Adoption of Improved Wheat Technologies by Small-Scale Farmers in **Mbeya District, Southern Highlands, Tanzania**

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Abstract: This study was conducted to gain an understanding of how small-scale farmers in Mbeya District have adopted improved wheat technologies promoted by the wheat research program at MARTI-Uyole. The specific objectives were to assess farmers' wheat management practices, determine the technical and socioeconomic factors affecting the adoption of improved wheat technologies, and draw implications for research, extension, and policy. A purposive multistage sampling procedure was used to select 202 farmers, 160 from Tembela Division and 42 from Isangati Division, which are two important wheat-growing areas in Mbeya District. Primary data were collected using structured questionnaires and supplemented by secondary information obtained from MARTI-Uyole. Juhudi was the preferred improved wheat variety grown by adopters. For all farmers, the most important characteristics preferred in a variety were high yield, marketability, grain color, and early maturity. In 1997, about 74% of sample farmers adopted improved wheat varieties. The rate of adoption increased between 1989 and 1995 for a number of reasons, including provision of seed and fertilizer by Sasakawa Global-2000 (SG-2000), the collapse of the pyrethrum industry, and market liberalization. After 1995, adoption declined because SG-2000 was phased out and the varieties had succumbed to stem rust and foliar diseases. Tobit analysis showed that farm size, family size, and the use of hired labor were significant factors affecting the proportion of land allocated to improved wheat. Farm size, family size, hired labor, and credit all significantly affected the amount of fertilizer used. Additional improved varieties need to be developed, not only to replace the old varieties, but to give farmers a wider choice. Fertilizer recommendations need to be reviewed to take into consideration farmers' circumstances such as cash availability and soil fertility. Extension services in the area should be increased and the link between extension workers and landholders strengthened to promote the adoption of improved wheat technologies. The formal credit market is only weakly involved in supplying credit to wheat farmers, but rising input prices, especially for fertilizer, make access to credit increasingly important for farmers. Policymakers and bankers should focus on providing loans to small-scale wheat farmers with high rates of loan recovery and low cost of credit. Farmers should also be encouraged to form their own savings and credit cooperatives at the village level. Policymakers should continue to encourage and support the private sector to invest in input acquisition and distribution so that inputs (especially seed and fertilizer) are available when farmers need them.

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ACRONYMS AND ABBREVIATIONS

CSA	Central Statistical Authority
ARC	Agricultural research center
CAN	Calcium ammonium nitrate
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DAP	Diammonium phosphate
EU	European Union
IFAD	International Fund for Agricultural Development
MARTI	Ministry of Agricultural Research and Training
masl	Meters above sea level
MOA	Ministry of Agriculture
NGO	Non-governmental organization
SG-2000	Sasakawa-Global 2000
SHERFSP	Southern Highlands Extension and Rural Financial Services Project
TLU	Tropical livestock unit
TSP	Triple super phospate

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EXECUTIVE SUMMARY

This study was conducted to gain an understanding of how small-scale farmers in Mbeya District have adopted improved wheat technologies promoted by the wheat research program at MARTI-Uyole. The specific objectives were to assess farmers' wheat management practices, determine the technical and socioeconomic factors affecting the adoption of improved wheat technologies, and draw implications for research, extension, and policy.

Tembela and Isangati Divisions were selected for the study because they are two important wheat-growing areas in Mbeya District. A purposive multistage sampling procedure was used to select 202 farmers, 160 from Tembela and 42 from Isangati. Primary data were collected using structured questionnaires, supplemented by secondary information obtained from MARTI-Uyole.

The results showed that adopters of improved wheat varieties were more literate, slightly younger, had larger families, owned smaller farms, and had fewer years of farming experience compared to nonadopters. Adopters had less wheat area but retained more grain for home consumption, owned less livestock, and had more access to credit than nonadopters. Also, more adopters supplemented their income from off-farm activities.

About 60% of adopters and 38% of nonadopters prepared their land at the recommended time between January and February. Eighty-four percent of adopters and 57% of nonadopters planted at the recommended time between February and March. About 33% of adopters and 2% of nonadopters drilled their crops. Most (84%) adopters used the recommended spacing of 30-40 cm between rows and all used the recommended seed rate of 120 kg/ha. Adopters used significantly more wheat seed (134 kg/ha) for broadcasting than nonadopters (88 kg/ha), though both groups used less than the recommended rate (150 kg/ha).

Bidens sp. was the most important weed in the study area. More adopters (77%) used weed control compared to nonadopters (48%), although most farmers weeded only once and did not use herbicides. Leaf rust was the most important disease and 27% of adopters and 37% of nonadopters used disease control. Birds were the most important pest for adopters, while rodents were the most important pests for nonadopters. More nonadopters (41%) used pest control than adopters (27%).

Of all sample farmers, 40% of adopters used fertilizer. The main constraint on fertilizer use was its high price. About 67% and 68% of adopters and nonadopters, respectively, used crop residues to improve soil fertility, and one adopter used copper spray. The main reason given by both adopters (85%) and nonadopters (86%) for not using copper was lack of knowledge.

Juhudi was the improved wheat variety grown by most adopters. All nonadopters grew local wheat varieties. For all farmers, the most important characteristics preferred in a variety were high yield, marketability, grain color, and early maturity. Only a few farmers had discontinued growing a variety. The main reason why nonadopters did not grow improved varieties was the unavailability of seed. Of all sample farmers, 11% of adopters used credit. The main constraints on using credit were unavailability, lack of information, and complicated bureaucratic procedures. About 41% of adopters and 57% of nonadopters had never received a visit from an extension agent.

In 1997, about 74% of sample farmers adopted improved wheat varieties. The rate of adoption increased between 1989 and 1995 for a number of reasons, including the provision of seed and fertilizer by Sasakawa-Global 2000 (SG-2000), the collapse of the pyrethrum industry, and market liberalization. After 1995, adoption declined because SG-2000 was phased out and the varieties had succumbed to stem rust and foliar diseases.

The tobit analysis showed that farm size, family size, and the use of hired labor were significant factors affecting the proportion of land allocated to improved wheat. A unit increase in farm size among adopters decreased the probability of allocating land to improved wheat by about 10%, whereas family size increased the probability of adoption by 20%. The use of hired labor increased the probability of adoption by about 24%.

The analysis showed that farm size, family size, hired labor, and credit were significant factors affecting the amount of fertilizer used. A unit increase in farm size among adopters decreased the probability of adopting fertilizer by about 2%, whereas family size increased the probability of adoption by about 10%. Hired labor and credit increased the probability of adoption by about 5% and 6%, respectively. Extension increased the probability of adopting fertilizer among adopters by 5.1%.

The popular variety Juhudi, which was released over ten years ago, has succumbed to stem rust and foliar diseases. Additional improved varieties need to be developed, not only to replace the old varieties, but to give farmers a wider choice. Furthermore, the present fertilizer recommendations need to be reviewed to take into consideration farmers' circumstances such as cash availability and soil fertility. Extension services in the area should be increased and the link between extension workers and landholders strengthened to promote the adoption of improved wheat technologies.

The formal credit market is only weakly involved in supplying credit to wheat farmers, but rising input prices, especially for fertilizer, make access to credit increasingly important for farmers. Policymakers and bankers should focus on providing loans to small-scale wheat farmers with high rates of loan recovery and low cost of credit. Farmers should also be encouraged to form their own savings and credit cooperatives at the village level. Policymakers should continue to encourage and support the private sector to invest in input acquisition and distribution so that inputs (especially seed and fertilizer) are available when farmers need them.

Adoption of Improved Wheat Technologies by Small-Scale Farmers in Mbeya District, Southern Highlands, Tanzania

Ahaz Mussei, Judicate Mwanga, Wilfred Mwangi, Hugo Verkuijl, Rose Mongi, and Anthony Elanga

1.0 INTRODUCTION

1.1 Wheat Research in the Southern Highlands of Tanzania

Wheat research in the Southern Highlands started in the early 1970s at the Ministry of Agriculture, Research, and Training (MARTI), Uyole, with an emphasis on improving yields and developing agronomic recommendations. Initial research focused on the evaluation of wheat varieties such as Tai, Mbuni, Trophy, and Mamba, which were introduced from northern Tanzania. These varieties were susceptible to foliar diseases, however, thereby limiting their dissemination in the zone. In the early 1980s, new lines were introduced from the International Maize and Wheat Improvement Center (CIMMYT), Mexico. The genetic yield potential of the current improved wheat varieties is 4 t/ha, although farmers' yields are only 0.4 t/ha.

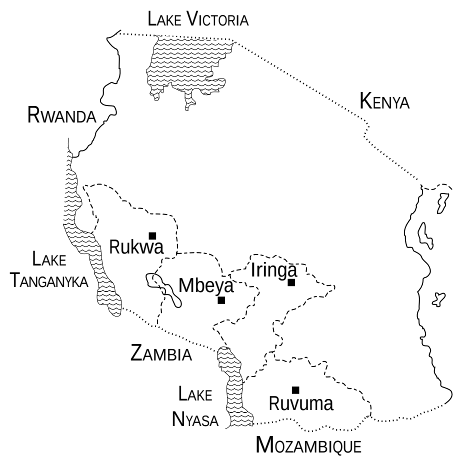

Figure 1. Southern Highlands, Tanzania.

The objectives of this study were to assess farmers' wheat management practices, determine the technical and socioeconomic factors affecting the adoption of improved wheat technologies, and draw implications for research, extension, and policy.

1.2 The Study Area

Mbeya District, located in Mbeya Region, comprises five divisions, including Tembela and Isangati (Figures 1 and 2). Tembela is located to the southeast and Isangati to the southwest of Mbeya town and the Uyole Agricultural Research Station (ARS). The Mporoto highlands and the Umalila undulating plateau are located in the two districts.

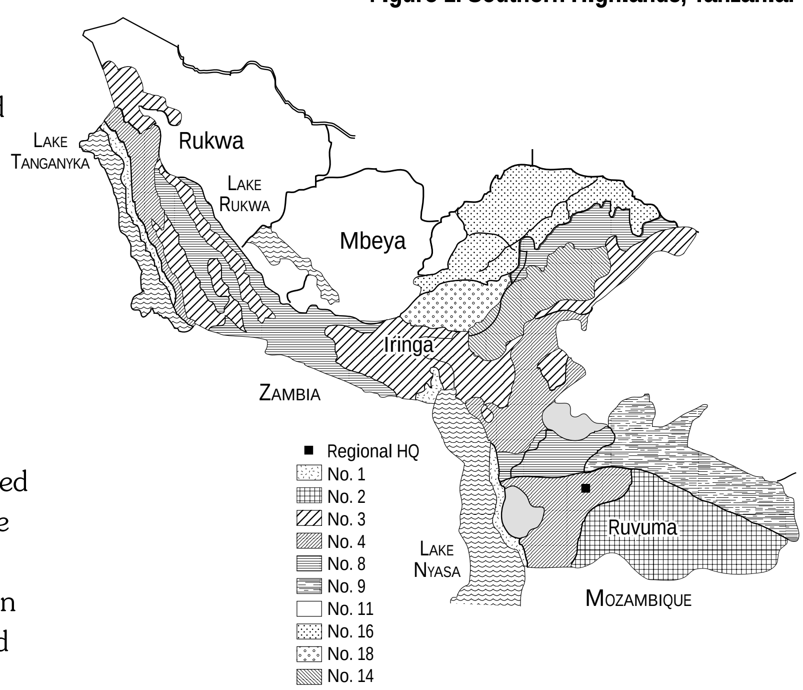

Figure 2. Agro-ecological zones in the Southern Highlands, Tanzania.

The elevation of the study area ranges between 1,500 and 2,400 meters above sea level (masl). The mean annual rainfall is 1,200-1,500 mm and usually unimodal, from November to May. Temperatures are isothermic and range between 12°C to 28°C. In July and August, frost can occur on the valley floors. Soils are a mixture of ash and pumice gravel in alternate layers. Grassland and forest are found at high altitudes, and cropland with Hagenia montane forest remnants occurs at lower altitudes. The divisions can be classified in either the Mporoto-Umalila agro-ecological zone (Mussei et al. 1997; Croon 1982) or the pyrethrum zone (Kirway and Kidunda 1981).

Tembela and Isangati Divisions were selected for this study because they are the major wheat-producing areas in Mbeya District, where wheat is a major subsistence and commercial crop. Farmers in the divisions supply wheat to the rural and urban markets of Uyole, Mbeya, and Mbalizi. The divisions were also selected on the basis of their proximity to Uyole-ARS and because farmers in the area have been exposed to improved wheat technologies.

The farming systems in the study area encompass crop, livestock, and agroforestry productions. Major crops include maize, wheat, ground potatoes, beans, green peas, pyrethrum, coffee, vegetables, and temperate fruits. Livestock include cattle, goats, pigs, sheep, and chickens. The average farm size is about 0.4 ha per household.

2.0 METHODOLOGY

2.1 Sampling Procedure

A multistage purposive sampling procedure was used to identify divisions, villages, and farmers to be included in the study. Sixteen villages were selected from Tembela Division and four villages were selected from Isangati Division (Table 1). In each village, the survey team, extension officer, and/or village chairman and secretary selected ten wheat-growing farmers to be included in the study. The total sample size was 202 farmers.

Table 1. Divisions and villages included in the study, Mbeya District, Tanzania

Division	Village
Tembela	Tembela, Shibolya, Ikokho, Usoha Muungano, Idunda, Usoha, Njia Panda, Galijembe, Iyela, Ifiga, Ijombe Ntangano, Iwalanje, Idimi, Haporoto, Itala, Irambo, Iduda
Isangati	Izuo, Masoko-Ilomba, Ilembo, Izumbwe II

Primary data were collected from farmers using structured questionnaires and were supplemented with field observations on farmers' practices and circumstances. Secondary information was obtained from MARTI-Uyole and the Department of Extension, Mbeya District.

During the first stage of the survey, the study was introduced to the district agricultural extension officers; division and village extension officers were selected to work with the research team throughout the study. The questionnaire was pre-tested at Uyole-ARS and modifications were made where necessary. Research assistants from the Farming Systems Research and Wheat Research Programs were trained as enumerators and supervised by the researchers. Interviews were conducted during the wheat-growing season, February to December, 1997.

For the study, an adopter was defined as a farmer who grew improved wheat varieties during the 1996/97 cropping season. Adopters included farmers who had participated in on-farm trials as well as those who had not.

2.2 Analytical Model

Factors influencing the adoption of new agricultural technologies can be divided into three major categories: 1) farm and farmers' associated attributes; 2) attributes associated with the technology (Adesina and Zinnah 1992; Misra et al. 1993); and 3) the farming objective (CIMMYT 1988). Factors in the first category include the farmer's education level, age, and family and farm size. The second category varies with the type of technology, e.g., the characteristics a farmer prefers in an improved wheat 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 wheat varieties and the amount of nitrogen fertilizer (N kg/ha) used (intensity of adoption). A tobit model (McDonald and Moffitt 1980; Maddala 1983) that tests the factors affecting the incidence and intensity of adoption can be specified as follows:

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

where:

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

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

$$X_t = \beta_0 + \beta_1 X_1 + \ldots + \beta_9 X_9 + \varepsilon_i$$

where:

β_0 = constant;
X_1 = AGE (age of household head, years);
X_2 = ADULT (number of adults working permanently on the farm);
X_3 = LITERACY (literacy of the farmer, dummy variable);
X_4 = FSIZEHA (farm size, hectares);
X_5 = CREDIT (access to credit, dummy variable);
X_6 = TLVUNITS (number of livestock owned);

X_7 = HLABOR (use of hired labor by the farmer, dummy variable);
X_8 = OFFINCOM (farmer's off-farm income, Tsh);
X_9 = EXTEN (access to extension services, dummy variable); and
ε_i = error term.

Formation of the model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to adopt or reject a new technology at any time is influenced by the combined (simultaneous) effect of a number of factors related to the farmer's objectives and constraints (CIMMYT 1993). Several variables were hypothesized to influence the allocation of land to improved wheat varieties and the amount of fertilizer used. The model was estimated using the maximum likelihood method of Shazam, version 7.0.

Farmer's age. A farmer's age (X_1) can either generate or erode confidence in new technology. In other words, with more experience, a farmer can become more or less risk-averse when judging new technology. This variable could thus have a positive or negative effect on a farmer's decision to adopt improved wheat technology.

Household size/labor. Large households will be able to provide the necessary labor required for timely land preparation, weeding, and harvesting. Thus, household size or labor (X_2) is expected to increase the probability of adopting improved wheat technologies.

Education. Exposure to education (X_3) should increase a farmer's ability to obtain, process, and use information relevant to the adoption of improved wheat technology. Education is thus thought to increase the probability that a farmer will adopt an improved wheat technology.

Farm size. Farm size (X_4) 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 wheat technologies.

Access to credit. Farmers who have access to credit can relax their financial constraints. Also, in some cases, access to credit is tied to a particular technology package. It is expected that access to credit (X_5) will increase the probability of adoption of improved wheat.

Livestock. Ownership of livestock (X_6) is a proxy for wealth, and wealthier farmers have the means to purchase improved wheat technologies. Therefore, ownership of livestock is expected to be positively related to adoption.

Hired labor. Hired labor (X_7) helps farmers to overcome labor constraints, especially with respect to timely land preparation, weeding, and harvesting operations required for improved wheat varieties. Thus, hired labor is expected to have a positive influence on the adoption of improved wheat.

Off-farm income. Access to off-farm income (X_8) enables farmers to purchase inputs and is expected to have a positive influence on the adoption of improved wheat.

Extension. Agricultural extension services provided by the Ministry of Agriculture (MOA) are the major source of agricultural information in the study area. It is hypothesized that contact with extension workers (X_9) will increase a farmer's likelihood of adopting improved wheat technologies.

3.0 WHEAT PRODUCTION TECHNOLOGY RECOMMENDATIONS

One of the major factors contributing to low wheat yields in the Southern Highlands has been poor agronomic practices. As a result, wheat production recommendations were developed to exploit the yield potential of improved wheat varieties, as outlined below.

3.1 Wheat Varieties

Varietal choice is determined by the farmer's objectives, environmental factors, and attributes of the variety. Five wheat varieties have been recommended for the different locations and agro-ecological zones in the Southern Highlands (Table 2).

3.2 Land Preparation and Planting

The recommended time for land preparation is between January and February, while the recommended planting time is mid-February to mid-March, depending on the variety and agro-ecological conditions of the area. Thorough seedbed preparation is recommended prior to sowing to facilitate rapid and even germination. A sowing depth of 4-5 cm is preferable. Drilling is recommended at a rate of 100-120 kg/ha with inter-row spacing of 20-25 cm. If broadcasting is used, the seed rate should be increased to 150 kg/ha.

3.3 Weed and Disease Management

Efficient tillage is the most effective method of weed control for wheat production. Thorough land preparation prior to planting, together with a carefully calculated sowing date and seed rate and the use of weed-free seed, should give a crop maximum competitive advantage against weeds. Herbicides 2,4-D amine or MCPA (2-methyl-4-Chlorophenexy acetic acid), each applied at 1.2 l/ha at the four- to five-leaf stage, effectively control broadleaf weeds.

The major wheat diseases are leaf and stem rusts and leaf and glume blotches. Chemical control can be achieved using Benlate, Labilite, or Tilt 250 EC. Early planting can minimize the incidence of disease.

3.4 Fertilizer

Most soils in the Southern Highlands are volcanic and are low in phosphorus (P), nitrogen (N), and copper (Cu). Recommended fertilizer rates are 50 kg/ha N and 20-25 kg/ha P. Farmers are advised to apply all P fertilizer and 50% of N fertilizer at planting and top-dressing, and the remaining N at tillering. About 20-40 kg/ha of copper sulfate ($CuSO_4$), in addition to N and P, is recommended. Blitox (copper oxychloride) as a foliar spray is also recommended at a rate of 1-2 kg/ha.

Table 2. Improved wheat varieties recommended for the Southern Highlands, Tanzania

Variety	Year of release	Yield potential (t/ha)	Plant height (cm)	Maturity (days)	Grain color
Viri	1983	3.5	85	110-120	White
Azimio 87	1987	4.0	90	110-120	Red
Juhudi	1987	4.0	66	95-100	White
Selian 87	1987	4.0	78	125-130	White
Njombe 7	1988	4.5	90	125-130	Red

Source: Wheat Program, MARTI-Uyole, unpublished data.

3.5 Suggested Sequence of Wheat Production Technologies

In the early 1990s, the wheat improvement program at MARTI-Uyole established on-farm trials to facilitate the transfer of research findings to the farming community and to test and verify potential recommendation packages under farmers' field conditions. On-farm wheat research has been undertaken in all major wheat growing areas in the Southern Highlands and has determined that the genetic yield potential of current varieties is 4 t/ha.

Farmers tend to adopt one technological component at a time. Financial constraints, competition for labor, and the perceived risks associated with adopting new technology are some of the reasons for this behavior. To assist adoption, a sequence of innovations for wheat farmers in the Southern Highlands was suggested (Table 3). The estimated yields resulting from the stepwise adoption of recommendations are taken from trials conducted in farmers' fields with their participation.

4.0 DEMOGRAPHIC AND SOCIOECONOMIC CHARACTERISTICS

Demographic and socioeconomic characteristics of the sampled households are shown in Table 4. Most adopters (94%) were from Tembela Division. On average, adopters were slightly younger (41 years) than nonadopters (42 years) and had slightly less farming experience (21 years and 23 years, respectively), although these differences were not statistically significant. Average household size was significantly larger for adopters (7 persons) than for nonadopters (5 persons). Most households were headed by men.

Average farm size was significantly larger for nonadopters (3 ha) than adopters (2 ha). Likewise, cultivated area was larger for nonadopters (2.4 ha) than for adopters (1.7 ha). Land was a constraint for most farmers (68% of adopters and 60% of nonadopters) in the study area. Farmers used different strategies to solve the problem of land shortage. Adopters rented land (49.6%), used farm planning (18%), or applied improved farming techniques (16%), while most nonadopters rented land

Table 3. Suggested sequence of innovations to aid the adoption of improved wheat technologies, Southern Highlands, Tanzania

Management practice	Characteristic	Estimated yield (kg/ha)
Zero management	Local variety, poor land preparation	400
Variety	Local variety, improved practices	1,000
	Improved variety, minimum tillage	1,700
Optimum tillage	Two tillage operations prior to planting	2,060
Sowing	Broadcasting	2,260
	Drilling	2,740
Fertilizer	Addition of optimal N + P, and hand weeding	3,320
Weeding	Use of herbicides	3,960
Micronutrients	Addition of copper	4,250

Source: Elanga and Kisandu (1992).

(60%) or practiced intercropping (16%). Both farmer groups had equal areas under wheat (0.7 ha), but adopters sold more wheat (6 bags) per harvest than did the nonadopters (2 bags). This difference was not statistically significant.

Significantly more (85%) adopters were literate compared to nonadopters (71%) ($\chi^2 = 4.2$; $p<0.05$). Fifty-six percent of adopters and 61% of nonadopters used hired labor, most of which was used for plowing and harvesting. About 45% of adopters and 41% of nonadopters used hired labor for plowing, while 46% of adopters and 12% of nonadopters used hired labor for harvesting. This difference was not statistically different. The main constraint on hiring labor for both adopters (50%) and nonadopters (86%) was its high cost. More nonadopters engaged in off-farm work (38%) than adopters (28%). For adopters, off-farm work included brewing local beer (28.9%), trading (26.3%), masonry (13.2%), and carpentry (10.5%), while for nonadopters it included carpentry (29.4%), trading (23.5%), brewing local beer (17.6%), and masonry (11.8%). Adopters had a higher average off-farm income (Tsh 87,600) than nonadopters (Tsh 67,700) (US$ 1= Tsh 660). About 17% of adopters and 15% of nonadopters had family members working off-farm, and the annual remittance was Tsh 98,800 and Tsh 51,250, respectively.

Table 4. Demographic and socioeconomic characteristics of farmers in Mbeya District, Tanzania

	Adopters (n = 160)		Nonadopters (n = 42)		
Characteristic	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**	**t-test**
Age of farmer (yr)	40.5	11.1	42.2	13.2	0.79 (NS)
Farming experience (yr)	20.9	11.0	23	13.4	0.93 (NS)
Household size (no. persons)	6.6	3.6	5.4	2.5	2.0**
Farm size (ha)	1.9	1.3	2.9	2.5	2.7***
Cultivated area (ha)	1.7	1.2	2.4	2.2	2.2**
Wheat area (ha)	0.7	0.6	0.7	0.8	0.5 (NS)
Wheat grain sales (bags)	5.7	18.2	2.3	2.8	1.0 (NS)
Livestock units	1.3	2.1	2.0	2.4	1.5 (NS)
	Number of farmers	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	**χ^2**
Division					84.6*
Tembela	150	93.7	13	31.0	
Isangati	10	6.3	29	69.0	
Gender of household head					0.1 (NS)
Male	87	54.4	24	57.1	
Female	73	45.6	18	42.9	
Education level of farmer					4.2**
Illiterate	24	15.0	12	28.6	
Literate	136	85.0	30	71.4	
Hired labor					0.2 (NS)
No	68	42.5	16	39.0	
Yes	92	57.5	26	61.0	
Off-farm income					1.6(NS)
No	115	71.9	26	61.9	
Yes	45	28.1	16	38.1	

Note: NS = not significant; * = significant at p< 0.1; ** = significant at p<0.05; *** = significant at p<0.01. 1 ha = approximately 2.45 acres.

Nonadopters owned significantly more livestock (3.0 tropical livestock units, TLU) than adopters (1.9 TLU). There were, however, no significant differences in the number of cattle, goats, sheep, poultry, or pigs owned (Table 5). The average number of farm implements owned was about 3 hand hoes, 2.5 sickles, and 1 ox plow. These differences were not statistically different. The main constraints on the use of oxen for adopters were a lack of cash (56.3%) and hilly terrain (24.4%), while for nonadopters constraints were a lack of cash (40.9%), hilly terrain (31.8%), and unavailability of oxen (25%).

5.0 WHEAT PRODUCTION PRACTICES AND ADOPTION OF RECOMMENDATIONS

5.1 Crops and Cropping System

The most important crops grown in the Southern Highlands in 1996 were wheat, maize, and ground potatoes (Table 6). The mean wheat area was 1.7 acres for adopters and 1.8 acres for nonadopters. This difference was not statistically significant. The adopters had significantly more (3) wheat plots compared to the nonadopters (2) ($t=3.0$; $p<0.01$). All nonadopters and 97% of adopters monocropped their wheat. The mean maize area was 2.2 acres for nonadopters and 1.6 acres for adopters. Similarly, the area under beans was higher for nonadopters (1.1 acres) than adopters (0.6 acres). The area under maize and beans for adopters and nonadopters were both significantly different at $p<0.05$. Both farmer groups had about three maize plots and, on average, two bean plots.

Of all sample farmers, only 3% of adopters intercropped their wheat, using green peas or beans. More nonadopters (42.1%) intercropped their maize compared to adopters (29.5%). About 86% of adopters and 78% of nonadopters rotated their wheat crop. The adopters rotated wheat with potatoes (53.5%) and beans (28.5%), while the nonadopters rotated wheat with maize (55.6%) and potatoes (22.2%).

Table 5. Livestock ownership and farm mechanization by farmers in Mbeya District, Tanzania

	Adopters		Nonadopters		
	Mean	Standard deviation	Mean	Standard deviation	t-statistic
Tropical livestock units (TLU)	1.9	2.5	3.0	2.7	1.9*
Livestock type (no.)					
Cattle	3.4	2.8	3.9	2.4	0.7 (NS)
Goats	4.6	2.8	4.0	2.9	0.9 (NS)
Sheep	3.0	2.4	3.0	2.0	0.0 (NS)
Poultry	7.7	6.5	7.1	6.5	0.4 (NS)
Pigs	1.8	1.1	1.9	1.2	0.2 (NS)
Farm implements (no.)					
Hand hoes	3.1	1.6	3.3	1.6	0.8 (NS)
Sickles	2.3	1.0	2.7	1.7	0.6 (NS)
Ox plows	1.1	0.3	1.0	0.0	0.5 (NS)

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

5.2 Crop Management

5.2.1 Land preparation. The timing and method of land preparation in the study area are shown in Table 7. The main farm implement used for land preparation by adopters (84%) and nonadopters (98%) was the hand hoe. About 88% of adopters prepared their land between January and March, while 93% of nonadopters prepared their land between January and May. Adopters timed their preparation based on extension recommendations (40.1%), tradition (25.5%), or to coincide with the rains (21.7%). Nonadopters timed their preparation based on tradition (47.6%) or extension recommendations (26.2%). Most farmers (66% of adopters and 50% of nonadopters) prepared their land at the recommended time.

5.2.2 Planting time, spacing, and seed rate. About 84% of adopters and 57% of nonadopters planted at the recommended time between February and March (Table 8). Significantly more adopters (88%) than nonadopters (76%) were aware of the recommended time for planting ($\chi^2 = 3.8$; $p<0.05$).

Table 6. Area (acres) of crops grown by farmers in Mbeya District, Tanzania, 1996

	Adopters		Nonadopters		
Crop	Mean	Standard deviation	Mean	Standard deviation	t-statistic
Wheat	1.7	1.4	1.8	2.0	0.5 (NS)
Maize	1.6	1.4	2.2	1.3	2.5**
Ground potatoes	1.1	1.1	0.9	0.9	0.7 (NS)
Pyrethrum	0.5	0.4	0.5	0.3	0.4 (NS)
Vegetables	0.6	0.7	0.6	0.4	0.1 (NS)
Beans	0.6	0.6	1.1	1.2	2.0**
Finger millet	0.6	0.4	0.9	0.7	1.3 (NS)

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

Table 7. Timing and method of land preparation by farmers in Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of land preparation				
January	35	22.0	6	14.3
February	64	40.3	10	23.8
March	41	25.8	11	26.2
April	16	3.8	4	9.5
May	1	0.6	8	19.0
Other	12	7.5	3	7.2
Method of land preparation				
Hand hoe	134	84.3	41	97.6
Ox plow	10	6.3	-	-
Tractor	2	1.3	1	2.4
Hand hoe/Ox plow	13	8.2	-	-

Table 8. Time and method of planting, Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of planting				
February	26	16.6	9	21.4
March	106	67.5	15	35.7
April	23	14.6	6	14.3
May	1	0.6	10	23.8
Other	1	0.6	2	4.8
Method of planting				
Broadcasting	95	57.9	41	97.6
Drilling	52	32.7	1	2.4
Broadcasting and drilling	15	9.4	-	-
Spacing between rows				
30-40 cm	57	83.9	-	-
Other	11	16.1	1	100.0

Most adopters (about 58%) and nonadopters (about 98%) broadcasted their seed. The two groups used less seed for broadcasting than the recommended rate of 150 kg/ha, although adopters used significantly more (134 kg/ha) than nonadopters (87.9 kg/ha) (t=5.5; $p<0.01$). The major reasons for broadcasting seed were tradition and ease of sowing.

Drilling was used by 33% of adopters and most (84%) followed the recommendations for spacing and seed rate. Adopters drilled their crops for the ease of weeding (47.9%) and higher yields (31%). The main sources of drilling information were extension (56.1%) and other farmers (33.3%).

5.2.3 Wheat intercropping and crop rotation. Only 3% of the adopters intercropped wheat with green peas or beans, while none of the nonadopters intercropped wheat. Crop rotation was practiced by 86% of the adopters and 78% of the nonadopters. About 54% of the adopters used potatoes in the rotation and 29% used beans. For the nonadopters, about 56% used maize in the rotation and 22% used potatoes.

5.2.4 Management of weeds, pests, and diseases. Table 9 shows the major weeds, pests, and diseases in the study area. *Bidens* sp. was the most important weed for 50% of adopters and 43% of nonadopters. Other important weeds were couch grass, *Cyperus* sp., *Galinsoga* sp., *Commelina* sp., and Chinese Lantern. Significantly more adopters (77.2%) used weed control than nonadopters (47.5%) ($\chi^2 = 13.7$; $p<0.01$). Hand weeding was used by significantly more (86%) nonadopters than adopters (60%) ($\chi^2 = 5.5$; $p<0.05$). Forty percent of adopters used hand hoes to control weeds. Most farmers (90%) weeded only once. About 70% and 82% of adopters and nonadopters, respectively, weeded at tillering, while 25% of adopters and 18% of nonadopters weeded at heading. No farmers used herbicides. The main reasons for this were a lack of information, cited by 70.4% of adopters and 82.1% of nonadopters, and high price, cited by 19.7% of adopters and 14.3% of nonadopters. Significantly, more adopters (48.3%) knew of the recommended weed control methods than nonadopters (23.7%) ($\chi^2 = 7.4$; $p<0.01$).

Table 9. Major weeds, pests, and diseases of wheat in Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Weed species/name				
Bidens	80	50.0	18	42.9
Couch grass	53	33.1	6	14.3
Cyperus	51	31.9	7	16.7
Galinsoga	44	27.9	4	9.5
Commelina	30	18.8	3	7.1
Chinese Lantern	21	13.1	4	9.5
Number of weedings				
One	113	91.1	21	95.5
Two	9	7.3	1	4.5
Three	2	1.6	-	-
Pests				
Army worms	28	19.7	-	-
Birds	53	37.3	12	29.3
Aphids	34	23.9	4	9.8
Rodents	22	15.5	24	58.5
Other	5	3.5	1	2.4
Diseases				
Leaf rust	64	52.0	11	64.7
Stem rust	37	30.1	4	23.5
Other	11	8.9	-	-
Frost	11	8.9	2	11.8

Leaf rust was the most important wheat disease for most adopters (52%) and nonadopters (64.7%). About 27% of adopters and 37% of nonadopters used disease control. Birds were the most important pest for adopters (37.3%), while rodents were the most important pest for nonadopters (58%). Significantly more nonadopters (40.5%) used pest control than adopters (26.9%) ($\chi^2 = 2.9$; $p<0.1$). The most popular methods for controlling pests for nonadopters were crop rotation (82.4%) and burning crop residues (17.6%). Adopters controlled pests by burning crop residues (37.2%), crop rotation (34.9%), or with chemicals (20.9%). Only 17% and 12% of adopters and nonadopters, respectively, knew of the recommended pest control methods.

5.2.5 Wheat harvesting, transportation, and storage. Details of wheat harvesting, transportation, and storage are shown in Table 10. Adopters harvested wheat between July and August, while nonadopters harvested between September and November. Most farmers carried their harvest to storage on their heads. About 70% and 79% of farmers used their wheat for home consumption and sale, respectively. Adopters and nonadopters sold their wheat at home (63.3% and 50%, respectively) or in the market place (34.8% and 47.6%, respectively).

About 39% and 37% of adopters and nonadopters, respectively, faced wheat marketing problems. The main problems for adopters were low market prices (57.6%) and poor transport facilities (40.7%), while for nonadopters the main problems were poor transport (50%), low market prices (28.6%), and insufficient buyers (21.4%). Between 1992 and 1996, the farm gate price of wheat was significantly higher for nonadopters than for adopters at $p<0.1$ (Figure 3).

Table 10. Wheat harvesting, transportation, and storage, Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Time of harvest				
July	40	25.2	6	14.6
August	94	59.1	8	19.5
September	18	11.3	12	29.3
October/November	5	3.1	15	36.6
Method of transportation				
Headload	149	93.1	42	100.0
Carts	6	3.8	-	-
Other	5	3.1	-	-
Storage				
Gunny bags	144	92.9	40	95.2
Granary	8	5.2	2	4.8
Other	3	1.9	-	-

Most farmers stored their wheat in gunny bags. More nonadopters (21.4%) treated their wheat prior to storage than adopters (18%). Adopters (96.4%) treated their wheat with actellic super dust while nonadopters used a local treatment (50%) and actellic super dust (50%). About 26% and 28% of adopters and nonadopters, respectively, knew of the recommended methods of wheat storage.

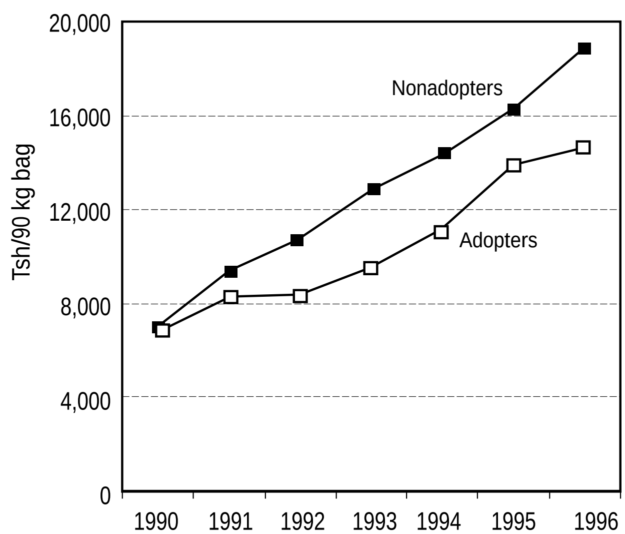

Figure 3. Wheat farm gate price (Tsh/90 kg bag) for adopters and nonadopters of improved wheat technologies, Mbeya District, Tanzania, 1990-96.

5.3 Fertilizer and Copper

Of all sample farmers, 40% of the adopters used fertilizer (Table 11). The most popular fertilizers used were urea and diammonium phosphate (DAP). About 89% of adopters applied urea between March and April, while about 84% applied DAP between February and March. Average application rates were 41 kg/ha of urea and 57 kg/ha of DAP. Most adopters (86%) applied fertilizer in bands along rows. The main reason given by all farmers for not using fertilizer was its high price. Sixteen percent of adopters knew of the recommended fertilizer rate.

About 67% and 68% of adopters and nonadopters, respectively, used crop residues to improve soil fertility. Only one adopter sprayed his crop with copper. The main reason given by both adopters (88%) and nonadopters (86%) for not using copper was a lack of knowledge. Other constraints were the unavailability of copper for 7% of adopters and 10% of nonadopters, and high price for 5% of both adopters and nonadopters.

Table 11. Fertilizer use for wheat production in Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Farmers using fertilizer	64	40.0	0	0.0
Type of fertilizer				
Urea	22	40.0	-	-
DAP	18	32.7	-	-
CAN	6	10.9	-	-
TSP	5	9.1	-	-
Other	4	7.2	-	-
Reasons for not using fertilizer				
High cost	50	55.9	15	37.5
Fertile soils	12	13.3	14	35.0
Use/prefer crop rotation	11	12.2	1	2.5
Use/prefer organic manure	0	0.0	5	12.5
Lack of knowledge	7	7.8	0	0.0
Unavailability	5	5.6	2	5.0
Other	5	5.6	3	7.5

5.4 Adoption of Improved Wheat Varieties

5.4.1 Current wheat varieties grown and sources of seed. About 79% and 21% of sample farmers grew improved and local wheat varieties, respectively. Most adopters grew the improved variety Juhudi. Nonadopters did not grow improved wheat because seed was unavailable (75.8%), they lacked knowledge of improved varieties (21.2%), or the price of seed was high (3%). About 82% of adopters and 41% of nonadopters knew of the recommended improved wheat varieties.

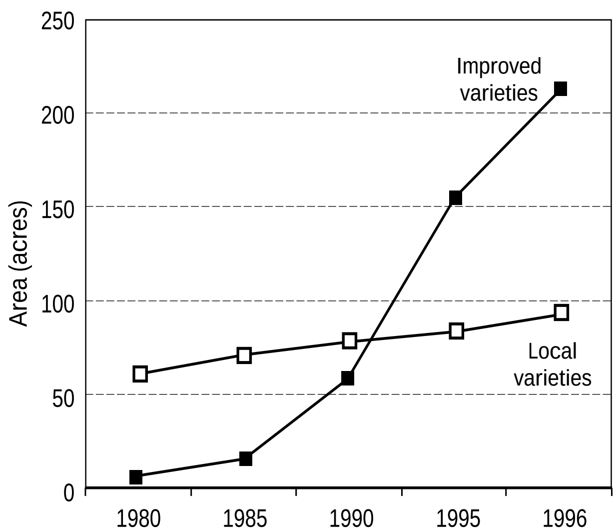

Figure 4. Total area (acres) under local and improved wheat varieties, Mbeya District, Tanzania, 1980-96.

Figure 4 shows that the improved wheat area has increased dramatically since 1990. At the time of the study, about 71% of adopters were planning to reduce the area under local wheat varieties, while about 47% of nonadopters were planning to increase the area under local wheat varieties. All nonadopters and 72% of adopters were planning to increase their improved wheat area. The main reasons given by adopters for wanting to increase improved wheat area were to make more money (40.3%), increase yield (27%), or improve food security (23.3%). Similarly, nonadopters wanted to increase their improved wheat area to make more money (38.9%), increase yield (30.6%), and improve food security (22.2%).

Adopters obtained their wheat seed from other farmers (40.5%), the local market (34.2%), research (9.5%), extension (7%), NGOs (5.7%), or other sources (3.2%). Nonadopters obtained their seed from other farmers (69%), the local market (16.7%), or used seed retained from the previous year's harvest (14.3%).

5.4.2 Preferred wheat varieties. Most adopters (91.2%) preferred Juhudi, while most nonadopters (60%) preferred local wheat varieties. Reasons for farmers' preferences are listed in Table 12. Nonadopters (65%) preferred local wheat varieties mainly because no alternatives were available. Adopters preferred Juhudi because of its high yield (47.2%), marketability (19.2%), and early maturity (10.4%). About 9% of adopters and 8% of nonadopters had discontinued growing improved wheat varieties, with Selian being the main variety dropped.

6.0 CREDIT AND EXTENSION

6.1 Credit Availability

Table 13 shows farmers' use and sources of credit in the study area. Of all sample farmers, about 11% of adopters used credit, with the most important source being the Sasakawa-Global 2000 project (SG-2000). Most adopters (87.5%) used credit to purchase inputs (seed and fertilizer). All nonadopters and 95% of adopters had difficulties obtaining credit. The main constraints were unavailability, lack of information, and complicated bureaucratic procedures. Only 7% and 2% of adopters and nonadopters, respectively, were members of a credit group.

Table 12. Reasons for farmers' preferences for local and improved wheat varieties, Mbeya District, Tanzania

Reason for preference	Percent of nonadopters preferring local wheat varieties	Percent of adopters preferring Juhudi
Grain color	5.0	6.4
High yield	5.0	47.2
Early maturity	-	10.4
Baking quality	-	8.8
Marketability	10.0	19.2
No alternatives	65.0	0.8
Other	15.0	7.2

6.2 Extension Services

Access to extension services by farmers in the study area is shown in Table 14. About 41% of adopters and 57% of nonadopters had never received a visit from an extension agent. For 33% of adopters and 32% of nonadopters, the last extension visit was

Table 13. Farmers' use and sources of credit, Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Access to credit	17	10.6	0.0	0.0
Source of credit				
SG-2000	8	50.0	-	-
IFAD/SHERFSP	3	18.8	-	-
Cooperatives	2	12.5	-	-
Other	3	18.8	-	-
Availability of credit				
Easy	8	5.2	0	0.0
Difficult	145	94.8	42	100.0
Constraints				
Unavailability	70	46.4	18	42.8
Lack of information	59	39.1	15	35.7
Bureaucracy	22	14.6	9	21.4

about one month prior to the interview for this study. About 27% and 31% of adopters and nonadopters, respectively, had been visited about
1-3 months before the study, and 22% of adopters and 21% of nonadopters had been visited about 4-6 months before the study. For 18% of adopters and 16% of nonadopters, the extension visit was received more than six months prior to the study.

About 24% of adopters and 14% of nonadopters were members of an extension group. For the adopters, the main extension group activities covered wheat production (36.6%), potato production (29.3%), and bean production (14.6%). Nonadopters received information on wheat production (50%) and bean production (33.3%). For the two farmer groups, the most important sources of information on wheat production were other farmers (57.1% and 61% for adopters and nonadopters, respectively) and extension (28.8% and 23.6%, respectively). About 12% of adopters and 5% of nonadopters had participated in on-farm research.

7.0 FACTORS AFFECTING ADOPTION OF IMPROVED WHEAT VARIETIES AND FERTILIZER

7.1 Definitions

Feder et al. (1985) defined adoption as the degree of use of a new technology in a long-run equilibrium when a farmer has all of the information about the new technology and its potential. Adoption at the farm level reflects the farmer's decision to incorporate a new technology into 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, the adoption level may not reach equilibrium. 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 the percentage of farmers using a technology at a specific point in time (e.g., the percentage of farmers using fertilizer). The intensity of adoption is defined as the aggregate level of adoption of a given technology (e.g., the number of hectares planted with improved seed).

Table 14. Access to extension services by farmers in Mbeya District, Tanzania

	Adopters		Nonadopters	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Access to extension				
None	66	41.3	24	57.1
Rarely	44	27.5	8	19.0
Regularly	50	31.3	10	23.8
Member of extension group	39	24.4	6	14.3
Participated in on-farm research	19	12.3	2	4.8

7.2 Rate of Adoption of Improved Wheat Varieties

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

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

where:

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

Figure 5 shows the rate of adoption of improved wheat varieties in the Southern Highlands. In 1997, about 74% of farmers had adopted improved wheat. The rate of adoption for 1973-97 was 0.3. The figure shows that the adoption rate of improved wheat was low between 1985 and 1989 owing to low wheat producer prices coupled with a poor marketing system.

During 1989-95, adoption of improved wheat increased for the following reasons: SG-2000 established on-farm production management training plots, which included the provision of seed and fertilizer on credit to promote the use of improved wheat technologies; the pyrethrum industry (farmers' main cash crop) collapsed, and farmers switched to wheat production as an alternative; and the market was liberalized, which resulted in higher producer prices for wheat.

Since 1995, the adoption of improved wheat has declined. The main reason for this is that SG-2000 has been phased out, which has dramatically reduced farmers' access to seed and fertilizer. Furthermore, no new improved wheat varieties have been released since 1988. As a result, improved varieties, especially the popular Juhudi, which was released over ten years ago, have lost their resistance to stem rust and foliar diseases.

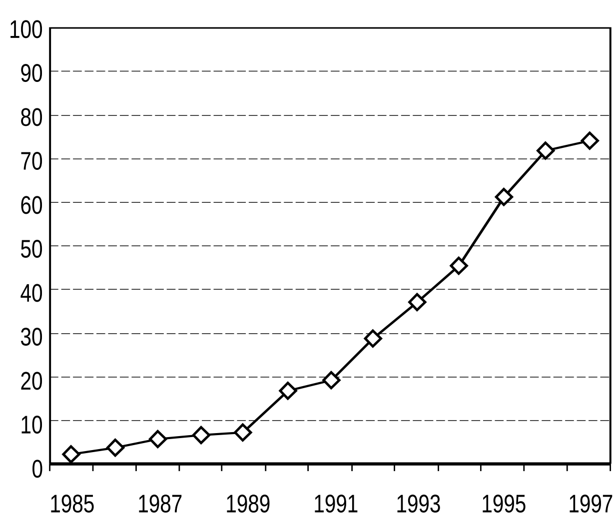

Figure 5. Rate of adoption of improved wheat in the Southern Highlands of Tanzania, 1985-98.

7.3 Tobit Analysis of Land Allocation to Improved Wheat Varieties

The tobit model results on the proportion of land allocated to improved wheat varieties are presented in Table 15. The tobit model was used because the proportion of land allocated to improved wheat seed is continuous but truncated between zero and one. The use of ordinary least squares will result in biased estimates (McDonald and Moffitt 1980). In the table, $\delta EY/\delta X_i$ shows the marginal effect of an explanatory variable on the expected value (mean proportion) of the dependent variable, $\delta EY^*/\delta X_i$ shows changes in the intensity of adoption with respect to a unit change of an independent variable among adopters, and $\delta F(z)/\delta X_i$ is the probability change among nonadopters (the probability of adopting improved wheat) with a unit change of independent variable X_i (Roncek 1992). The Wald chi-square statistic was significant at $p<0.01$.

Farm size, family size, and the use of hired labor significantly influenced the probability of land allocation to improved wheat varieties. A unit increase in farm size among adopters decreased the probability of allocating land to improved wheat by 10.3%. In the Southern Highlands, farmers with smaller farms have to intensify production by using improved wheat technologies to maximize output. Feder et al. (1985) found that farm size could have a positive or negative effect on the adoption of improved technologies. Family size increased the probability of allocating land to improved wheat among adopters by 20%. Improved wheat production requires more labor and hence large households can more easily adopt new wheat technologies. The use of hired labor increased the probability of land allocation to improved wheat among adopters by 23.8%. Farmers who can afford to hire labor are in a better position to adopt labor-intensive improved wheat technologies.

7.4 Tobit Analysis of Fertilizer Use

The coefficients of the tobit model used to investigate factors affecting the adoption and quantity of fertilizer used are shown in Table 16. The model is significant at the 1% level on the basis of the Wald chi-square statistic with 10 degrees of freedom. Farm size, family size, the use of hired labor, and credit significantly influenced the probability of fertilizer use. A unit increase in farm size among adopters decreased the probability of adopting fertilizer by 2.4%. Family size increased the probability of adopting fertilizer among adopters by 9.7%. The use of hired labor increased the probability of

Table 15. Tobit model estimates for land allocation to improved wheat varieties

Parameter	Coefficient	Wald statistic	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	0.2075	0.39	0.188539	0.11919	0.119045
Farmer's age (yr)	-0.005017	0.50	-0.004557	-0.00288	-0.002878
Education	0.25857	1.67	0.234952	0.148537	0.148344
Extension	0.010258	0.46	0.009321	0.005893	0.005885
Farm size (ha)	-0.11383	4.26**	-0.103432	-0.06539	-0.065305
Family size (no.)	0.22093	19.05***	0.200751	0.126915	0.12675
Hired labor	0.26118	2.84*	0.237324	0.150037	0.149842
Livestock (no.)	0.0511	1.86	0.046436	0.029355	0.029317
Off-farm income	0.000001	1.33	0.000009	0.000006	0.000006
Credit	-0.006186	0.00	-0.005621	-0.003554	-0.003549
Sigma	0.50095				
Number of samples	202				
Number of positive observation	160				
Proportion of positive observation (%)	79.21				
z-score	0.81				
f(z)	0.2874				
Log of likelihood function	-155.96				
Wald chi-square (β_i=0)	94.72***				

Note: * = significant at p<0.1; ** = significant at p<0.05; *** =significant at p<0.01.

Table 16. Tobit model estimates for amount of fertilizer used (N kg/ha)

Parameter	Coefficient	Wald statistic	$\delta EY/\delta X_i$	$\delta EY^*/\delta X_i$	$\delta F(z)/\delta X_i$
Constant	-0.76413	3.15*	-0.073426	-0.212437	-0.005255
Farmer's age (yr)	-0.01284	2.11	-0.001233	-0.003569	-0.000088
Education	0.42019	2.48	0.040376	0.116818	0.002889
Extension	0.52818	7.7***	0.050753	0.146840	0.003632
Farm size (ha)	-0.25331	8.26***	-0.024341	-0.070423	-0.001742
Family size (no.)	0.1031	2.85*	0.096739	0.286631	0.000709
Hired labor	0.48719	6.42***	0.046814	0.135444	0.00335
Livestock (no.)	0.05842	1.60	0.005614	0.016241	0.000402
Off-farm income (Tsh)	-0.0000005	0.16	-0.000000	-0.0000001	0.000000
Credit	0.61869	4.69**	0.059451	0.172003	0.004255
Sigma	53.12				
Number of samples	202				
Number of positive observation	68				
Proportion of positive observation (%)	33.66				
z-score	-0.42				
$f(z)$	0.3653				
Log of likelihood function	-428.35				
Wald chi-square (b_i=0)	44.07***				

Note: * = significant at p<0.1; ** = significant at p<0.05; *** =significant at p<0.01.

adopting fertilizer by 4.7%. Credit increased the probability of adopting fertilizer among adopters by 5.9%. Credit enables farmers to purchase inputs. Extension increased the probability of adopting fertilizer among adopters by 5.1%.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This study has shown that adopters of improved wheat technologies were more literate, slightly younger, had larger families, owned smaller farms, and had fewer years of farming experience compared to nonadopters. Adopters also had less area under wheat cultivation but retained more grain for home consumption, owned less livestock, had more access to credit, and more adopters supplemented their income from non-farm activities than nonadopters.

About 60% of adopters and 38% of nonadopters prepared their land at the recommended time, and 84% of adopters and 57% of nonadopters planted at the recommended time. About 33% and 2% of adopters and nonadopters, respectively, drilled their crops, and, of these, 84% of adopters used the recommended spacing of 30-40 cm between rows. Adopters also used the recommended seed rate of 120 kg/ha. The adopters used significantly more seed (134 kg/ha) for broadcasting than nonadopters (88 kg/ha), although both groups used less than the recommended rate (150 kg/ha).

Bidens was the most important weed in the study area. More adopters (77%) controlled for weeds compared to nonadopters (48%); however, more than 90% of farmers weeded only once and did not use herbicides. Leaf rust was the most important disease and 27% of adopters and 37% of nonadopters used disease control. Birds were the most important pest for adopters, while rodents were the most important pests for nonadopters. More nonadopters (41%) used pest control than adopters (27%).

Of all sample farmers, 40% of adopters used fertilizer. The adopters used about 41 kg/ha of urea and 57 kg/ha of DAP. The main constraint on using fertilizer for all farmers was its high price. About 67% and 68% of adopters and nonadopters, respectively, used crop residues to improve soil fertility. Only one adopter used copper. The main reason for not using copper for both adopters (88%) and nonadopters (86%) was lack of knowledge.

Juhudi was the improved wheat variety grown by most adopters. All nonadopters grew local wheat varieties. For both adopters and nonadopters, the most important characteristics for preferring a variety were high yield, marketability, grain color, and early maturity. Only a few farmers had discontinued growing a variety. The main reason why nonadopters did not grow improved varieties was the unavailability of seed.

Of all sample farmers, 11% of adopters used credit. The main constraints on the use of credit were unavailability, lack of information, and complicated bureaucratic procedures. About 41% of adopters and 57% of nonadopters had never received a visit from an extension agent.

In 1997, about 74% of sample farmers had adopted improved wheat varieties. The rate of adoption increased during 1989-95, mainly because SG-2000 provided seed and fertilizer to farmers, pyrethrum production collapsed so farmers grew wheat as an alternative, and markets were liberalized. Since 1995, the adoption of improved wheat has declined because the SG-2000 project has been phased out, and the varieties have become vulnerable to stem rust and foliar diseases.

The tobit analysis showed that farm size, family size, and the use of hired labor were significant factors affecting the proportion of land allocated to improved wheat. A unit increase in farm size among adopters decreased the probability of land allocation to improved wheat by about 10%, and family size increased the probability of adopting improved wheat by 20%. The use of hired labor increased the probability of adopting improved wheat by 23%.

The tobit analysis also showed that farm size, family size, the use of hired labor, and credit were significant factors affecting the amount of fertilizer used. A unit increase in farm size among adopters decreased the probability of adopting fertilizer by about 2%, and family size increased the probability of adoption by about 10%. The use of hired labor and credit increased the probability of adopting fertilizer by about 5% and 6%, respectively. Extension increased the probability of adopting fertilizer among adopters by 5.1%.

8.2 Recommendations

The results of this study have implications for everyone concerned with wheat improvement in Mbeya District. Wheat breeders should develop more wheat varieties, not only to replace the old varieties, but also to give farmers a wider choice. The popular variety Juhudi, which was released over ten years ago, has succumbed to stem rust and foliar diseases. The present fertilizer recommendations should be reviewed to take into consideration farmers' circumstances such as cash availability and soil fertility status.

Extension services should be strengthened to promote the adoption of improved wheat technologies. The formal credit market is weakly involved in supplying credit to wheat farmers, but rising input prices, especially fertilizer, make it increasingly important to ensure that farmers have access to credit. Policymakers and bankers should focus more on providing loans to small-scale wheat farmers and ensure a high rate of loan recovery and low cost of credit. Farmers should also be encouraged to form their own savings and credit cooperatives at the village level. Policymakers should continue to encourage the private sector to invest in input acquisition and distribution so that inputs (especially seed and fertilizer) are available when farmers need them.

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