone reported disadopting improved maize (about 59% of intermediate zone farmers and 57% of highland farmers. In the intermediate zone, 65.3% of farmers had disadopted H614 and 19.4% had disadopted H6302. In the highlands, 50.7% of the farmers no longer grew H614, 30.4% no longer grew H6302, and 11.6% no longer grew UCA. The main reason for disadopting H614 was its high price (Table 23). H6302 was disadopted in the intermediate zone because of its unavailability, while its susceptibility to pests and diseases was the main reason that farmers in the highlands no longer grew it. High seed costs and unavailability of seed were also the primary reasons for disadoption reported by Bisanda and Mwangi (1996). Most farmers disadopted improved maize between 1988 and 1994. This period coincides with the gradual removal of subsidies on agricultural inputs, which may have contributed to the high disadoption rates during this period.

Table 22. Farmers' reasons for preferring different maize materials, Southern Highlands, Tanzania

		Reason for preference (% farmers)		
Altitude	**Variety**	**High yield**	**Drought resistance**	**Good standability**
Intermediate zone	H6302	100.0	—	—
	H614	99.1	—	0.9
	UCA	37.5	62.5	—
Highlands	H6302	100.0	—	—
	H614	98.4	1.6	—
	UCA	25.0	75.0	—

Table 23. Varieties no longer grown by farmers, and reasons for disadoption, Southern Highlands, Tanzania

		Reason for disadoption (% farmers)				
Altitude	**Variety**	**Low yield**	**Susceptible to pests**	**Not available**	**High cost**	**Other**
Intermediate zone	H6302	22.2	22.2	44.4	—	10.0
	H614	13.6	6.8	8.5	62.7	8.4
		Reason for disadoption (% farmers)				
Altitude	**Variety**	**Low yield**	**Attacked by storage pests**	**Late maturity**	**High cost**	**Other**
Highlands	H6302	5.3	36.8	15.8	26.3	15.8
	H614	23.3	16.7	3.3	36.7	20.0

7.0. Credit and Extension Services for Farmers in the Southern Highlands

7.1. Credit Availability

Agricultural credit is extremely important in stimulating increased agricultural productivity, especially where farmers lack capital to purchase inputs. The provision of appropriate credit for seed and fertilizer to smallholders tremendously increased maize production in the Sasakawa-Global 2000 project area of Tanzania (Quiñones et al. 1992). Some few years ago, cooperative societies used to be the most dependable source of credit, but because of poor management these arrangements are no longer available. Most cooperative unions faced serious liquidity problems, some of which were administrative and some of which arose from farmers' failure to repay loans. As a result, farmers no longer have any reliable source of credit.

Only 22% of farmers in the intermediate zone and 20% in the highlands reported having received credit (Table 24). Almost all farmers reported that credit was not readily available. The main source of credit was non-governmental organizations (NGOs). About 60% of the farmers in both zones used NGOs as a credit source, mainly Sasakawa-Global 2000. The major drawbacks of credit provided by Sasakawa-Global 2000 were 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). In the intermediate zone, about 36% of farmers reported lack of collateral as the main impediment to receiving credit, and 35% reported lack of knowledge as the main difficulty. In the highlands, these reasons were cited by 52.8% and 18.3% of farmers, respectively.

Credit was used only to purchase seed and fertilizers. About 21% of intermediate zone farmers and 17% of highland farmers used credit to buy fertilizer, and only 7% of intermediate zone farmers and 4% of highland farmers used credit to purchase seed.

Table 24. Farmers' sources and use of credit, Southern Highlands, Tanzania

	Intermediate zone		Highlands	
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers
Access to credit	47	22.2	36	20.0
Source of credit				
NGO	28	60.9	20	58.8
Bank	1	2.2	3	8.8
Cooperative Union	17	37.0	11	32.4
Availability of credit				
Difficult	209	98.1	179	99.4
Not difficult	4	1.9	1	0.6
Constraint				
No collateral	76	35.8	95	52.8
Lack of knowledge	74	34.9	33	18.3
Bureaucracy	24	11.3	42	23.3
Other	38	18.0	10	5.5

7.2. Extension Services

A study in Mbeya region revealed that unreliable sources of information may be a constraint to the use of new technologies (Bisanda and Mwangi 1996). Experience with Sasakawa-Global 2000 showed that with close extension interaction, farmers could increase their crop yields tremendously (Quiñones et al. 1992).

In this study, 83% of farmers in the intermediate zone and 86% in the highlands said they had received information on improved maize technologies. Most farmers in both zones had received information on improved maize varieties, planting methods, fertilizer use, weed management, pest management, and post-harvest maize storage (Table 25).

Information about the use of herbicides, ox-drawn implements, and disease control methods was not widespread among the samples farmers. In addition, for these three technologies the farmers in the intermediate zone had received significantly more information than farmers in the highlands. Only in the case of storage practices had farmers in the highlands received significantly more information than the other farmers. The main source of information for all practices in both zones was the MOA extension service. Farmer-to-farmer interaction was also important for farmers to exchange not only ideas but also technologies. Usually this happened when a technology was good and farmers deemed it acceptable. This source of information became efficient where extension services were weak and inefficient.

Table 25 also shows that most farmers received information about the improved maize varieties, planting methods, fertilizer, weed management, pest management, and storage practices. Farmers in the intermediate zone were significantly higher adopters of improved maize, planting methods, and fertilizer than farmers in the highlands. The adoption of herbicides, ox-drawn implements, and disease control measures was lower among farmers in both zones. Farmers in the intermediate zone were significantly better adopters of herbicides and ox-drawn implements than farmers in the highlands.

Table 25. Farmers' sources and adoption of maize production information technology, Southern Highlands, Tanzania

	Intermediate zone		Highlands		
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers	χ^2
Improved maize					
Received information	174	97.8	147	95.5	1.4 (NS)
Adopted improved variety	112	63.6	67	43.5	13.4*
Source of information					
Extension	130	74.3	120	82.8	..[a]
NGOs	10	5.7	1	0.7	..[a]
Other farmers	9	5.1	9	6.2	..[a]
Other	26	14.9	14	10.3	..[a]
Planting method					
Received information	179	86.9	161	89.4	0.6 (NS)
Adopted planting method	170	97.1	142	92.2	4.1**
Source of information					
Extension	141	81.5	112	77.8	..[a]
NGOs	4	2.3	1	0.7	..[a]
Other farmers	9	5.2	18	12.5	..[a]
Other	19	11.0	13	9.0	..[a]

Cont'd...

Table 25. Cont'd.

	Intermediate zone		Highlands		
	Number of farmers	Percentage of farmers	Number of farmers	Percentage of farmers	χ^2
Fertilizer					
Received information	191	96.0	173	96.1	0.0 (NS)
Adopted fertilizer	128	76.6	132	85.7	4.3**
Source of information					
Extension	125	76.6	125	83.3	..[a]
NGOs	6	3.7	1	0.7	..[a]
Other farmers	11	6.8	8	5.3	..[a]
Other	19	11.9	16	10.7	..[a]
Weed management					
Received information	150	93.8	131	85.6	5.6**
Adopted weed management	148	92.5	133	91.2	0.2 (NS)
Source of information					
Extension	105	71.9	76	61.3	..[a]
NGOs	5	3.4	1	0.8	..[a]
Other farmers	17	11.6	24	19.4	..[a]
Other	19	13.1	23	18.5	..[a]
Herbicide					
Received information	62	41.6	16	10.5	37.9*
Adopted herbicide	33	23.4	5	3.4	25.1*
Source of information					
Extension	52	70.3	15	78.9	..[a]
NGOs	1	1.4	—	—	..[a]
Other farmers	7	9.5	—	—	..[a]
Other	14	18.8	4	21.1	..[a]
Ox-drawn tools					
Received information	108	67.1	42	27.6	48.8*
Adopted tools	83	53.2	29	19.6	36.9*
Source of information					
Extension	50	48.1	18	54.5	..[a]
NGOs	6	5.8	—	—	..[a]
Other farmers	37	33.7	7	21.2	..[a]
Other	13	13.4	8	24.3	..[a]
Pest management					
Received information	147	84.5	128	83.7	0.04 (NS)
Adopted pest management	134	80.7	117	77.0	0.7 (NS)
Source of information					
Extension	102	73.9	96	82.1	..[a]
NGOs	4	2.9	1	0.9	..[a]
Other farmers	19	13.8	18	15.4	..[a]
Other	13	9.4	2	1.6	..[a]
Disease control measures					
Received information	47	33.3	37	24.7	2.7***
Adopted measures	36	27.7	37	25.2	0.2 (NS)
Source of information					
Extension	42	84.0	34	91.9	..[a]
NGOs	—	—	—	—	..[a]
Other farmers	6	12.0	3	8.1	..[a]
Other	2	4.0	—	—	..[a]
Storage practices					
Received information	158	93.5	150	97.4	2.8***
Adopted practices	150	89.8	132	86.3	0.9 (NS)
Source of information					
Extension	97	69.3	101	76.5	..[a]
NGOs	7	5.0	—	—	..[a]
Other farmers	23	16.4	14	10.6	..[a]
Other	13	9.3	17	12.9	..[a]

Note: NS = not significant; *** = significant at 10% level; ** = significant at 5% level; * = significant at 1% level.
a χ^2 not calculated.

8.0. Factors Affecting Adoption of Agricultural Technologies in the Study Area

8.1. Definitions

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

8.2. Rate of Adoption of Improved Maize and Fertilizer

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

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

where:

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

8.2.1. Maize adoption over time

Figure 5 shows the rate of adoption of improved maize in the intermediate zone and highlands. In 1994, the cumulative adoption of improved varieties in the intermediate zone and highlands was 72% and 77%, respectively. The rate of adoption for the 1970-94 was 0.35 for the intermediate zone and 0.17 for the highlands. This figure shows that farmers in the highlands used improved varieties earlier than farmers in the intermediate zones. In fact, maize production in the highlands started in Iringa during the colonial era and in the intermediate zone in the 1970s (Mussei and Shiyumbi 1992).

8.2.2. Fertilizer adoption over time

Figure 6 shows the rate of fertilizer adoption in the intermediate and highland zones. In 1994, the cumulative adoption of fertilizer was 67.3% for the intermediate zone and 90% for the highlands. The adoption rate for 1965-94 was 0.18 for the highlands and 0.15 for the intermediate zone. After 1985, farmers in the highlands were using more chemical fertilizer than farmers in the intermediate zones, perhaps as a result of several circumstances. In 1985, trade liberalization began, and private companies and individual traders started to distribute agricultural inputs. Tanganyika Farmers' Association and Tanzania Fertilizer Company opened input distribution depots in Iringa region, where most of the highland sites for this study were selected. All of the seed farms are also located in Iringa region. These circumstances enabled farmers to purchase improved seed and fertilizer to maximize output. The intermediate zone is not so easily accessible and inputs were not available on time. Also, maize storage facilities were constructed in Iringa town and some villages in the region. Putting such facilities closer to farmers gave them an incentive to invest in commercial maize production. Also, most highland areas have good, all-weather tarmac roads by which maize can be transported to other areas.

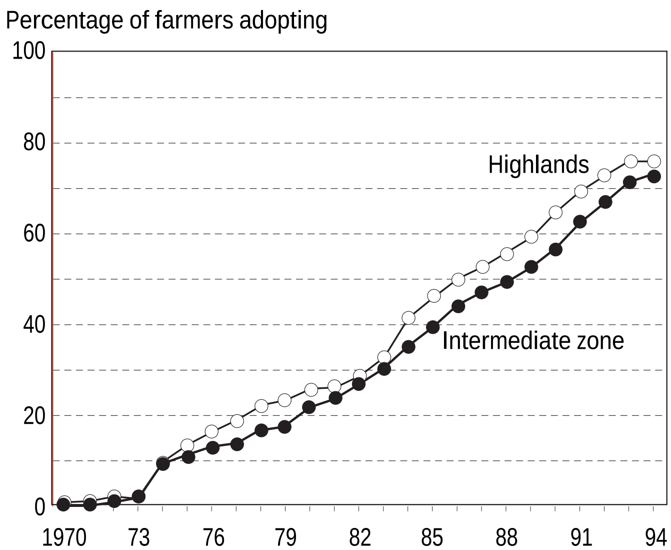

Figure 5. Adoption of improved maize, intermediate zone and highlands, Southern Zone, Tanzania.

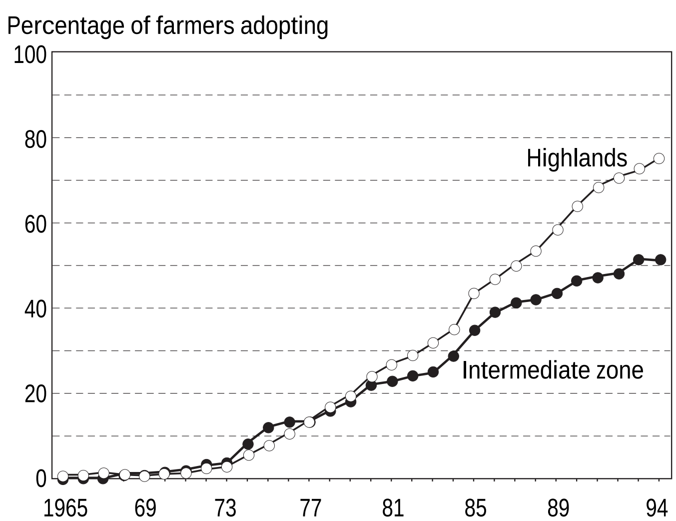

Figure 6. Adoption of inorganic fertilizer, intermediate zone and highlands, Southern Highlands, Tanzania.

8.3 Tobit Analysis of Improved Maize and Fertilizer

8.3.1. Tobit analysis of land allocated to improved maize varieties

The coefficients of the tobit model used to investigate factors affecting adoption of improved maize and the amount of land allocated to improved maize are reported in Table 26. The model is significant at the 1% level on the basis of the Wald χ^2 statistic with 11 degrees of freedom. Extension contact, intermediate zone, and livestock units were significantly associated with the adoption of improved maize varieties and land allocated to improved maize varieties.

Extension had a positive impact on the adoption of improved maize varieties. Farmers with frequent extension contact are contact farmers. They have access to information about improved maize technologies and extension agents encourage them to adopt these technologies. Contact farmers also have access to study tours, training, and occasionally credit.

The intermediate zone had a negative effect on the adoption of improved maize. The Southern Highlands have growing seasons of seven months in the highlands and five months in the intermediate zone. Farmers in the highlands are aware that recommended varieties will mature during the dry season (after July), but they prefer hybrids that mature later. Materials that mature before July cause labor competition with other crops, especially beans. In the intermediate zone, farmers use varieties that mature before July, because after July farming starts in the valley bottoms. Therefore, farmers in the intermediate zone are less likely to adopt late-maturing hybrids.

Ownership of livestock is positively related to the adoption of improved maize varieties. Farmers who own livestock are wealthier and can afford to buy imported maize seed.

The regression coefficients and the model were used to calculate probabilities of adoption of improved maize varieties and predict the amount of land allocated to improved maize varieties (Table 27). The method for calculating the values in Table 27 is shown in Appendix 1.

The probability that an average farmer in the intermediate zone who received extension and owns two animals would grow improved maize varieties is 48%. The area a farmer is expected to plant to improved maize is 1.56 acre. The probability that a farmer without extension will grow improved maize drops to 38%, and the area under improved maize varieties decreases to 1.09 acres.

Table 26. Tobit model estimates for land allocated to improved maize varieties, Southern Highlands, Tanzania

Parameter	Coefficient	t-statistic	Standard error	Mean
Constant	-1.2234	2.3**	0.533	—
Intermediate zone	-0.4584	3.4*	0.1339	—
Farm size (acres)	0.0012	0.2	0.0078	9.62
Hand hoe (no.)	-0.2352	1.2	0.1929	—
Ox-plow (no.)	-0.0813	0.4	0.202	—
Extension	1.1001	2.4**	0.457	—
Experience (yr)	0.0035	0.6	0.0063	19.63
Livestock units (no.)	0.0408	4.2*	0.0979	3.24
Labor (no.)	0.0379	1.5	0.0246	5.48
Hired labor	0.0308	0.2	0.1519	—
Credit	0.0754	0.5	0.1545	—
Log likelihood function	-504.76			
Standard error of estimate	4.1701			
Wald χ^2	44.41 *			
Sample size	314			

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

The probability that an average farmer in the highlands would grow improved maize varieties is 52%. The expected area under improved maize is 1.79 acre. The probability that a farmer without extension would grow improved maize drops to 42%, and the area under improved maize varieties decreases to 1.27 acres. Table 27 also shows that the adoption of improved maize varieties and the area under improved maize varieties increases with the number of livestock a farmer owns.

8.3.2. Tobit analysis of amount of fertilizer used

The coefficients of the tobit model used to investigate factors affecting the adoption and quantity of fertilizer used are shown in Table 28. The model is significant at the 1% level on the basis of the Wald χ^2 statistic with 11 degrees of freedom. Farm size, hand hoe use, and years of experience were significantly associated with adoption and quantity of fertilizer used.

Table 27. Predicted probabilities of adoption and expected amount of land allocated to improved maize, Southern Highlands, Tanzania

		Intermediate zone		Highlands	
Number of livestock		Probability (%)	Acres	Probability (%)	Acres
2	Extension	48	1.56	52	1.79
	No extension	38	1.09	42	1.27
4	Extension	49	1.60	53	1.83
	No extension	39	1.12	42	1.31
6	Extension	50	1.64	54	1.88
	No extension	40	1.14	43	1.34

Table 28. Tobit model estimates of amount of fertilizer used (kg/acre) by farmers in the Southern Highlands, Tanzania

Parameter	Coefficient	t-statistic	Standard error	Mean
Constant	0.6069	1.6	0.3909	
Intermediate zone	-0.0546	0.4	0.1238	
Farm size (acres)	-0.0377	4.1*	0.0092	9.62
Hand hoe	0.3181	1.6***	0.1960	
Ox-plow	.2495	1.2	.2057	
Extension	.3564	1.3	.2830	
Experience (yr)	0.0150	2.4**	.0062	9.63
Livestock units (no.)	0.0035	0.3	.0107	3.24
Labor (no.)	0.0141	0.6	0.0254	5.48
Hired labor	-0.172	1.2	0.1431	
Credit	-0.0656	0.5	0.1457	
Log likelihood function	-801.5			
Standard error of estimate	8.3027			
Wald χ^2	59.4*			
Sample size	314			

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

Fertilizer use is positively related with wealth. In the highlands, cash-producing enterprises such as potatoes, tea, coffee, pyrethrum, and dairy farming enable farmers to purchase fertilizer. Also, these commercial enterprises are associated with cooperatives, which formerly provided fertilizer and other input to farmers, who became accustomed to using them. Furthermore, most highland survey sites were located in Iringa region, where the zonal fertilizer depot of the Tanzania Fertilizer Company is located (at Makambako). Farmers in these areas get fertilizer at relatively lower prices compared to farmers in the intermediate zone. Also, four TFA shops are located in the area. In the highlands, nutrient leaching is high because of the hilly terrain, and nutrient mining is high because farmers grow late-maturing hybrids. Farmers in the highlands also have significantly fewer cattle (4.3) than farmers in the intermediate zone (8.5) ($t = 3.1$; $p = 0.01$) and thus they have less manure to use as fertilizer. Therefore, farmers in the highlands have to use chemical fertilizer to replenish soil nutrients.

Farmers with smaller farms have to intensify production by applying fertilizer to maximize output. These small farms are common in highland areas, where use of fertilizer is already high. Also, the fallow period in the highlands is shorter because of the limited farm area, and therefore fertilizers are used to regenerate soil. In most cases younger farmers have smaller farms. These younger farmers have gone through primary education and have learned about the benefits of soil fertility management through the “self-reliance” programs.

The regression coefficients and the model were used to calculate probabilities of adoption of fertilizer and predict the quantity of fertilizer used (Table 29). The method for calculating the values in Table 29 is shown in Appendix 1.

The probability that an average farmer with 10 years of experience, five acres of land, and a hand hoe will adopt fertilizer is 52%. The amount of fertilizer used would be 3.6 kg N/ha. A farmer who does not own a hand hoe has a probability of 51% of adopting fertilizer, and the amount of fertilizer used drops to 3.4 kg N/ha. Both the adoption and quantity of fertilizer use decrease with increasing farm size and experience.

Table 29. Predicted probabilities of adoption and amount of fertilizer used (kg/acre), Southern Highlands, Tanzania

	Farm size (acres)					
	5		10		15	
Years of experience	Probability (%)	Acres	Probability (%)	Acres	Probability (%)	Acres
10						
Hand hoe	52	3.6	52	3.5	50	3.4
No hand hoe	51	3.4	50	3.3	49	3.2
20						
Hand hoe	52	3.5	51	3.4	50	3.3
No hand hoe	50	3.3	49	3.3	48	3.1
30						
Hand hoe	51	3.4	50	3.3	49	3.2
No hand hoe	50	3.3	48	3.2	48	3.1

9.0. Conclusions and Recommendations

9.1. Conclusions

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

The mean age of the household head was 44 and 41 years for the intermediate zone and highlands, respectively. The educational level of the household head averaged five years of formal schooling for both zones. Sample households had about nine and eight family members comprising at least two male and female adults and five (four) children in the intemediate and highland zones, respectively. Land is mainly a constraint in the highlands, where the average farm size (8.0 acres) was lower compared to the intermediate zone (9.2 acres). Livestock ownership is more common in the intermediate zone. Farmers owned an average of 8.5 cattle in the intermediate zone compared to 4.3 in the highlands. Hand hoes were the major farm tools used in both zones.

Maize is the major food and cash crop in the study area. Intercropping of maize with beans or sunflowers was common in both zones. However, maize monocropping was preferred by 83% and 58% of farmers in the intermediate zone and highlands, respectively. Land preparation depended on the onset of rain in each zone, and the hand hoe was the major tool used to prepare land for planting maize. Maize was mostly planted in rows at the recommended spacing and weeded at least twice. The majority of farmers in both zones used inorganic fertilizer; the main constraint on fertilizer use was a lack of cash. Virtually all farmers applied organic manure. Other soil fertility management activities included fallowing and crop rotation with legumes.

Stalk borers were the most serious field pests, and most farmers used chemical control methods. Maize streak virus was the most important disease and was controlled by roguing diseased plants.

Most maize was harvested in June/July in the intermediate zone (84.7%) and August/September in the highlands (66.2%). Intermediate zone farmers used the ox-carts to transport maize, whereas highland farmers used head loads. Most farmers in both zones stored their maize in a *kihenge*. About 69% and 75% of the farmers in the intermediate and highland zones, respectively, selected maize seed at the homestead. A big cob was the most important seed selection criterion. About 97% of intermediate zone farmers and 90% of highland farmers purchased seed every year.

In the 1994/95 cropping season, about 36% and 51% of the sample farmers in the intermediate zone and highlands, respectively, grew improved maize. H614 was the most preferred variety in the intermediate zone (75%) and highlands (60%), mainly because of its high yield. In both zones, farmers had stopped growing H6302 and H614 because they were not available, susceptible to diseases, had low yields, or the price of seed was too high.

About 20% of the farmers in both zones obtained credit, most often from NGOs (60%). Lack of knowledge and lack of collateral were the major constraints to obtaining credit. Most farmers had received information on improved maize practices such as improved maize varieties, weeding, use of fertilizer, planting dates, pest management, and storage. Less information was disseminated about herbicides, ox-drawn implements, and disease control methods. The main source of information was extension.

The tobit analysis showed that living in the intermediate zone, extension contact, and numbers of livestock units were significant factors that affected the proportion of land allocated to improved maize. Extension increased the probability of allocating land at the means with 10%. Farmers in the intermediate zone are about 4% less likely to allocate land to improved maize varieties. An increase in the number of livestock by two units increased the probability of using improved maize varieties by 1%.

The tobit analysis also showed that farm size, hand hoe ownership, and the farmer's experience were significant factors affecting the amount of fertilizer used. An increase of farm size by five acres decreased the probability of adopting fertilizer by 1%, and an increase of experience of 10 years decreased the probability of adopting fertilizer by 1%. The use of a hand hoe to prepare land increased the adoption of fertilizer by 1%.

9.2. Recommendations

Research should address the problems of stalk borers, cutworms, and MSV by developing resistant or tolerant varieties. TMV1 is resistant to MSV but has not yet reached the farmers. New varieties should be developed and promoted through participatory on-farm research.

Extension services should increase educational contacts with farmers, especially in relation to herbicide use and ox-powered implements, which could reduce labor bottlenecks during land preparation and weeding. Only about 11% of farmers in the intermediate zone had received information on herbicides, and only 28% had heard about ox-drawn implements. Maize streak virus is a serious disease, yet only 33% and 25% of the farmers in the intermediate and highland zones, respectively, have received information on how to control it and other maize diseases. Extension should therefore continue to extend messages through farmer groups and on-farm demonstrations so as to reach more farmers in a short time at a relatively low cost.

Farmers should also receive more information about various credit schemes, and the requirements for collateral should be reviewed. About 20% of farmers received credit for maize production, largely from NGOs. The formal credit market is hardly involved in supplying credit to maize farmers, but rising input prices make it increasingly important to ensure that farmers have access to credit. Policy makers and bankers should direct more effort to providing loans to small-scale maize farmers in ways that will ensure a high rate of loan recovery and low cost of credit.

Policy makers should continue to encourage and support private sector investments in input acquisition and distribution so that inputs are available when farmers need them. Credit and efficient import regulations should be provided to private traders to avoid unnecessary delays in importing inputs. Also, farmers who plant during the dry season should be supplied with inputs when they need them. Finally, government policy should strengthen the input delivery system if the smallholder sector, which produces over 85% of Tanzania's maize, is to maintain its productivity.

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Appendix 1

Calculation of Probability of Adoption and Amount of Land Allocated to Improved Maize Varieties

Consider an "average" farmer growing improved maize varieties in the intermediate zone who receives extension and owns two units of livestock.

From Table 26 the probability that this farmer grows improved maize varieties is:

1. I = -1.2234-0.4584 * (1) + 0.0012 * (9.62) -0.2352 * (0) –0.0813 * (0) + 1.1001 * (1) + 0.0035 * (19.63) + 0.0408 * (2) + 0.0379 * (5.48) +0.0308 * (0) + 0.0754 * (0)

2. I/σ = -0.21/4.1701 = -0.05

3. The area under the normal probability curve for (I/σ) = -0.05 = 1-0.52 = 0.48. Therefore, there is a 48% chance that the farmer as defined would adopt improved maize varieties, and so $F(I/\sigma)$ = 0.48.

4. The expected area allocated to improved maize varieties is:

$$E(Y/I) = I^{*} F(I/\sigma) + ({}^{*}F(I/\sigma)$$
$$= -0.21 * 0.48 + 4.1701 * 0.3984$$
$$= 1.56 \text{ acres}$$

$F(I/\sigma)$ is the value of the ordinate of the normal density function at 0.05.

Similar calculations can be made for fertilizer adoption and the quantity of fertilizer used.