CIMMYT Economics Working Paper 91/04

Chimanga Cha Makolo, Hybrids, and Composites: An Analysis of Farmers' Adoption of Maize Technology in Malawi, 1989-91

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Abstract. This paper profiles farmers' adoption behavior and varietal choices with respect to local and improved maize technologies (variety, fertilizer application, and other agronomic practices) in three agroeconomic zones of Malawi. Farmers' consumption preferences, which are related to processing and storage characteristics of flinty varieties, appear to affect adoption decisions. Even when farmers adopt improved maize technology on some of their land, they continue to sow flinty local varieties in order to meet their subsistence requirements. No single variable, however, determines farmers' adoption choices in Malawi; in choosing maize technology, farmers seek to meet multiple objectives while facing multiple constraints. The data presented in this report suggest the need for a flexible policy approach to encourage hybrid maize adoption, which would suit the complexity of farmers' adoption decisions.

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Executive Summary

Objective

This paper represents the first of several reports to be produced from data collected by researchers from CIMMYT and the Evaluation Units of the Malawian Ministry of Agriculture (MOA) during the 1989-90 and 1990-91 cropping seasons. The purpose of the CIMMYT/MOA data collection and analysis is to profile farmers' adoption behavior and varietal choices, and to elucidate how farm household factors influence farmers' selection of maize varieties in Malawi.

Based primarily on the first year of data collection, this working paper summarizes and interprets the detailed descriptive statistics from the survey. Another paper presents a causal analysis of adoption decisions.* Subsequent work will provide a time-series profile of maize technology generated from the larger ASA data set, and a companion piece relating maize yields to specific agronomic practices. The combined reports are intended to compose a statistical and informational base that government officials can use to draw policy conclusions and monitor changes in adoption behavior as new varieties are released.

Selected Findings

Selected statistics on maize technology and varietal adoption in Malawi are presented in the summary table. The most striking finding revealed by the data is the complexity of farmers' adoption patterns. Farmers' adoption decisions consist of several interrelated but distinguishable choices. The first choice—*adoption*—is the decision to adopt or not to adopt the recommended variety and related practices, and in what combination. The second choice—*extent of adoption*—is how much land to allocate to the new and old techniques. The third choice—*intensity of adoption*—is the level per hectare, or rate of application, of inputs such as fertilizer.

The percentage of farmers adopting hybrid maize seed (adoption) appears to vary sharply by agroeconomic zone. Only 14% of sample farmers in Blantyre, nearly 40% in Mzuzu, and about 33% in Kasungu sowed hybrid seed in the 1989-90 season. Few farmers in any zone grew composite maize. The proportion of farmers who used fertilizer on their local maize was similar across survey zones, although Blantyre farmers were slightly less likely than Kasungu and Mzuzu farmers to apply fertilizer to local maize. Over all zones, roughly half of

* See Smale and Heisey (1991).

Selected statistics on maize technology and varietal adoption, 1989-90

Characteristic	Agroeconomic stratum[a] Blantyre	Kasungu	Mzuzu	All strata
General				
Cultivated area (ha)	0.8*	1.4	1.5	1.2
Maize as percent of farm area	98*	84	85	89
Adoption of seed				
Percent of farmers growing:				
Local maize	97	99	97	98
Hybrid maize	14*	33	38	27
Recycled hybrid	4*	7	9	6
Composite variety	4	4	5	4
Percent of farm maize area sown to hybrid maize by adopters	30*	35	42	34
Percent of aggregate maize area in:				
Local maize	91	84	74	85
Hybrid maize	6	13	22	12
Recycled hybrid	1	2	2	2
Composite variety	1	1	2	1
Hybrid maize as percent of aggregate maize output	18	44	47	35
Adoption of fertilizer				
Percent of local maize growers apply	44*	52	58	50
Percent of hybrid maize growers apply	71*	97	97	87
Application rate of adopters (kg N/ha)				
Local maize	48*	37	37	41
Hybrid maize	64*	86*	111*	82
Other agronomic practices				
Percent of aggregate area intercropped				
Local maize	32	2	16	15
Hybrid maize	31	3	1	13
Percent of aggregate area weeded twice				
Local maize	77	54	56	63
Hybrid maize	90	68	66	76
Yield (t/ha)				
Local maize, unfertilized	0.7	0.9	0.6	0.8
Local maize, fertilized	1.2	1.4	1.2	1.3
Hybrid maize, fertilized	2.2*	3.0	2.9	2.7

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Combined figures are weighted by probability of selection. Strata n=140. Total N=420.

* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

the sample farmers fertilized local maize. Almost all farmers used fertilizer on hybrid maize, but compared to the Mzuzu and Kasungu farmers, Blantyre farmers were less likely to adopt *both* seed and fertilizer. (See Appendix B for information on changes in adoption rates during the 1990-91 season; changes were particularly apparent in the Blantyre zone.)

The average proportion of farmers' maize area allocated to hybrid maize (extent of adoption) varied little by agroeconomic zone. Farmers universally grew local maize for home consumption, and even when they chose to adopt hybrid maize, they tended to devote over 60% of their maize area to local varieties. This feature of maize varietal choice, although not unique to Malawi, appears to be more pronounced in Malawi than in other nations that have experienced similar seed-fertilizer transformations. The similarity of this pattern across agroeconomic zones also suggests that the factors affecting the land allocation decision are not necessarily the same factors that affect farmers' initial choice to sow new seed.

The third aspect of the technology adoption decision (intensity of adoption) is illustrated by farmers' choice of fertilizer application rates. The mean and modal nitrogen application rates in all three zones were near recommended levels for local maize, and in Kasungu and Mzuzu the same was true for hybrid maize. Relative to the Mzuzu and Kasungu farmers, Blantyre farmers reveal a propensity to apply higher rates of fertilizer to local maize and lower rates to hybrid maize. (This pattern was less evident in data from the 1990-91 season; see Appendix B.)

Because hybrid maize adopters continue to allocate a large proportion of their maize area to local varieties, aggregate maize area sown to hybrid varieties, recycled hybrids, and composites remains fairly low, or about 15% of the maize area in the combined survey zones. Although hybrid maize may represent a fairly small percentage of aggregate maize area, aggregate hybrid maize output constitutes a sizeable percentage of total maize output (slightly under 20% in Blantyre and over 40% in both Kasungu and Mzuzu). The fact that hybrid maize constitutes a relatively large proportion of aggregate output, and the evidence that many food-deficit farm households must and do rely on their own or purchased hybrid maize to bridge annual consumption needs, underscore the growing role of hybrid maize in both national and household food security.

Selected agronomic practices associated with local and hybrid maize varieties are also presented in the summary table. The percentage of maize area that is intercropped is highest, for either local or hybrid maize, among the Blantyre farmers. Mzuzu and Kasungu farmers, who tend to have larger land areas, are more likely to bring fallow land into maize cultivation, especially for hybrid varieties. Corresponding to general rainfall patterns, the frequency of plots planted after mid-December is higher the more northern the location, but planting is also shifted to later dates for hybrid maize in all zones. Blantyre farmers, with their limited land areas, are more likely to weed either their local or hybrid maize plots twice.

The divergent patterns found among the survey zones probably reflect differing objectives and constraints faced by farmers, some of which are hypothesized in greater detail in the text of this working paper and tested in the analytical paper. For example, most of the Blantyre hybrid maize growers learned about hybrid maize on their own or from neighboring farmers, rather than from extension agents, and purchased their inputs with cash earned from off-farm employment, rather than through the formal credit system. The combination of practices these self-styled hybrid maize growers select is distinctly different from the practices found among the full-time, larger maize producers of the Mzuzu and Kasungu zones, who are more likely to use credit and obtain extension advice.

Chimanga Cha Makolo, **Maize Hybrids, and Composites: An Analysis of Farmers' Adoption Behavior in Kasungu, Blantyre, and Mzuzu Agricultural Development Divisions, Malawi, 1989-91**

Introduction

Malawi is a nation of maize-growing smallholders. Although maize became the dominant crop only 60 to 70 years ago, over three-quarters of Malawi's cultivated area is now sown to maize each cropping season, and per capita consumption of maize as a starchy staple is one of the highest in the world. For farmers, soil fertility maintenance by traditional methods such as fallowing and rotation has become increasingly difficult as they expand their maize area and monocrop in an attempt to secure family grain requirements in the face of chronically low maize yields. Releasing land for the cultivation of other food crops that are essential to improving nutritional standards and for production of export crops that earn valuable foreign exchange cannot be accomplished without improving maize yields. As staple food requirements to sustain a growing population increase, diffusion of suitable higher yielding varieties has become a food security imperative. In the short term, land-saving technological change can be achieved in Malawi only through adoption of seed-fertilizer technology.

Relative to other sub-Saharan agricultural economies, Malawi has a high labor-land ratio that compares with ratios in some Asian nations (Binswanger and Pingali 1988) and relatively favorable agroclimatic conditions for maize production. Malawi's maize improvement program has in the past met with limited success relative to the achievements of programs in Zimbabwe and Kenya, two other major maize producers and consumers in the region (Rohrbach 1988; Gerhart 1975). The data presented in this paper demonstrate that the proportion of Malawian farmers willing to sow hybrid maize is much higher than previously reported. Aggregate area sown to hybrid maize remains relatively low, however, because even when farmers adopt hybrid maize, they continue to devote a large proportion of their maize area to local varieties. Though the aggregate fertilizer application rate is high by standards of other African countries, it is low compared to the rest of the developing world, and less than half of the rate in Kenya, a sub-Saharan country with a similar ratio of human population to arable land (Lele and Stone 1989; FAO 1989).

Certain consumption preferences of Malawian farmers, among other features of input supply and distribution, have been frequently cited as factors constraining the acceptability of improved maize varieties and hybrids. In Malawi, decision-making in farm households is motivated by the need to provide the annual staple food supply. "Maize is life (*chimanga ndi moyo*)," and the ideal of producing sufficient maize for the porridge (*nsima*) needs of the household "informs everyone's actions and rationales for their actions before, during, and after the maize harvest."[1] Malawians reveal a distinct consumption preference for the flinty varieties loosely categorized as "local" or "maize of the ancestors" (*chimanga cha makolo*). These varieties are more efficiently processed into the fine white flour (*ufa woyera*) used to prepare the preferred type of porridge, and their hard grain is more resistant to weevil attack in storage than most of the white dent hybrids introduced in the past. Yet farmers sowing hybrids tend to believe they are higher yielding on their own fields, and the evidence suggests that farmers do not reject hybrid maize on the basis of yield risk.

Consequently, hybrid maize has often been characterized and promoted as a cash crop, even though there is a perceptible substitution in consumption between local and hybrid maize varieties, particularly when a household's harvest of local maize is not sufficient to meet annual subsistence requirements. The government of Malawi has promoted hybrid seed as part of a seed-fertilizer package extended through formal credit clubs with stringent repayment requirements. Although credit club membership has facilitated adoption by relieving seasonal cash flow problems, non-members also adopt hybrid seed and fertilizer by carefully organizing the cash they obtain from selling alternative crops or from off-farm wages. Credit club membership has generally been associated with greater chances of personal attention from extension workers. Currently, in recognition of the need to address a wider range of technological options, the government has begun to provide technology packages of varying size and composition. The Department of Agriculture has also initiated a revised extension program to disseminate technological information to a more broadly representative base of farmers.

The Department of Agricultural Research, in response to the growing concern for household food security in Malawi, released two new flintier hybrids at the beginning of the 1991-92 cropping season. The data assembled in this report profile farmers' adoption patterns at an historical juncture in Malawi's maize improvement program, against which the relative success of the flintier hybrids can in the future be compared.

Objective

This paper is the first of several reports to be produced from data on maize technology and varietal adoption collected by researchers from CIMMYT and the Evaluation Units of the Ministry of Agriculture (MOA) during the 1989-90 and 1990-91 cropping seasons. The purpose of the CIMMYT/MOA effort is to

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1 From villagers' statements, cited by Peters (1988).

profile farmers' adoption behavior and varietal choices, and to elucidate how farm household factors influence farmers' selection of maize varieties in Malawi.

Based primarily on the first year of data collection, this working paper summarizes and interprets the detailed descriptive statistics from the survey. Another paper presents a causal analysis of adoption decisions.[2] Subsequent work will provide a time-series profile of maize technology generated from the larger ASA data set, and a companion piece relating maize yields to specific agronomic practices. The combined reports are intended to compose a statistical and informational base that government officials can use to draw policy conclusions and monitor changes in adoption behavior as new varieties are released.

Coverage

The CIMMYT/MOA Maize Variety and Technology Adoption Survey (MVTS) was administered in three of the five major maize-producing Agricultural Development Divisions (ADDs) of Malawi to a subset of households participating in the Annual Survey of Agriculture (ASA). Following the recommendations of the Department of Agricultural Research, segments of Blantyre, Kasungu, and Mzuzu ADDs were chosen as representative of contrasting agroecological and economic characteristics found among major maize-producing regions.[3]

Within each ADD, households were selected from the multi-stage, stratified cluster sampling frame designed by the National Statistical Office for the ASA. The survey households form a statistical sample drawn with equal probability of selection within each of the three zones and varying probability of selection between zones. Statistical statements generated from the data are broadly representative of farm households located in the major maize-producing, higher potential adoption areas of Malawi. Details of the survey design are included in Appendix A.

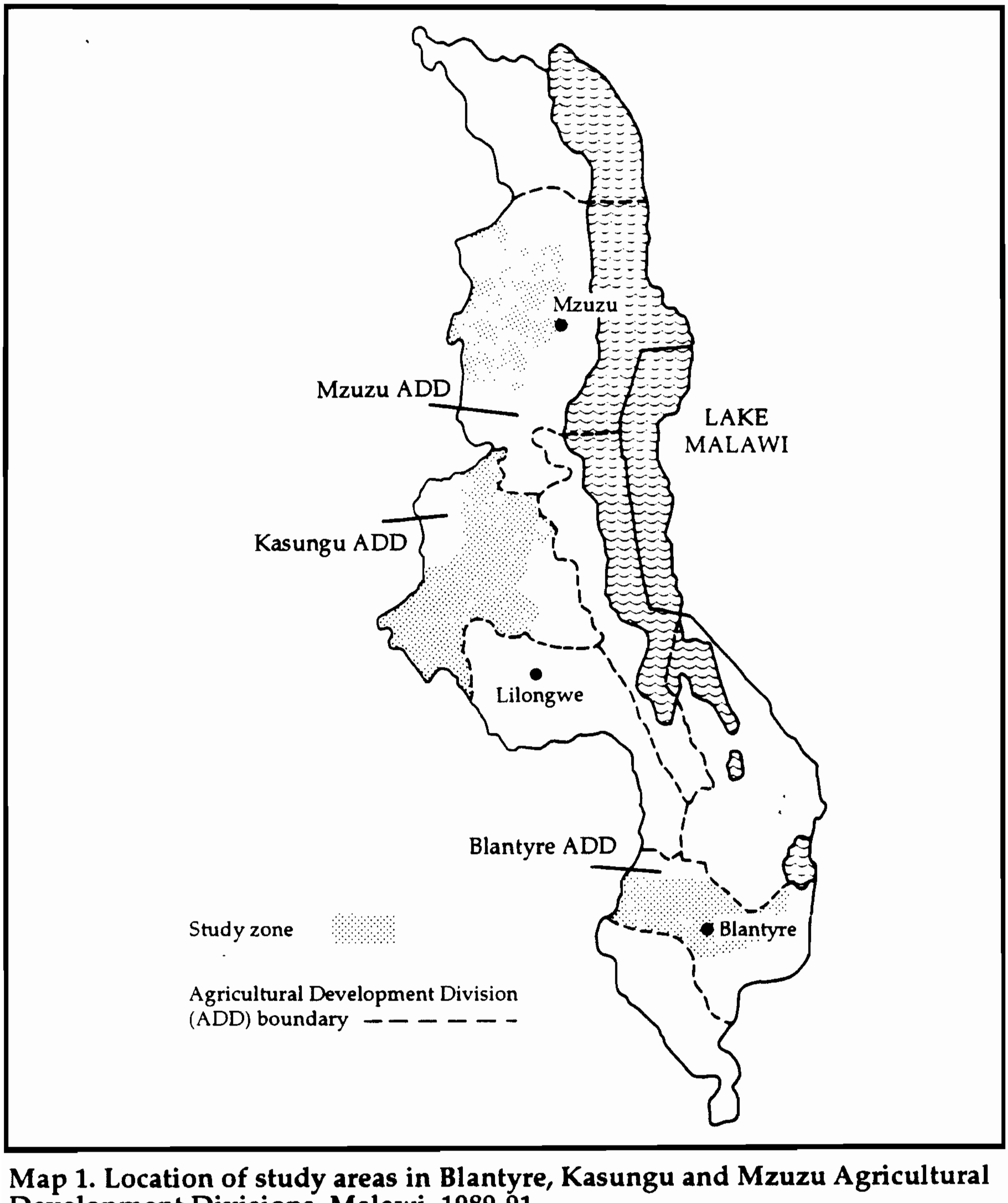
Three Distinct Settings for Technology Adoption

The three zones under study are known to represent potential adoption areas with distinct agroecological and economic features, and constitute the strata for the MVTS (Map 1). Farmers in the more densely populated Blantyre region

2 See Smale and Heisey (1991).

3 The low-altitude, warmer Lakeshore Region is not represented within the zones. Although the Lakeshore zone is not a major maize-producing region, the Department of Agricultural Research has developed composite and hybrid maize varieties suitable for that environment, and future work should evaluate the success of these materials.

cultivate smaller areas under a wider range of microclimatic and soil conditions, with a longer history of estate agriculture. Farmers in the Kasungu survey zone cultivate the more fertile soils of the Central Plains, under a relatively homogeneous rainfall and temperature regime. Of the survey zones, the Kasungu stratum is today the foremost maize and tobacco producer. The Mzuzu stratum consists of more sparsely populated areas of Mzimba District, historically organized as one large political unit. The agroclimate of the cultivated areas of this stratum is broadly similar to that of Kasungu.



Map 1. Location of study areas in Blantyre, Kasungu and Mzuzu Agricultural Development Divisions, Malawi, 1989-91.

The survey data confirm the varying household economic characteristics that reflect these underlying differences between strata. Characteristics that are particularly relevant to the maize technology adoption decision are summarized in Table 1 by zone, and illustrate the differing contexts that frame the technological options of farm households in the three strata.[4]

Farmers in the Blantyre region are less likely to be credit club members, more likely to be female, and less likely to have formal education (Table 1). Their households earn relatively high off-farm incomes, both absolutely and as a proportion of total annual income. Their average earnings from livestock sales and remittances are almost negligible, and because they have little land to sow to crops other than maize, the value of their non-maize output is also limited. Although almost all the area they cultivate is sown to maize as a primary crop, their total cultivated area is only half that of the Kasungu and Mzuzu farmers, and the total value of their maize output is also dramatically lower.[5]

Given their relatively high off-farm earnings, the total non-maize income flow of Blantyre farmers is not statistically lower than that of the Mzuzu and Kasungu farmers. Although farmers in Mzuzu and Kasungu may have greater credit opportunities, Blantyre farmers have organized their household labor resources so that they can use cash, if possible, to finance their maize production. Opportunities for casual off-farm labor and payment in kind for farm labor (*ganyu*) by family members appear to be greater among many of the Blantyre farmers, because of their proximity to towns and estates. Relative to Mzuzu and Kasungu farmers, Blantyre farmers could be termed part-time farmers, based on the value of their non-farm output relative to total income flows. The principal

4 In the Kasungu ASA design for 1989-90, the last five households in each cluster of 20 were purposively selected as members of credit clubs, whereas the first 15 were drawn by systematically random sampling from the full household lists for each cluster, as is usually the procedure. The statistics in the tables are presented either for the full Kasungu sample or the 15-household-based sample, depending on whether each statistic differed between the two samples. The full sample of Kasungu farmers numbers 140; the subset (which does not include those selected from credit club members) numbers 105. Few variables differed between the groups. Notably, these included the probability of credit club membership, probability of sowing any hybrid maize, value of non-maize output, and aggregate maize area estimates for local and hybrid maize. Most statistics reported in the following tables were not affected significantly, and in order to retain as many degrees of freedom as possible, they are based on the sample of 140.

5 The estimated value of income from intercropping has not been included because of difficulties in measuring and valuing the intercrop output, although intercrop output may often contribute substantially to the value of the farm household's production. Similarly, *dimba* (dry season hand-irrigated gardens) and horticultural crop production are not generally measured in the ASA, although these clearly contribute significantly to income, especially in the hungry season, for many households. Other surveys, such as the Food Security and Nutrition Survey, have revealed the importance of *dimba* and successive crops in relieving seasonal food shortages.

objective for many of these farmers may be to assure a relatively cheap food supply, while seeking more remunerative off-farm activities.[6]

With their comparatively large off-farm earnings, Blantyre farmers are able to spend as much on total hired labor in maize production, and more per hectare, than farmers in the other two survey zones. They spend less on fertilizer both

Table 1. Farm household characteristics by agroeconomic stratum, 1989-90

Characteristic	Agroeconomic stratum[a]		
	Blantyre	Kasungu	Mzuzu
Sociodemographic			
Percent of farm operators:			
Female	36*	16	21
Credit club members	16*	35	32
Any formal education	61*	72	73
Farm size			
Average cultivated area (ha)	0.8*	1.4	1.5
Average percent of cultivated area in maize	98*	84	85
Household income flows			
Mean non-maize income flows (MK/yr):			
Off-farm earnings	190	85*	146
Value of livestock sales	5*	39	37
Net returns from non-maize crops	7*	148*	66*
Remittances	6	7	28*
Mean value of maize output (MK/yr)	229*	481	495
Cash maize production expenditures per year (MK/yr)			
Mean fertilizer expenditures	25*	60*	98*
Seed costs	6*	12*	17*
Mean payments to hired labor	14	7*	12
Mean expenditures, other purchased inputs[b]	0*	7	7
Total cash maize production expenditures	45*	86*	134*

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.
[b] Pesticide, input and harvest transport, and oxen hired for land preparation.
* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

6 Parts of the southern region of Malawi, represented here by the Blantyre survey zone, resemble the kind of rural economy described and modeled by Low (1986) in his farm household model for southern Africa. In that model, rural-urban migration and relative wages play an important role in declining food crop productivity.

because they fertilize smaller areas and perhaps because they tend to purchase with cash rather than credit. Their total cash expenditures on maize are also lower because they farm a smaller area and transport their maize harvest without oxen.

Farm operators in Mzuzu and Kasungu are more likely to be credit club members, male, and formally educated (Table 1). A higher proportion of Mzuzu farmers, in particular, have five or more years of education. Both Kasungu and Mzuzu farmers tend to cultivate similar total areas, non-maize areas, and maize areas. Maize as a proportion of their total cultivated area, although high, is lower than for the Blantyre farmers. For Mzuzu farmers, maize is not only a food crop but also a cash crop, and they rely on the value of maize output for by far the largest share of their annual income. Among the survey farmers, they were more likely to have carried maize stocks from the 1988-89 season to planting time, although this finding may be conditional on the previous season's weather conditions or a more general pattern.

Value of livestock sales, remittances, and net returns from non-maize farm output do supplement the income flows of Mzuzu farmers, but compared to Kasungu farmers, these farmers tend to have fewer opportunities to grow highly valuable alternative crops. The most frequent alternative crops found among the Mzuzu survey farmers were, in order of importance, millet, groundnuts, cassava, and sweet potato. Millet, one of the staple foods before maize became the dominant crop, is now important to Mzuzu farmers in brewing beer for social gatherings and sale. Although millet has a high value relative to the inputs required, it is probably not as remunerative as tobacco. With their extensive land area, most of which is allocated to maize,[7] Mzuzu farmers spend more on maize production than farmers in the other strata, hiring labor and using oxen more frequently to prepare land and transport the harvest.

The distinguishing household characteristic of Kasungu farmers, compared to the Mzuzu farmers, is the greater importance of net returns from non-maize output in their annual income flows, which results primarily from tobacco sales. Most frequently the Kasungu survey farmers grew groundnuts and tobacco, with some sweet potato and beans. As stated above, the proportion of cultivated area they allocate to maize is similar to that of the Mzuzu farmers. (Appendix B describes changes in the 1990-91 season, when a larger proportion of household cultivated area in Kasungu was sown to crops other than maize.) They also spend more and earn more from their maize production than Blantyre farmers, fertilizing larger areas and using oxen in land preparation and transport.

7 According the ASA results from Mzuzu ADD, the mean percentage of household cultivated area allocated to maize has been increasing steadily over at least the past four years, from 67.4% in 1986-87 to 84.1% in 1989-90.

A Universal Consumption Preference for Local Maize

Despite the many differences among zones, farmers stated almost universally that they preferred local maize for consumption and consume their own or purchased local maize during more than six months of a typical year (Table 2). Consumption of a variety for over six months of the year, over the past few years, was interpreted to mean "usual" consumption, and over 95% of all households usually consume local maize. Only one or two households in the full sample of 420 households have changed their consumption preferences toward hybrid maize, despite the fact that over three-quarters of the households in all zones consume their own hybrid maize in years of poor local maize harvests or duress.[8]

The preference for consuming local maize is based primarily on processing and storage characteristics, which are related to the flintiness of the varieties. Historically, the maize known as "local" or "maize of the ancestors" has had a higher proportion of hard starch than is found in the denty hybrids. The hard grains tend to store better without chemical treatment.

The traditional methods used to produce the socially preferred, fine white flour (*ufa woyera*) involve multiple stages and are labor intensive. Typically, shelled maize is dehulled with a mortar and pestle, winnowed, soaked for lactic fermentation, dried, and pounded again by mortar and pestle or, increasingly, by hammer-mill. Some of the denty hybrids can be used to produce *ufa woyera*, but their relative softness leads to a lower flour extraction rate, and additional sand and water are often needed to create a proper pounding medium. Otherwise, hybrid maize can be processed more quickly by hammer-mill and without lactic fermentation to produce a nutritious, although coarser and less prestigious, flour (*mgaiwa*).

Observers of hybrid maize adoption patterns in Malawi and other zones where local varieties are flinty have often speculated that, when labor-saving mills are widely introduced in rural areas, households will find it optimal to substitute milled grain for the traditionally preferred fine white flour so painstakingly produced through repeated stages of pounding by hand. Once again, Malawians appear to have defied such easy explanations—almost all the women

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8 Maize-deficit households are obliged to consume hybrid maize because it constitutes most of the maize available on the official market during the hungry season. Local maize can sometimes be purchased or obtained from other farmers through *ganyu*, but only a small percentage of farmers produce a surplus of local maize, and even fewer are willing to part with local maize. Instead, it is often the poorer households who must sell a basket or a bag of local maize to meet some pressing cash need.

respondents in each survey zone have combined the traditional with the modern method. They continue to pound by hand, but whereas they used to pound two or three times, they now substitute grinding at the local mill for the final stage in the traditional process.[9]

Most hybrid maize adopters do occasionally consume a portion of their own hybrid maize harvest as a means of bridging food requirements, although less so in Mzuzu. Many report, as expected, that they suffer efficiency losses in pounding hybrid maize (a lower grain-flour extraction rate). Others also state that when *ufa woyera* is made from hybrid maize flour, they need larger amounts of flour to produce the same amount of *nsima*. These findings are well known.

Table 2. Maize varietal consumption, processing, and storage characteristics, by agroeconomic stratum

Characteristic	Agroeconomic stratum[a]		
	Blantyre	Kasungu	Mzuzu
Consumption preferences			
Percent of households:			
Prefer to consume local maize	99	99	99
Consume local maize more than 6 mo/yr	98	96	99
Changed preferred variety in past 5 years	0	0	1
Consumed hybrid maize in the hungry season	78	89	78
Processing of local maize			
Percent of women pounding by hand once or twice and also taking the flour to the hammer mill	94	99	92
Processing of hybrid maize by adopters[b]			
Percent of adopters not consuming their own hybrid maize	7	0	19
Percent of adopters who have problems pounding hybrid maize	79	88	71
Percent of adopters solving pounding problems by:			
Eating *mgaiwa*	30	8	10
Using different pounding methods	35	60	51
Storage of hybrid maize by adopters[b]			
Percent of adopters not storing hybrid maize	33	13	29
Percent of adopters solving weevil problems by:			
Applying actellic	44	16	8
Consuming maize soon after harvest	16	61	40
Percent of adopters not solving problem	7	3	19

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

[b] Residual categories not listed.

9 R. T. Ellis (1959) noted the same occurrence as long ago as the late 1950s.

What is less well known is that a large percentage of adopters try to solve the problem by pounding differently—rather than by consuming *mgaiwa*. For example, women often pound hybrid maize with larger amounts of sand and water for a shorter period of time and soak the maize for fewer days. Some are more successful than others in producing an acceptable *ufa woyera*. The Blantyre households do seem comparatively more willing to consume *mgaiwa*, perhaps because they have less experience modifying their pounding methods or perhaps because a larger proportion of them are food-deficit households which have grown accustomed to consuming *mgaiwa* in the hungry season.

A smaller proportion of hybrid maize adopters store their hybrid maize than consume it, and a large proportion of them, especially in the Kasungu and Mzuzu zones, consume it soon after the maize harvest rather than apply actellic. Perhaps the relatively high percentage of Blantyre farmers who stated that they apply actellic are the recent adopters who are following recommendations (see Appendix B). Following the recommended treatment is also easier for Blantyre hybrid maize growers because they produce a much smaller volume of the total hybrid output. The proportion of their maize area they sow in hybrid maize is lower, and their total maize area is considerably smaller.[10]

In general, a higher percentage of the Kasungu farmers, and a lower percentage of Mzuzu farmers, consume and store some of their own hybrid maize output. The Mzuzu farmers produce hybrid maize as their principal cash crop, and are more likely to sell all of their hybrid output. The average proportion of their hybrid maize production saved for consumption by hybrid growers in their last (pre- 1989-90) harvest was about 50% in Blantyre and Kasungu, and only about 20% in Mzuzu. Since the Mzuzu farmers normally carry over more local maize from one harvest to another but have less valuable non-maize crops, this difference probably reflects their ability to satisfy their consumption requirements and the need to sell at least some hybrid maize to meet their credit repayments. The Kasungu figure probably reflects farmers' willingness to substitute hybrid maize for local maize in consumption, combined with their capacity to repay loans through sales of higher value non-maize crops.

Farmers' hybrid maize output is not an unimportant factor in household food security, despite the prestige of *ufa woyera*, the lower extraction rates from processing hybrid maize for *ufa woyera*, and storage losses that occur when actellic is not applied. For the majority of farm households, who purchase from ADMARC rather than from other farmers, the data also indicate that the modal consumption period for hybrid maize, over the past few years, has been approximately two months, across strata. Whether farm households like it or

10 Other strategies for solving weevil problems that are not reported in Table 2 include applying tung oil, tobacco dust, millet husks, ash, and DDT.

not, they are often obliged by their production and market conditions to consume denty hybrid maize.[11]

Toward a Taxonomy of Local Maize

Whether or not varietal consumption preferences change over time will be affected not only by the release of flintier hybrids but also by the quality and characteristics of local seed. Certainly in regions where a number of imported varieties have been introduced in the past, cross-pollination has occurred. Where food-deficit households who are obliged to consume their seed actually sow dent varieties obtained as food, the degree of contamination of local maize must be noticeable to farmers. Under these conditions, over time, the polarity between the flintiness of local maize and dentiness of existing hybrids becomes less clear.

The term "local" is usually associated with certain traits in maize, such as flintiness and whiteness. *Cha makolo* means "maize of the ancestors," or a gift conferred by families through generations. Some researchers have suggested that "local" is not so much a term referring to grain characteristics, and that *cha makolo* does not literally describe the origin of the seed, but that both terms signify the seed's institutional affiliation. In some sense, "local" maize is the maize of rural people or of farmers. By contrast, released varieties are brought to the locality from outside (formal) institutions, whether national or international (Hansen 1986). Occasionally, survey farmers called hybrid maize *chimanga cha boma,* which means, in common parlance, "maize of the government."[12] Since hybrid seed is either purchased or provided on credit, which is repaid by selling at least some of the harvest, farmers probably do not perceive that the seed is their own or was produced with their long-term interests in mind.

In the CIMMYT/MOA survey, enumerators questioned farmers extensively about the origin of what they called *cha makolo* or *lokolo,* seeking alternative names in Chichewa or Chitumbuka and information about how long the seed had been retained. The descriptive data they collected in their farmer interviews provide some new insights into the composition of local maize (Table 3).

First, there are indeed, after over 60 years of intensive maize production and continual infusion of imported and nationally released varieties, some types of maize that farmers identify by special traits in addition to those usually associated with local maize (flintiness, whiteness, and resistance to weevils).

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11 Other DAR and Evaluation researchers are also currently investigating consumption preferences, processing, and any grain price differentials that reflect the higher extraction rates associated with local maize.

12 The origin of the word *boma* is British Overseas Military Administration, administrative bases in colonial territories.

Some farmers claim to select and maintain seed with special traits such as early maturity, variegated grain color, and suitability for roasting or producing sweet beer. Other farmers sow maize seed with special grain characteristics, although these are not major factors they consider in seed selection. Listed in Table 3 as "special trait local," these types include Kafula (early maturing), Kampalapate or Kachiswe (kernels narrow at the neck, as if eaten by termites), Kaluluwede (purple and white grains), Mtsakinya (yellow grain), Kambirinje (white and yellow grain), Kanjere-njere waung'ono (early maturing, with a small tassel at the end of the cob), Chimutumapanga (two-headed), Kagolo (early maturing), Chisowa (purplish), Sereta (early maturing, large grained), and Kalibangweni (early maturing, yellow and white grains). Most of the farmers reporting special names were found in the Mzuzu group, the "maize seed specialists" among the groups. Although technically these maize types do not represent varieties, their existence indicates the continued cultural importance of seed selection and retention in the locality.

Second, farmers refer to some of their local seed by the names of previously introduced composites and hybrids, such as Bingo (LH11) and Asikari (SV17), which are listed in Table 3 as "old improved material." This finding is both an indicator of previous adoption activity and of varietal contamination. Again, farmers in the Mzuzu group and, to some extent, the Kasungu group, were more likely to cite such varieties, although the predominant named local variety among the Kasungu farmers was Bantum, the origin of which is not well known.

Table 3. Local maize seed characteristics, by agroeconomic stratum

	Agroeconomic stratum[a]		
Characteristic	**Blantyre**	**Kasungu**	**Mzuzu**
Genetic traits of local maize seed[b]			
Percent of farmers growing:			
Old improved variety	0*	11*	27*
Local variety with special traits	16*	3*	29*
Unknown origin, generic local maize	92	89	54*
Seed retention and purchase			
Percent of (generic) local maize growers planting:			
Seed retained over 10 years, inherited, or received as a gift	55*	76	80
Seed purchased or obtained through *ganyu* within the last 10 years	45*	24	20

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.
[b] Columns do not total because farmers grow more than one variety.
* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

From the standpoint of knowledge of local seed with special traits, and from the standpoint of past adoption activity, Blantyre farmers did not express themselves as well, although a number of special trait local names were found on the Phalombe Plain. Seed identified only as *cha makolo* was categorized as "generic local," and most of the local seed sown by Blantyre farmers fell into this category.

Only a certain proportion of local seed even suits the *cha makolo* definition literally. Although the evidence should only be taken roughly, the farmer interviews suggest that much of the *cha makolo* was actually purchased on the local market or obtained fairly recently through *ganyu*. Especially among food-deficit households in the Blantyre group, retaining seed from year to year has either become difficult or is not perceived as important. Although maize seed purchased locally appears to be of "local" origin as opposed to being directly "introduced," it may be a genetic mixture of many varieties, and the farmer no longer retains control or knowledge of its genetic content. *Cha makolo* also occasionally included such names as "Bera," for example, which may describe a variety originally imported from the port of Beira. Bera is generally large grained and fairly denty, and "Bera" sometimes refers to hybrid maize.

These findings indicate considerable variation within the "local" category, including introduced varieties, maize purchased as food, seed inherited through generations, and seed of maize with particular traits such as early maturity and variegated grain color. Although the figures suggest a high degree of contamination of local seed, the sample farmers, almost all of whom select their seed from the *nkhokwe* (traditional storage unit) rather than from the field, frequently stated that they search for flintiness and weevil resistance. Other names of local maize cited by farmers referred to desired traits, such as *ntuwa* (white), *kafupa* (hard as a bone), and *mkangala* (hard in pounding).[13] Flintiness is still an important trait and one which farmers associate with local maize, despite the mixed genetic characteristics of much of the maize they categorize as local.

Characteristics of the Maize Technology Adoption Decision

Three Technology Adoption Choices

Farmers' adoption of improved seed-fertilizer technology consists of three interrelated but conceptually distinct decisions. The first, *adoption*, is the choice of whether to adopt the components of the recommended technology (seed, fertilizer) and in which sequence or combination (seed only, fertilizer only, or

13 *Mkangala* is also a name used to identify local maize in Eastern Province, Zambia.

both). The second, *extent of adoption*, is the choice of how much land to allocate to new and old technologies. The third, *intensity of adoption*, is the choice of the level per hectare or rate of application, if fertilizer is adopted. The combination of these three decisions on any individual farm composes the technology adoption decision, and, aggregated over farms, national area and production figures by technology. The purpose of separating the components of the technology adoption decision is to illustrate how farmers in Malawi choose a variety of technological options in an attempt to satisfy their multiple objectives. The complexity of their decisions, and therefore the nature of adoption behavior, is obscured in the national aggregates.

The Decision to Adopt

The data show that, consistent with their consumption preferences, almost all farmers in each stratum grow some local maize (Table 4). The percentage of farmers also growing hybrid maize differs sharply between Blantyre and the other zones. In Blantyre, only 14% of the farmers grew hybrid maize in the 1989-90 season. In Mzuzu, two in five farmers grew hybrid maize, and in Kasungu, around one-third. (See Appendix B for changes in adoption rates in the 1990-91 season.)

As a percentage of all hybrid maize growers, recyclers are equally frequent in all strata, or about 20%. A recycler is a farmer who, instead of purchasing new hybrid seed each year, retains harvested grain as seed for the following season. Recycling results from late seed deliveries, receipt of seed as a gift from friends or relatives, farmers' desire to reduce the size of a seasonal loan, or farmers' belief that they will not suffer a large yield decrease. A very small proportion of farmers appear to have planted either new or recycled composite maize last season, and the proportion is similar across zones.[14]

The proportion of households applying fertilizer to their local maize is also similar across strata, or roughly half of all farmers (Table 4). Although the proportion of hybrid maize adopters varies by zone, almost all farmers who grow hybrid maize apply fertilizer to it. Despite the fact that they are less likely to belong to clubs, Blantyre farmers manage to adopt fertilizer on local maize almost as frequently as the Mzuzu and Kasungu farmers. When they adopt hybrid maize, they are slightly less likely to apply fertilizer.[15] (See Appendix B for changes in the 1990-91 season.)

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14 Enumerators found few farmers sowing composites, even though they attempted to identify composites by discussing the origin of the seed with farmers. More farmers claimed to remember having sown composites at some point in the past.

Major factors associated with opportunities for adoption, such as total land area per household, sex of household head (where it relates to wealth and access to services), credit, and opportunities to earn cash vary significantly between the agroeconomic zones, as does the percentage of hybrid adopters. Further multivariate analysis is required to isolate the distinct causal relationships among the variables, but the descriptive data in Table 5 tentatively confirm the more obvious relationships among categorical variables.

Table 4. Adoption and maize area allocation to technologies, by agroeconomic stratum, 1989-90

Characteristic	Agroeconomic stratum[a]		
	Blantyre	Kasungu	Mzuzu
Adoption of seed			
Percent of farmers sowing:			
Local maize	97	99	97
Hybrid maize	14*	33	38
Recycled hybrid	4	7	9
Composite variety	4	4	5
Adoption of fertilizer by farmers sowing variety			
Percent of farmers fertilizing:			
Local maize	44*	51	59
Hybrid maize	74*	97	98
Maize area allocation by farmers sowing hybrid maize			
Mean percent of area sown to:			
Local maize	62	62	54*
Hybrid maize	30*	35	42
Recycled hybrid	7*	3	4
Composite variety	1	—	—
Mean percent of area fertilized:			
Local maize	87	89	76*
Hybrid maize	100	99	99

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

15 The proportion of farmers who apply phosphorus to local maize is less than the proportion of farmers who apply nitrogen in all three maize survey zones, and is particularly low in Blantyre. The proportion of farmers fertilizing hybrid maize who use phosphorus is higher than the proportion of farmers fertilizing local maize who also use phosphorus, although this figure is also relatively low in Blantyre. In Malawi, the fertilizer that smallholders can purchase or obtain on credit consists of nitrogen only or of compounds combining both nitrogen and phosphorus. The data therefore imply that among fertilizer users, application of compound fertilizer is more likely on hybrid maize than on local, and more likely in Mzuzu and Kasungu than in Blantyre.

For the full sample, sex of household head, credit club membership, and farm size class are associated significantly with the probability of hybrid adoption. Wealth influences opportunities for adoption, and credit relaxes expenditure constraints, facilitating adoption—if only for a season. The larger the land area, the more likely is the household to qualify for credit or to have alternative crops that can generate cash income. Female heads of households who are divorced or widowed tend to be less wealthy and are less likely to be club members—and therefore have fewer opportunities to adopt.

The descriptive statistics alone are not sufficient to imply that any of these factors causes adoption, however. About 17% of female-headed households and the same percent of operators who are not credit club members planted hybrid maize in the 1989-90 season. Figures for Mzuzu ADD in particular indicate that, before ADMARC outlets were removed, the proportion of farmers purchasing inputs with cash was nearly twice the 1989-90 figure.[16] Other household factors cited above also vary by stratum and are likely to be associated with the decision to

Table 5. Relationship of credit, sex of household head, farm size class, and hybrid maize adoption

Household characteristic/ subgroup	Adoption characteristic: Percent of subgroup sowing hybrid maize	Adoption characteristic: Mean percent of maize area sown to hybrid maize by adopters
Sex of household head*		
Female	17	39
Male	38	43
Credit club membership*		
Yes	76	44
No	17	40
Farm size class*		
< 0.7 ha	13	44
0.7 - 1.5 ha	36	44
> 1.5 ha	56	37

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
* Indicates statistically significant differences between subgroups (5%), pairwise Chi-square or t-test.

16 The ASA figures from Mzuzu ADD demonstrate that the proportion of fertilizer users purchasing fertilizer with cash was between 60% and 76% for the 1986-87 through 1988-89 cropping seasons. In 1989-90, the proportion dropped to about 40%, probably reflecting the fact that ADMARC input sheds were withdrawn and inputs became more difficult to obtain with cash.

adopt. For example, Blantyre farmers had lower yield perceptions for all technologies, and less experience with new varieties (see later tables in this paper).

Extent of Adoption: Maize Area Allocated to Different Maize Types

Although the maize area allocated to hybrid and local maize varies among adopters, the mean proportion of their maize area they allocate to hybrid maize does not differ much by agroeconomic zone (Table 4). Unlike adoption probabilities, the mean proportion of maize area that adopters sow to hybrid maize is not associated significantly with sex of household head, credit club membership, or farm size class (Table 5). The land allocation aspect of the technology adoption decision reflects the need or desire of almost all farm households to produce sufficient local maize for home consumption and probably varies instead with family food requirements as a proportion of the output attainable from a household's total land area. Adopters tend to allocate less than half of their maize area to hybrid or recycled hybrid maize.

As with the initial adoption decision, differing objectives and constraints probably also affect the allocation decision. For example, one of the larger subsets of hybrid maize farmers in the Blantyre zone was found in Thyolo. These farmers grew short-season hybrid maize on tiny plots to consume or sell green in Blantyre, for supplementary food or cash during the hungry season. They also worked off of the farm to meet their local maize consumption needs and to buy their inputs in town. By contrast, some of the hybrid maize farmers in the northern Kasungu and Mzuzu areas had sold over 2 t of hybrid maize in the previous year, producing 3-4 t/ha of grain by applying high analysis fertilizer and using animal draft power for land preparation. These farmers also had enough land to produce large outputs of local maize, satisfying their consumption requirements at the same time that they earned profits from their hybrid maize. Both sets of farms may have grown hybrid maize, but with different land allocations and for different economic reasons.[17]

Although not unique to Malawi, the land allocation characteristic of Malawian farmers' adoption decision is nevertheless pronounced, both in its relative uniformity and as a reflection of the strong consumption preferences farmers revealed. The fact that 30-40% of farmers in Mzuzu and Kasungu grow some hybrid maize is an encouraging statement about their desire to experiment with maize varieties or to diversify their maize production prospects by growing

17 The fact that, in the past, credit packages have consisted of seed and fertilizer in fixed quantities also means that land allocated to hybrid maize by credit users has also exhibited a lumpiness around 0.4-ha (1-acre) intervals. For hybrid maize growers who are not credit club members, there is greater variation in hybrid maize hectareage. As packages are increasingly provided in various sizes, the lumpy pattern of allocation will undoubtedly diminish.

several varieties simultaneously. The fact that these farmers continue to allocate such a large proportion of land to local maize, even when they adopt hybrid maize, suggests a predominant and persistent preference for local varieties.

Growing several varieties simultaneously also allows farmers to exploit differing varietal characteristics, such as time to maturity, and to avoid the effects of dry spells during certain physiological stages of crop development. Such diversification can be viewed as an important risk management strategy. For that reason, encouraging farmers to reduce the number of varieties they sow may not be desirable.

Extent of Adoption: Maize Area Allocation to Fertilizer

When farmers use fertilizer on their local maize, they often fertilize some, but not all, of their plots. The data suggest that, rather than applying the fertilizer they can afford over all their local maize area, many farmers who use fertilizer on local maize allocate it to only a portion of their fields. An agronomic explanation for this choice could be differential soil fertility among plots; an economic justification could be hidden labor or other costs associated with attempting to cover broader areas less intensively. Finally, some farmers may feel obliged to follow extension recommendations closely, even when they could obtain a higher economic return by allocating slightly lower amounts to all of their local maize area.

The mean percentage of their local maize area that farmers fertilize is similar among zones: above 80% in Blantyre and Kasungu and just below 80% in Mzuzu. By contrast, most farmers who grow hybrid maize use fertilizer and apply it to all their hybrid maize area.

Intensity of Adoption: Fertilizer Application Rates

The distributions of rates of fertilizer application, as measured in nitrogen nutrient kilograms per hectare, differ by stratum. One reason for these differences is that those purchasing fertilizer with cash rather than credit tend to use the older, low analysis fertilizers. Farmers who purchase with cash may also experiment more with combinations of fertilizers, since they are less concerned about following recommendations as closely as club members who are in more frequent contact with extension agents and must repay their loans. Finally, the rate of fertilizer application by variety may depend on the objectives of the farmers—whether they seek to maximize profits from their hybrid maize production, given that they meet minimum consumption requirements for local maize, or whether they seek to maximize their local maize yields, obtaining a little supplementary cash from hybrid maize sales.

Figures 1a and 1b show the percentage distribution of farmers applying fertilizer, by nitrogen nutrient per hectare, for the three strata, and each variety.[18]

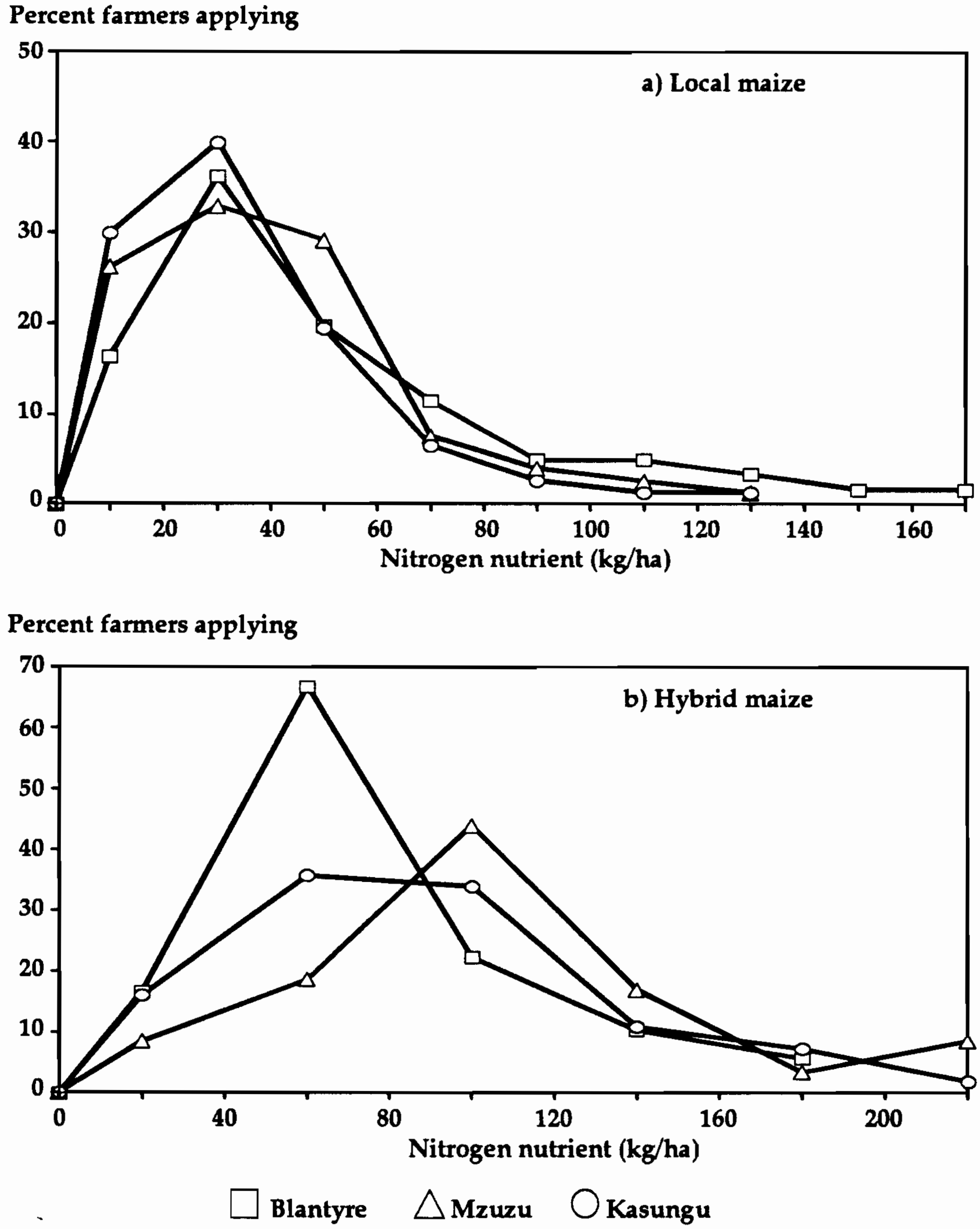

Figure 1. Fertilizer application rates for local and hybrid maize, percentage distribution, by stratum.

18 Rather than report nitrogen nutrient rates per hectare by plot, Figures 1a and 1b report them averaged over all fertilized area, by farmer. This approach is believed to reduce any systematic overestimation of amounts applied (see Appendix A). Converting the plot data to nitrogen nutrients and to household-level variables also entailed computational errors, although these should not bias the relationship of the distributions between zones since the errors are not expected to be systematic. The distributions by plot have the same shapes, but are shifted slightly to the right.

The percentage distributions for fertilizer application to local maize are similar for the three zones, although a larger percentage of Blantyre farmers applied extremely high levels of nitrogen relative to recommendations, or over 70 kg/ha, perhaps reflecting lower soil fertility or an overriding objective of meeting local maize subsistence requirements from a smaller land area. The modal application rates for the three zones, however, are around 30 kg/ha of nitrogen. The recommended level is 40 kg/ha. For all farmers fertilizing local maize, the mean application rate for nitrogen is 41 kg/ha, which expresses the skewness of the distribution of application rates.

Fertilizer application practices on hybrid maize are much more dispersed, both within and between zones. Although the modal application rates in Mzuzu and Kasungu are just over and just under the recommended level of 90 kg/ha of nitrogen, the most frequent rate in Blantyre is around 50 kg/ha, or only slightly more than the rate recommended for local maize. This finding is critical. The hybrid maize farmers of Blantyre, who are less likely to be club members and more likely to purchase their own fertilizer, tend to fertilize their hybrid maize almost as they do their local. For all farmers fertilizing hybrids in all survey zones, the mean application rate for hybrid maize is 82 kg/ha of nitrogen. (See Appendix B for changes in fertilizer application rates in the 1990-91 season.)

Figures 2a and 2b show the cumulative distribution of farmers by fertilizer application rate categories. The cumulative, as opposed to the percentage, distribution shows the likelihood of farmers applying less than any given amount. The figures again demonstrate that the Blantyre farmers are more likely to apply more nitrogen to their local maize, at every application level, than the Mzuzu and Kasungu farmers, who choose similar rates, with similar probabilities. By comparison, a higher percentage of Blantyre farmers apply lower levels of nitrogen, at any level, to their hybrid maize, than the Mzuzu and Kasungu farmers. In fact, between 80% and 90% of the hybrid maize growers in Blantyre apply less than recommended rates, as compared to 50% in Mzuzu and 40% in Kasungu.

This result is consistent with the hypothesis that securing an adequate supply of local maize is the major objective for Blantyre farmers. Both the difficulty in obtaining the proper fertilizer mix and the more modest goal of occasional sales or consumption of hybrid maize lead to a lower than recommended investment in hybrid maize production and a potentially higher than recommended investment in local maize production. If Blantyre farmers, who are short of land, seek to attain their local maize consumption requirements, the action that may appear most reasonable to them is to fertilize their local maize more heavily than their hybrid maize, relative to recommended rates. Perhaps fewer of these farmers are aware of hybrid maize recommendations and follow the application rates they know for local maize. Mzuzu and Kasungu farmers, who are more concerned about meeting their repayment schedules and maximizing the potential profits from both hybrid maize and competing alternative crops, behave in the opposite fashion.

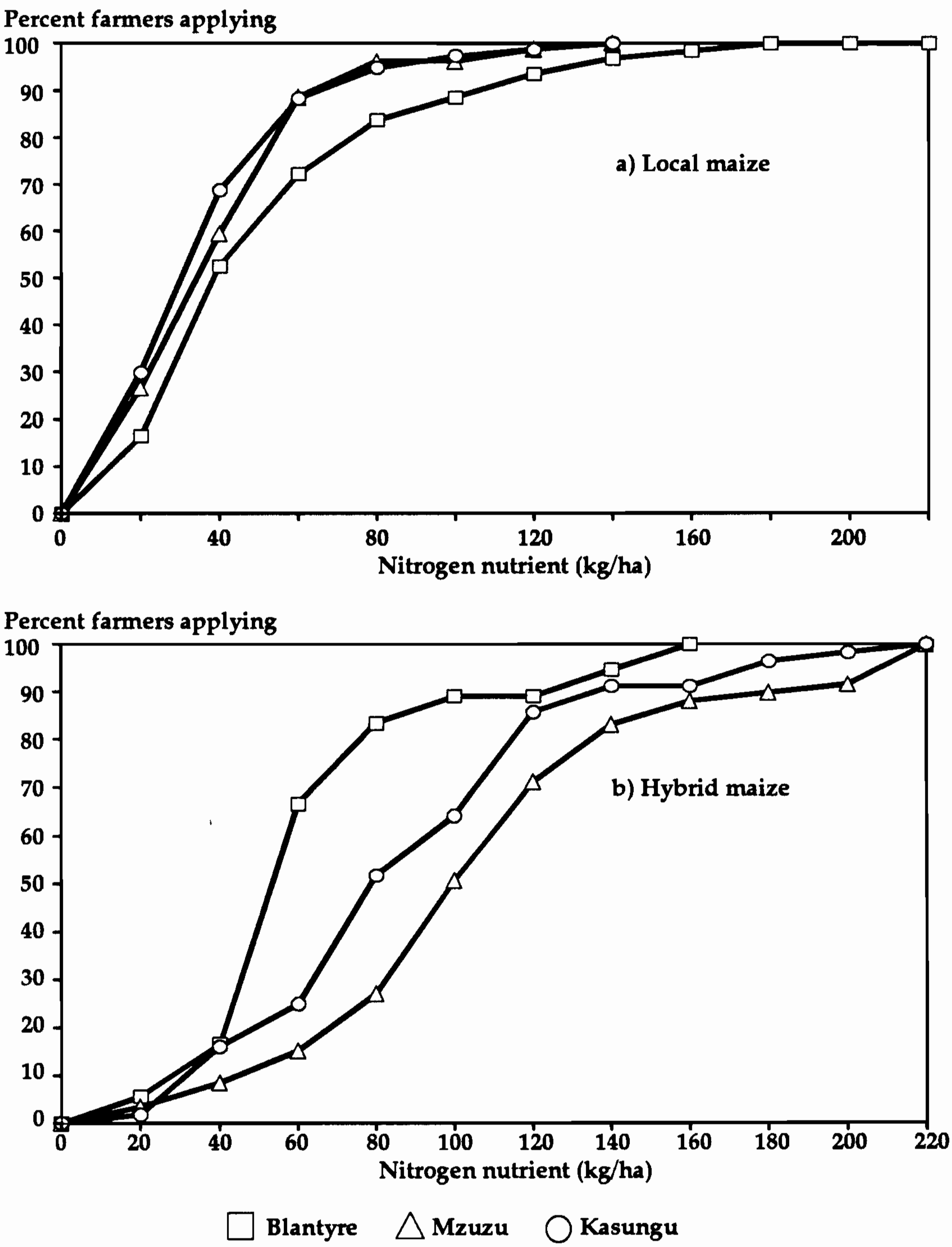

Figure 2. Fertilizer application rates for local and hybrid maize, cumulative distributions, by stratum.

Aggregate Area Sown to Varieties and Aggregate Production

Aggregate area estimates, which are composed of both the adoption and land allocation decisions, show that among the strata the lowest proportion of area sown to hybrid maize is in Blantyre (Table 6). The estimated aggregate percentages sown to hybrid varieties are similar to those frequently cited in national estimates and in recent surveys by the ADDs, although the CIMMYT/MOA figures illustrate the dramatic differences by zone. When weighted by probabilities of selection for an overall national figure, the higher farm population in the Southern Region probably generates the relatively low national figure. The new information in this table is the major difference, by zone, in the percentage of aggregate maize area sown to hybrid maize.

Since the categories in Table 6 include all farm household plots where maize was the primary crop, essentially all the cultivated area among the Blantyre farmers was occupied by local maize and local maize intercropped. Blantyre farmers believe they need (and do need) to allocate almost all their cultivable area to maize to attempt to meet their starchy staple needs. Although maize area represents about 80% of cultivated area in Mzuzu and Kasungu, nearly one-fourth of the maize area is sown to hybrid maize in Mzuzu, compared to about 13% in Kasungu. (The 1990-91 figures for Kasungu ADD are different—see Appendix B.)

Table 6. Aggregate maize area and output estimates, by technology and agroeconomic stratum, 1989-90

Characteristic	Agroeconomic stratum[a]		
	Blantyre	Kasungu	Mzuzu
Maize as percent of aggregate cultivated area	96	82	83
Percent of aggregate maize area in variety:			
Local maize	91	84	74
Hybrid maize	6	13	22
Recycled hybrid maize	1	2	2
Composite maize	1	1	2
Fertilized area as a percent of aggregate maize area in variety:			
Local maize	39	48	32
Hybrid maize	83	98	99
Percent of aggregate output from variety:			
Local maize	81	56	53
Hyrid maize	18	44	47

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

Hybrid maize also represents over one-third of aggregate maize output in the three survey zones, and nearly half of total maize output in Mzuzu and Kasungu. Thus even though the aggregate hybrid maize areas remain fairly low, the importance of hybrids in the national maize crop is evident.

Agronomic Practices Associated with Local and Hybrid Maize Technologies

With their limited land area, Blantyre farmers are obliged to crop maize continuously, although in all zones a high proportion of plots was planted successively to maize (Table 7). Because of their smaller farms and the fairly high amounts they can spend on hired labor, Blantyre farmers re-ridged almost all their plots by hoe and were more likely to weed twice and to bury maize stalks or other organic material to enrich the soil of both local and hybrid maize plots.

With their alternative crops, Kasungu farmers appear to rotate plots more frequently, and both Mzuzu and Kasungu farmers fallow some plots, sowing a higher proportion of hybrid maize than local maize on fallowed plots. On their large maize areas, the Mzuzu and Kasungu farmers use oxen more extensively in land preparation, especially on hybrid maize plots.

Farmers in the Mzuzu and Kasungu survey zones also appear to have more difficulty releasing household labor or hiring sufficient labor to weed either their local or hybrid maize plots twice. Since maize stalks are often used as livestock feed, they are not as frequently worked into the soil. In Kasungu, a sizeable percentage of both local and hybrid maize plots were manured.

A measurable proportion of both hybrid and local maize plots in Kasungu was cleared, but not re-ridged. An agronomic feature particular to the Kasungu zone explains this finding. To benefit from the manure and fertilizer applied to tobacco or the nitrogen fixed by groundnuts, Kasungu farmers often sow maize where they previously planted tobacco or groundnuts, without re-ridging. This practice may be more common in local maize than hybrid maize, because until recently farmers obtained fertilizer through credit only for hybrid maize. If they purchase fertilizer, farmers may choose to allocate it first to their hybrid maize. Farmers in the Kasungu zone, in particular, have such rotation opportunities.

The percentage distributions of planting dates for local and hybrid maize shift slightly to later dates for Kasungu and especially Mzuzu farmers, but so many factors determine the planting date, including timing of seed deliveries and location-specific rainfall patterns, that conclusions are difficult to draw. Cumulative percentage distributions in all zones appear to show that hybrid maize planting dates are shifting to later dates, as compared to those for local maize, particularly in Kasungu and Mzuzu. Over half of the local maize plots were sown before the second half of November in Blantyre and Kasungu, compared to about one-third in Mzuzu. Although about the same percentage of hybrid maize plots was sown by the second half of November in Blantyre, only

Table 7. Selected agronomic practices, by maize type and agroeconomic stratum, 1989-90

	Agroeconomic stratum[a]		
Practice and maize type	**Blantyre**	**Kasungu**	**Mzuzu**
Land preparation			
Percent of plots sown to maize last season:			
Local maize	90 *	53	79
Hybrid maize	88 *	53	70
Percent of plots sown after fallow:			
Local maize	1 *	6	8
Hybrid maize	0 *	17	14
Percent of plots ridged by hoe:			
Local maize	99 *	64	70
Hybrid maize	100 *	76	58
Percent of plots ridged by ridger:			
Local maize	0 *	10 *	27 *
Hybrid maize	0 *	17 *	42 *
Percent of plots not ridged or tilled:			
Local maize	0	25 *	2
Hybrid maize	0	8 *	0
Planting			
Percent of plots planted after 15 December:			
Local maize	3 *	22	33
Hybrid maize	12 *	34	42
Mean plant density (000 plants/ha)			
Local maize	30	33 *	29
Hybrid maize	31	39 *	35
Weeding			
Percent of aggregate area weeded twice:			
Local maize	77	54	56
Hybrid maize	90	68	66
Intercropping			
Percent of aggregate area intercropped:			
Local maize	32	2	16
Hybrid maize	31	3	1

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

about one-quarter of hybrid maize plots in Kasungu and less than 20% of hybrid maize plots in Mzuzu were planted by that date.

There are several possible explanations for this pattern. First, farmers' processing and storage preferences may encourage them to try to assure their supply of local maize by planting it first. Second, many of the hybrids have a shorter growing period. Third, in sowing their hybrid seed farmers are more dependent on the timely delivery of seed and other purchased inputs. (The relationship of timing of seed and fertilizer deliveries to planting dates would need to be verified with data that are not contained in the CIMMYT/MOA set.) Fourth, some farmers express concern about a higher incidence of stalkborer attacks and rotting with hybrid varieties, even though research results suggest that losses resulting from late planting are greater than those associated with rotting. Finally, in some areas of northern Kasungu, farmers reported that dry plowing and ridging wear their farm implements and reduce the germination rate. They also explained that, the earlier the preparation, the higher the incidence of daub grass (*Chloris gayana*). Given the large areas they farm, later land preparation may result in later planting dates.

Based on yield subplot estimates, the data include the number of maize plants per hectare at harvest, a measure of the plant density achieved by farmers.[19] In local maize, the number of planting stations per hectare was higher in Mzuzu and Kasungu than in Blantyre, but achieved densities were higher only for Kasungu. In hybrid maize, both the number of stations and achieved densities were higher only for Kasungu.[20]

Blantyre farmers intercropped about 30% of their local maize area and about the same percentage of their hybrid maize area in an attempt to intensify crop production. Intercropping of hybrid maize is infrequent in the Mzuzu and Kasungu zones, where farmers utilize their larger land areas to cultivate alternative crops in pure stands. In all zones, groundnuts and beans are the major intercrops for local and hybrid maize, although pigeon peas are a more frequent intercrop in Blantyre and mixed beans are more frequent in Mzuzu.

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19 In much of southern Africa, farmers plant maize in rows, placing several seeds at each planting station. The number of planting stations per hectare is one indicator of farmers' target densities; the remaining, unmeasured component is the number of seeds per station.

20 Large standard errors among the Blantyre farmers, reflecting either the considerable variability among survey farmers or smaller subsample sizes in Blantyre, may explain why the apparently higher hybrid maize densities in Mzuzu were not statistically significantly different from those in Blantyre.

Some intercropping of maize with sunflower was found on the Phalombe Plain, and a few plots were intercropped with sorghum, millet, cassava, or sweet potato.[21]

Indicators of Past Adoption Activity and Experience with Local Maize Technology

Farmers in all strata tend to be experienced in maize production, averaging about 20 seasons of farming and acting as head farmer, or primary decision-maker, in three-quarters of the seasons (Table 8). The number of farmers who have ever applied fertilizer to their maize is over 80% in Mzuzu and Kasungu zones, and significantly lower, or about 60%, in Blantyre. Yet the pattern of fertilizer use among those farmers is similar across zones. Well over half the farmers have moved in and out of the practice, probably in response to cash and credit availability. Around 10% in each zone were using fertilizer for the first time in the 1989-90 season. The mean initial year of fertilizer use was also the same across zones, and the mean number of years applying fertilizer was constant at 6-7 seasons. Farmers appear to have a fair amount of experience with fertilizer technology in all strata.

By contrast, their experience with improved seed differs by stratum and tends to be shorter. The difficulty in ascertaining whether farmers could distinguish composites from hybrids, and farmers' difficulty in recalling varietal names, means that figures are only very rough indicators of past adoption. While only one-quarter of farmers in Blantyre had ever grown hybrid seed, about two-thirds of farmers in Mzuzu and Kasungu have sown hybrid maize. Again, the pattern of discontinuity in planting hybrid maize appears across zones, but the percentage distribution among first-time users and those sowing discontinuously is significantly different between Blantyre and the other strata. The differences may not prove statistically significant in a larger sample, but it seems reasonable to conclude, based on the data in the other tables, that experience with hybrid maize is longest in Mzuzu and briefest in Blantyre. Kasungu farmers also appear more likely to have discontinued growing hybrid maize, which is consistent with the hypothesis that they consider relative profitability of competing non-maize crops in their adoption decision.

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21 These figures appear lower than those frequently cited, but there are several possible explanations for data discrepancies. The first is that figures frequently cited may reflect only occurrences in certain areas, rather than national patterns. The second is that intercropping as a practice may be decreasing over time. The third is that, although many farmers may intercrop a few ridges or even a plot for consumption purposes, the larger portion of their plots is actually pure stand. In Blantyre, the intercrop would compose a more significant portion of a household's maize area because of smaller total farm areas. The proportion of farmers practicing an intercrop on at least some portion of their fields is in any case considerably higher than the proportion of area intercropped.

One of the more salient features of these data is the pattern of discontinuity. Discontinuity in fertilizer use can be attributed almost entirely to the changing availability of cash and credit, but discontinuities in varietal choices can result from a combination of factors, including, but not limited to, the annual cash and credit situation of the household. Questions posed to farmers about the reasons for the discontinuity were also conceptually difficult, since the reasons are interrelated and most underlying causes were not easily disengaged from farmers' responses. The reasons most frequently cited by Blantyre farmers for ceasing to grow hybrid maize were money problems and susceptibility to weevils, and, for composite maize, ear rot and lodging. In Mzuzu, farmers most frequently cited credit default, low yields, or temporary absence of the head

Table 8. Farmer experience with maize technology, by agroeconomic stratum, 1989-90

	Agroeconomic stratum[a]		
Type of experience	Blantyre	Kasungu	Mzuzu
Farming experience			
Mean years as head operator, any farm	16	16	16
Mean total years farming	18	19	21
Experience using fertilizer			
Percent of farmers having used fertilizer	58*	83	85
Of those having used fertilizer:			
Using for the first time	7	7	10
Using continuously	31	25	35
Using discontinuously	61	68	55
Experience using released seed			
Percent of farmers having grown hybrid maize	27*	71	61
Of those having grown hybrid maize:			
Using for the first time	32*	18	20
Using continuously	24	22	31*
Using discontinuously	43	59*	49
Mean starting year growing hybrid maize	1987*	1984	1983
Mean years growing hybrid maize	2*	3*	4*
Percent of farmers having grown composite variety	12*	24	34
Source of information about released seed			
Percent of farmers learning first from:[b]			
Field Assistant (extension)	44*	66	66
Another farmer, family or non-family	42*	18	14
Own observation	2*	10	16

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

[b] Residual categories not listed.

* Indicates statistically significant differences between strata (5%), pairwise Chi-square or t-test.

farmer (household head) as causes for discontinuity in growing hybrid maize. Kasungu farmers resembled the Mzuzu farmers in their pattern of response, although absence of the head farmer in a given year was not mentioned.

Complaints of low yields, susceptibility to weevils, and lodging do signal possible rejection of a variety by that farmer. Statements of money or credit problems or temporary absence of the farm operator reflect only temporary discontinuities that may or may not be overcome, depending on farm household conditions and institutional arrangements in a given year.

When asked to specify the greatest advantage of hybrid maize, in both Mzuzu and Kasungu 87% of the farmers with experience confirmed that yield or profit motivated their decision, although about 10% in Mzuzu claimed that, in their experience, they saw no advantage to hybrid maize. Only a negligible percent of the farmers in Mzuzu cited early maturity as the most important advantage, whereas one-third of the Blantyre farmers and 10% of the Kasungu farmers had grown hybrid maize because of early maturity. The interesting feature here is the measurable proportion of Mzuzu farmers who had a bad experience with hybrid maize. Although hybrid maize generally fared better than local maize in 1989-90, the season was severe in many localities, and these farmers' responses may have corresponded to their most recent experience.[22]

Blantyre farmers who have grown hybrid maize again appear as self-styled adopters in Table 8. In Mzuzu and Kasungu, two-thirds of the farmers reported that the FA (extension agent) was their first source of information regarding new seed varieties. Since the late 1970s, as agricultural extension activities in donor-funded projects have increased, particularly with the "Block Extension System," extension workers have been able to reach a broader base of farmers. In Blantyre, where extension service resources are more widely dispersed among a larger population of farm households, a substantial proportion learned about new seed from another farmer or family member. The fact that hybrid maize farmers in Blantyre learned about new varieties first from other farmers does not necessarily imply that they have no contact with extension, however. The diffusion process is not limited to formal mechanisms in any of the agroeconomic strata, although the greater likelihood of involvement with credit clubs in Mzuzu and Kasungu means that the hybrid maize farmers there have tended in the past to be associated with credit and extension institutions, with the potential for greater exposure to recommendations.

22 The yield distributions shown in the following section for Mzuzu are dispersed from crop failure to over 4.5 t, supporting this conjecture. The dispersion may be a feature of last year's weather conditions only. The yield distributions from the ASA, over time, will provide a more reliable indication.

Measures of Performance

Observed Yields and Farmers' Yield Perceptions

In the CIMMYT/MOA survey, enumerators devoted considerable effort to eliciting farmers' perceptions of how maize yields varied depending on the technology used to grow the crop. Farmers were asked the minimum, maximum, and most frequent outputs they had observed for an identified garden or plot, for unfertilized local, fertilized local, and fertilized hybrid maize. Those who had not grown fertilized hybrid maize were asked to estimate yields, based on their observations of other farmers and their knowledge of their own capabilities. Farmer estimates by *nkhokwe* (granary), *ngolo* (oxcart), or bag amounts were then converted to kilograms and divided by associated garden or plot area measurements to obtain yield figures.

Enumerators encountered a number of measurement and conceptual problems in this process, but the overall results for the farmers as a group appear reasonable. The distributions of observed yield estimates for the 1989-90 season that are derived from yield subplots, and the expected yields calculated from farmers' subjective estimates, are closely related. Combined, the two sets of estimated yield distributions for the maize technologies provide a picture of the performance of the technologies in farmers' fields.

Figure 3 shows the cumulative probability distribution of observed yields or yields calculated from yield subplot measurements for fertilized and unfertilized local maize, as well as fertilized hybrid maize, for all plots. The cumulative distribution for each technology shows the total probability among farmers of obtaining a plot yield below a given level in the 1989-90 cropping season. Given the large variation in rainfall patterns among the survey farms in the last season, both among village clusters and within them, and the variation among yield subplots on a farmer's field, the cumulative probability can alternatively be interpreted as the risk, for any farmer, of a plot harvest below a given yield.

For example, Figure 3 demonstrates that in the 1989-90 cropping season the probability of falling below 1 t/ha on any plot was a little over 10% for fertilized hybrid maize, as compared to 45% for fertilized local and 75% for unfertilized local maize. The probability of falling below a given yield level is always higher with unfertilized local maize than with fertilized local maize, and higher with fertilized local maize than with fertilized hybrid maize. The implication of such a relationship is that, regardless of a farmer's attitude toward risk, on yield criteria alone, he or she would choose to grow fertilized hybrid maize. As emphasized above, farmers do not choose varieties on the basis of yield criteria alone, but Figure 3 provides evidence that yield risk is not likely to be farmers' reason for rejecting hybrid maize.[23]

The relationship of observed to expected yields calculated from farmers' estimates is closely distributed among farmers in each of the survey zones, especially for unfertilized and fertilized local maize, for which there are a large number of yield subplot estimates and with which farmers have a lot of experience (Figures 4-6). A comparison between technologies, using either the observed or expected estimates, suggests that the relative yield risk ranking by technology that appears in the full sample is also evident within each of the farmer subgroups. However, the shape of both expected and observed cumulative distributions for fertilized hybrid maize in Mzuzu and Kasungu differs from that of the distributions in Blantyre. Farmers in those zones appear to have obtained, and believe they can obtain, both a greater dispersion of yields

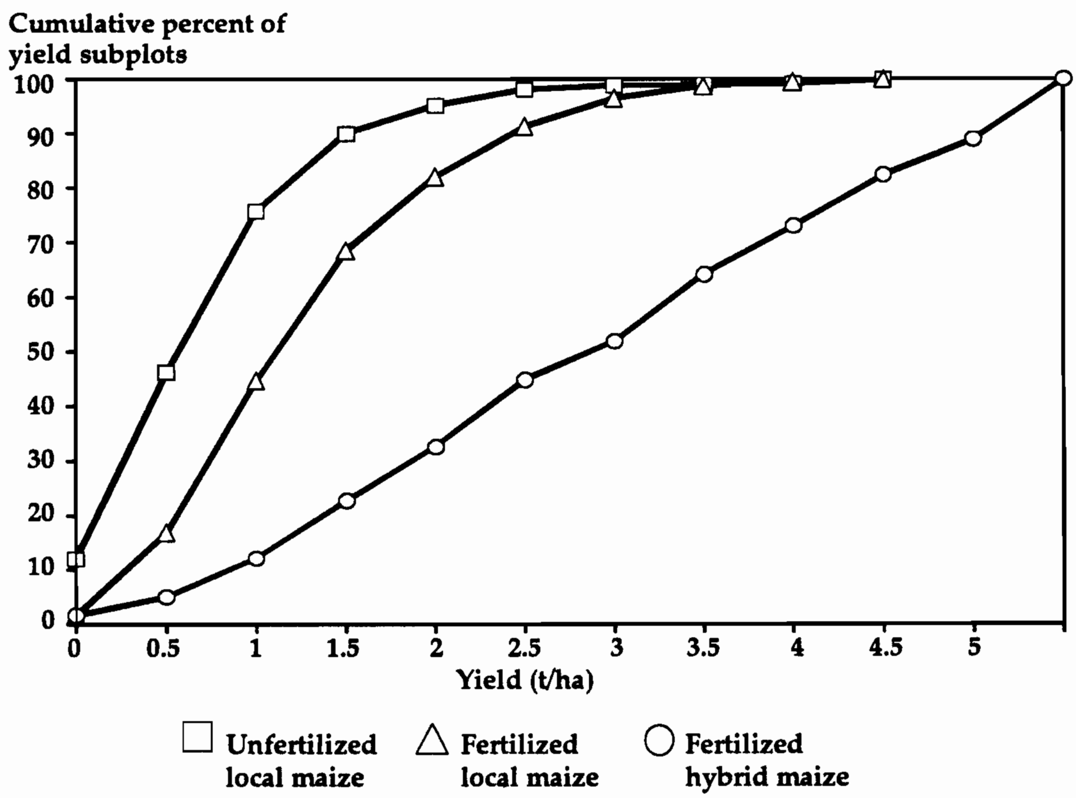

Figure 3. Cumulative observed yield distributions, maize technologies, all farmers.

23 For corroborating evidence that sowing hybrid maize does not involve greater yield risk than sowing local maize in Dowa West, Kasungu ADD, see Bulla (1990).

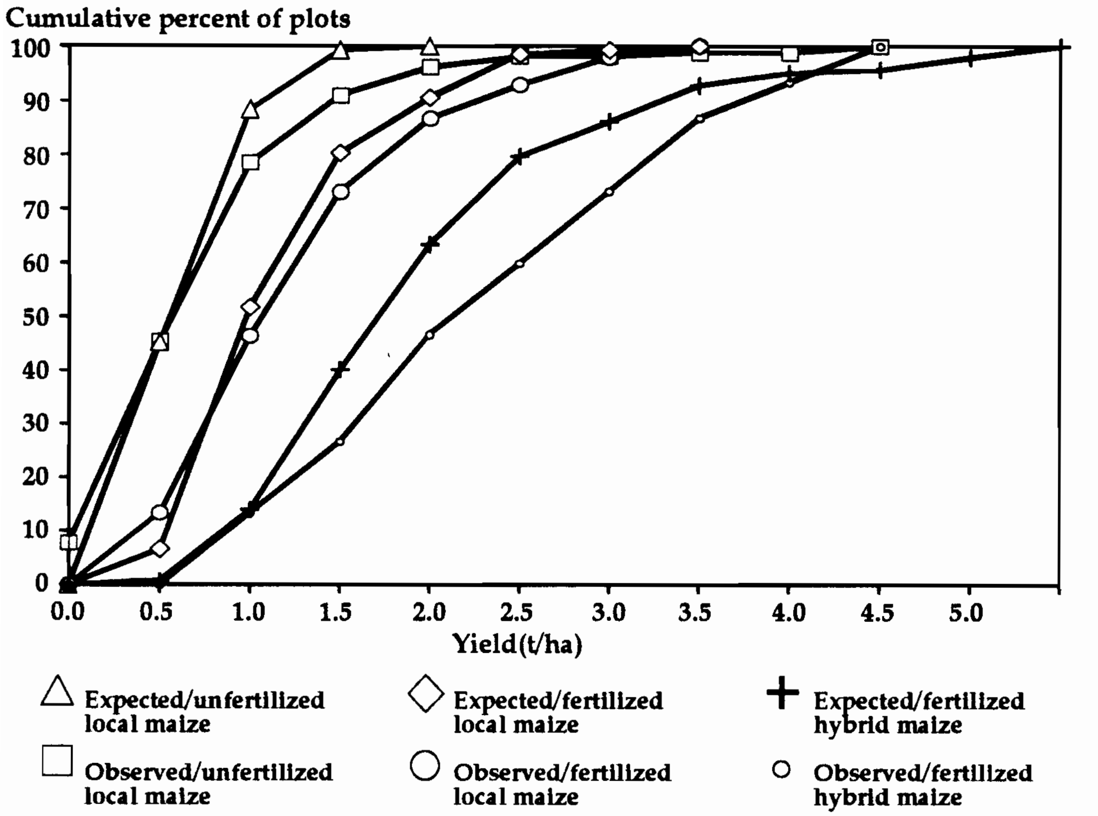

Figure 4. Cumulative yield distributions, expected and observed, Blantyre.

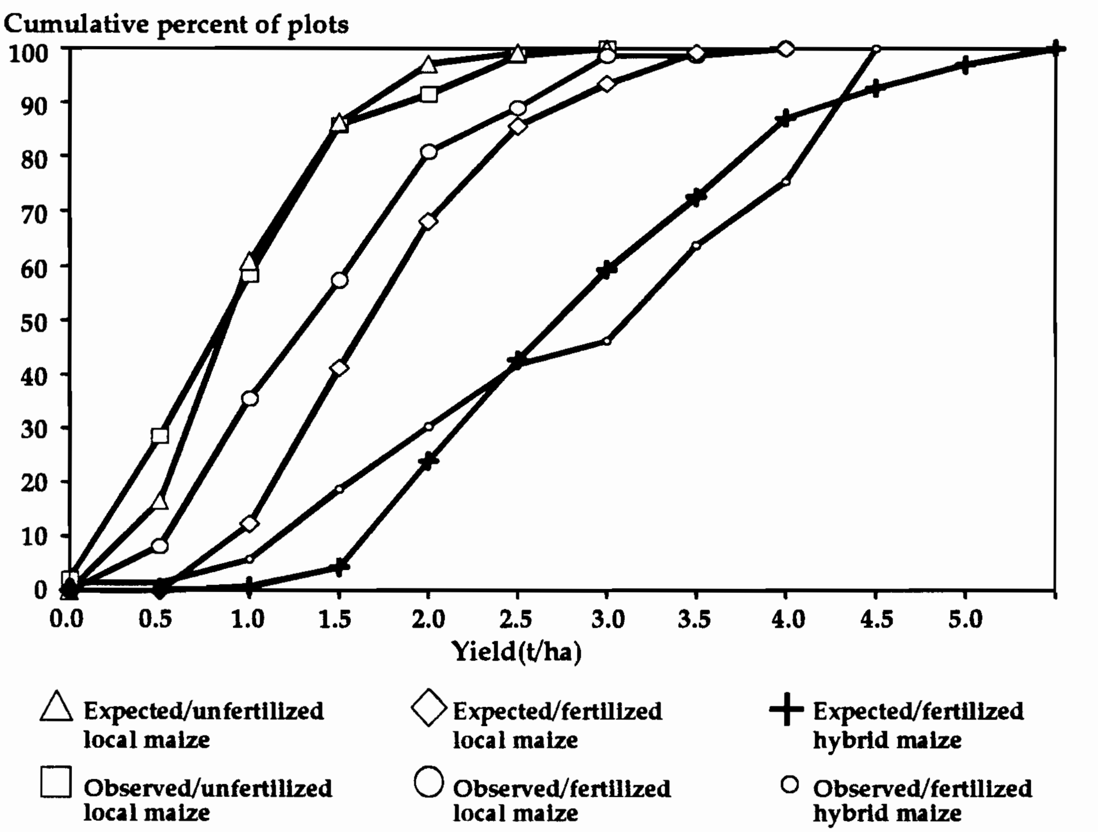

Figure 5. Cumulative yield distributions, expected and observed, Kasungu.

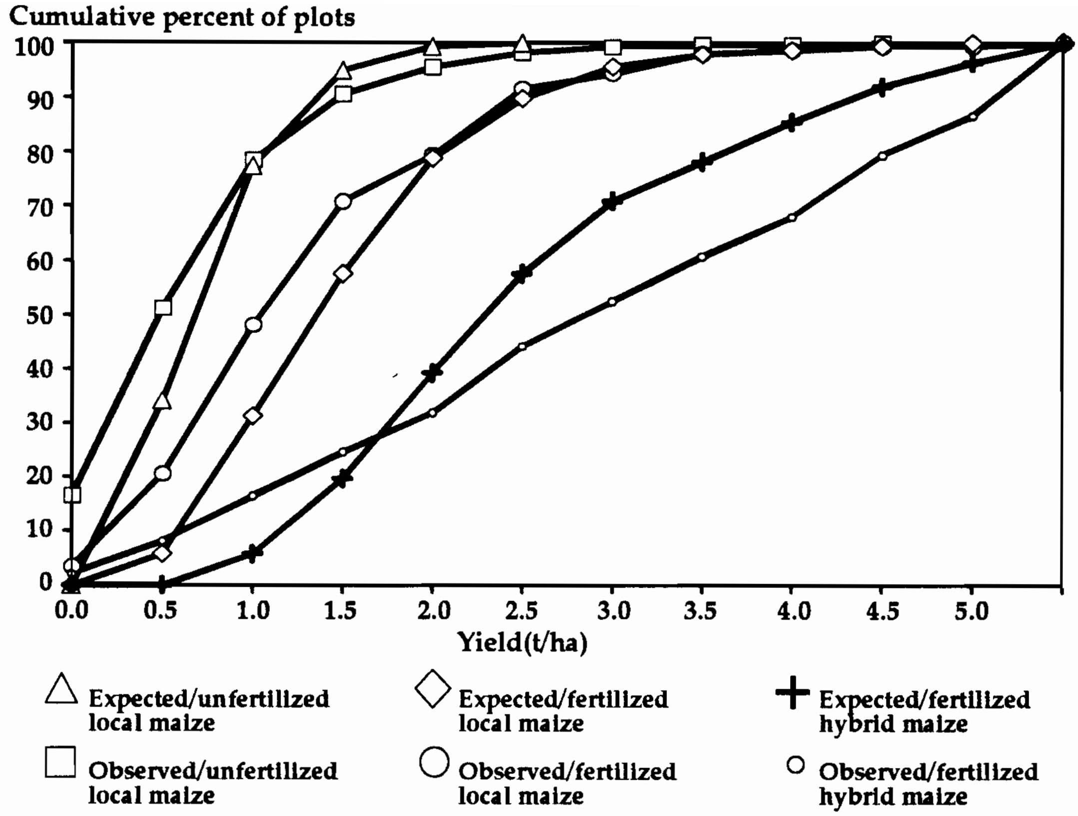

Figure 6. Cumulative yield distributions, expected and observed, Mzuzu.

and yields that are more likely to be high than those of the Blantyre farmers. A comparison of only farmers' estimates reveals that Blantyre farmers are systematically the least optimistic, and Kasungu farmers the most optimistic, about how maize technologies perform in their fields (Figures 7a, 7b, and 7c).

Three points emerge from the comparisons of cumulative yield distributions. The first is that farmers probably do not reject hybrid maize on the basis of yield risk. The second is that, although yields in the survey year may have been more disastrous than those of other years for any individual farmer, for all farmers the distribution of yields estimated from yield subplots conforms to the distribution of expected yields calculated from their own estimates. Farmers generally know the yield potential of their technologies, although they may be less familiar with hybrid maize. The third point is that the Blantyre farmers appear to believe they can obtain, and also do obtain, the lowest yields for each technology of the three strata. The Kasungu farmers are less likely to fall into the lower hybrid maize yield levels than Mzuzu farmers. The greater dispersion among hybrid maize yields in Mzuzu also means that on some plots the Mzuzu farmers were more likely to obtain over 3.5 t/ha. The first and final points can be substantiated or refuted by inspecting historical ASA data.

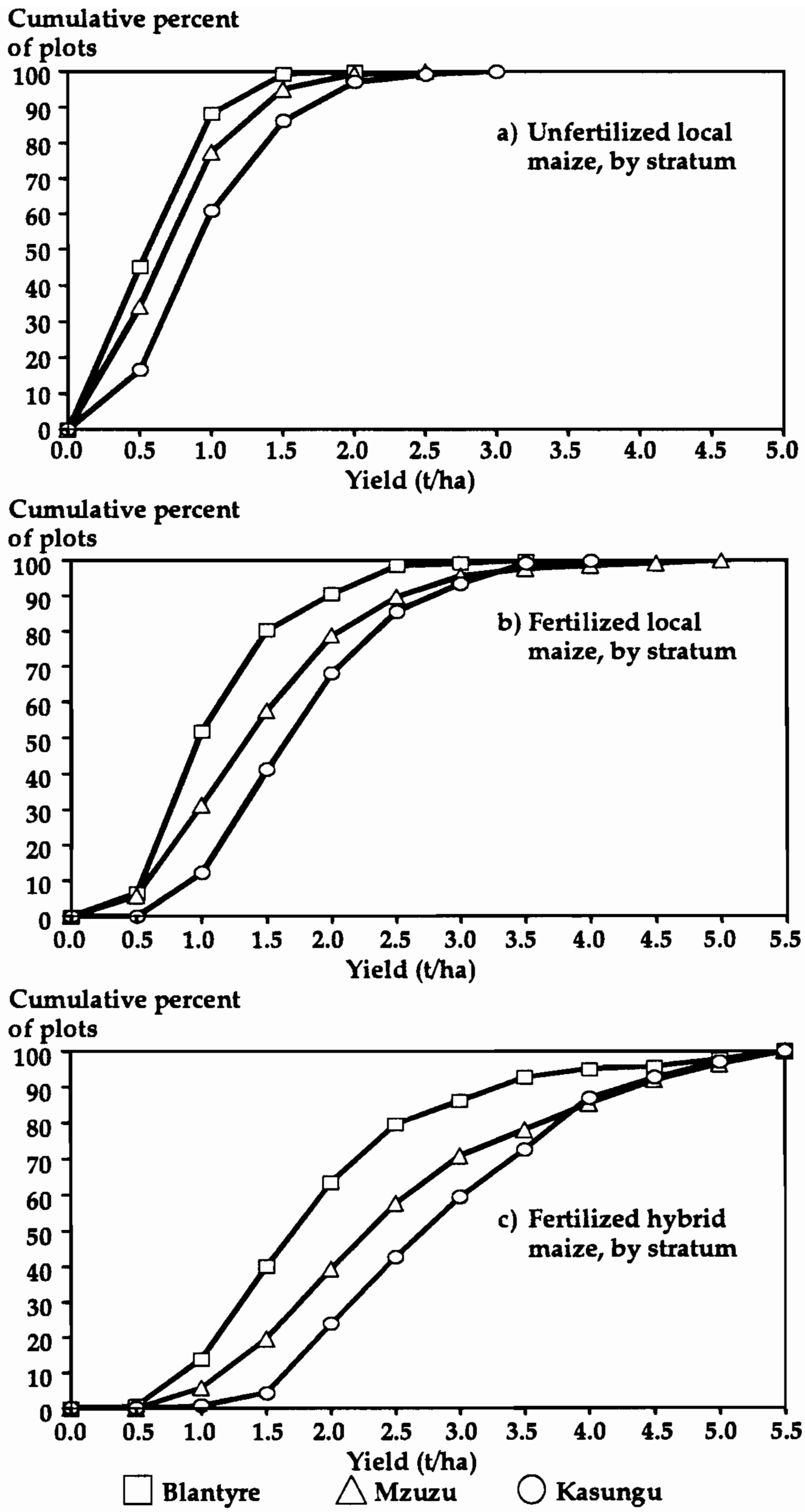

Figure 7. Cumulative expected yield distributions for different maize types and fertilizer status, by stratum.

The Capacity to Meet Local Maize Subsistence Requirements

The importance of maize as a starchy staple, and the processing and storage preference for local maize, imply that meeting local maize subsistence requirements is a principal farming objective for Malawian smallholders. Table 9 shows farmers' average expected yields in local maize, and an expected subsistence ratio that is a measure of farmers' perceptions of their capacity to meet their subsistence needs in local maize production. The expected subsistence ratio represents each farmer's expected local maize harvest as a proportion of the minimum amount of local maize required to feed his or her household for one year.[24] The expected subsistence ratio expresses a different concept than the

Table 9. Objective yield estimates, farmers' expected yields, and subsistence ratios for local maize, by agroeconomic stratum

Characteristic	Agroeconomic stratum[a]		
	Blantyre	Kasungu	Mzuzu
Objective yield estimates (t/ha), 1989-90			
Local maize, unfertilized	0.7	0.9	0.7
Local maize, fertilized	1.2	1.4	1.2
Farmers' expected yields (t/ha)			
Local maize, unfertilized	0.6	1.0	0.7
Local maize, fertilized	1.1	1.7	1.5
Mean ratio of expected local maize output to minum consumption needs			
Local maize, unfertilized	0.6	0.8	0.6
Local maize, fertilized	1.0	1.5	1.2
Mean ratio of observed local maize output to minum consumption needs			
All local	0.9	0.8	1.0

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

24 Expected yields were calculated for each farmer based on his or her statements about the maximum, minimum, and most frequent outputs he/she has obtained or would expect to obtain, with and without fertilizer, in a given plot. Output figures were divided by measured area of each plot for a yield figure. The minimum, maximum, and mode completely characterize a triangular distribution, which is the simplest form of continuous, subjective yield distribution that can be elicited from farmers. The expected subsistence ratio was computed by multiplying each farmer's expected yields by the hectares he or she planted to local maize in 1989-90, and dividing by the household's estimate of the minimum quantities of local maize the household would need to last from one harvest to the next. When the household included both a husband and wife, the consumption estimates were elicited from both. Output distributions were elicited from the head operator.

observed subsistence ratio. Since it is based on farmers' experience over a longer time, the expected subsistence ratio is less influenced by the specific climatic conditions farmers encountered during the 1989-90 cropping season.

Blantyre farmers tend to be the least optimistic and Kasungu farmers the most optimistic about their local yield and production potential. Given the land they sowed to local unfertilized maize in the 1989-90 season, farmers in each zone would on average expect to be deficit producers, although the proportion of farmers expecting to fall short of requirements would vary by zone. If farmers had applied fertilizer on all the area they sowed, the average household could expect to be a surplus producer of local maize only in Mzuzu and Kasungu. Even if they could afford to fertilize all their area, farmers in Blantyre would, on average, expect to just meet minimum consumption needs, and more than half would continue to be unable to meet their requirements. Based on actual allocations during the survey year, yields, and perceived subsistence requirements, the average household in each zone appears to have attained just under or equivalent to a unitary subsistence ratio.

The mean subsistence ratios do not reveal the skewness of the distributions. Although large surplus producers exist in all of the zones, many households still expected to be, and probably were, deficit producers. Figures 8a-8c show the cumulative probability distributions of the expected and actual subsistence ratios. In any of the three zones, the cumulative percentage of deficit households is dramatically reduced with full fertilization, but nevertheless remains over half of farmers in Blantyre, less than half in Mzuzu, and about one-third of farmers in Kasungu. A large proportion of Blantyre farmers simply have too little land to satisfy their consumption needs, regardless of the technology they use. If the area the farmers sowed last season had been entirely unfertilized, almost 90% of Blantyre farmers, about 80% of Mzuzu farmers, and around three-quarters of Kasungu farmers would expect to fall short of their requirements. Although the observed distributions indicate that the Mzuzu zone had the highest proportion of farmers who fell short of stated local maize requirements, when the distributions of expected subsistence ratios are compared, Mzuzu farmers are less likely than Blantyre farmers, and more likely than Kasungu farmers, to fall below their perceived requirements. The actual distribution for Mzuzu may therefore reflect relatively disadvantageous weather during the 1989-90 season, when rain ceased earlier than usual.[25]

25 The subjective estimates of minimum household local maize requirements have been compared to estimates calculated on the basis of 270 kg per person 12 years and over and half that amount per child over two and under 12 years. The two measures are correlated, and the means, range, and standard deviations are close. Mean household requirements were slightly over 1 t for each measure, and given the average household size of five in each zone, these correspond to a minimum requirement of slightly over 200 kg per capita.

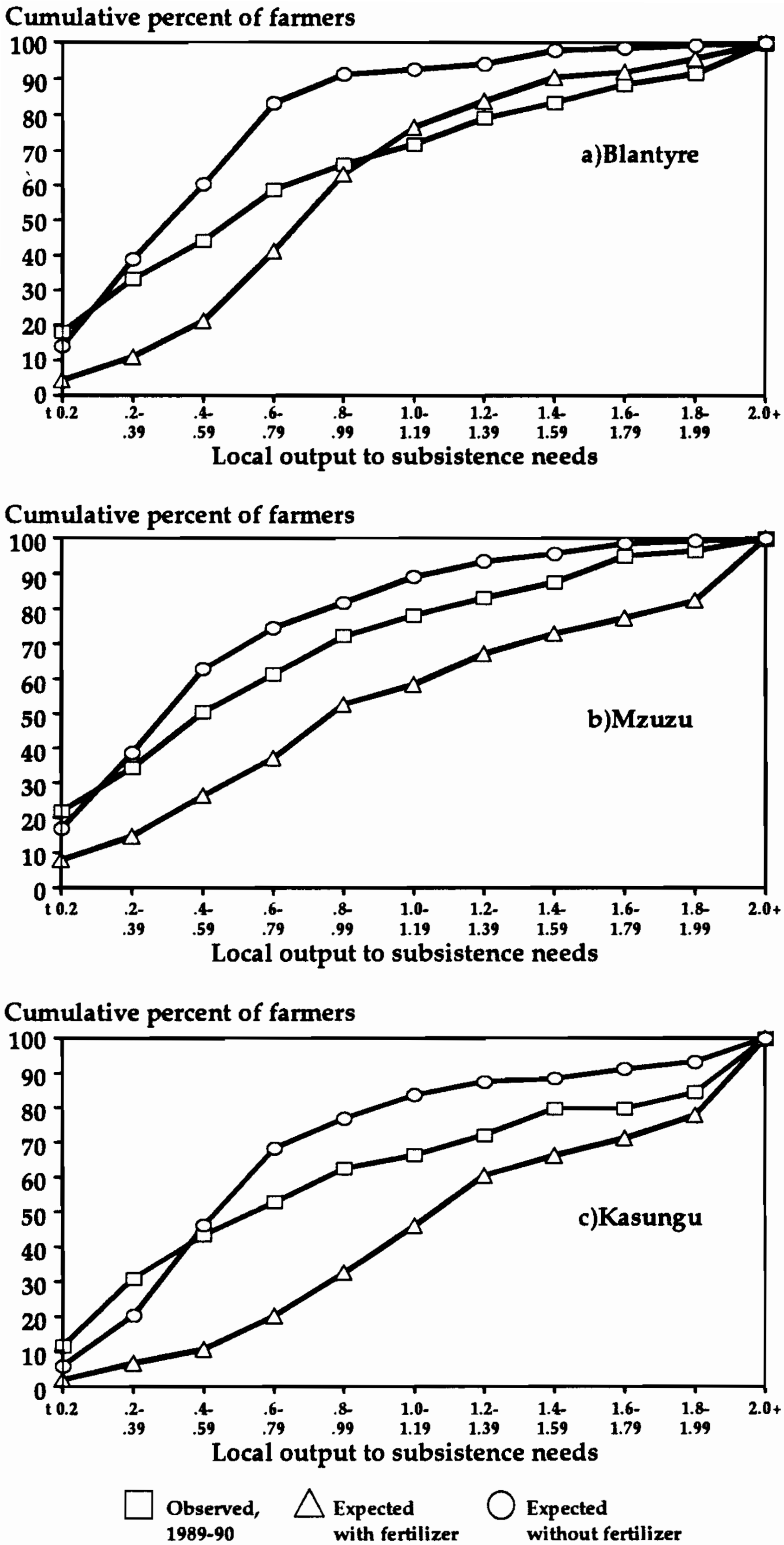

Figure 8. Cumulative distributions for observed and expected subsistence ratios in each survey zone.

Relative Riskiness of Net Returns from Local and Hybrid Maize

Although the data suggest that yield risk with fertilized hybrid maize is likely to be lower than with fertilized local or unfertilized local maize, they also indicate that, because of the strong consumption preference for local maize, and because of the fact that most hybrid maize is sold rather than consumed, farmers value local maize output differently than hybrid maize output. Differences in input use, particularly for fertilizer, lead to generally higher production costs for fertilized hybrid maize. Some of the important economic considerations motivating farmers' choice of variety can be expressed by comparing the distributions of net returns for each technology with varying assumptions about output valuation. Net returns have been calculated for each maize plot in the survey, using the expenditure information elicited from farmers, and with three output valuation scenarios that increasingly differentiate between local and hybrid maize.

In the first scenario, both local and hybrid maize output are valued at the 1989-90 ADMARC buying price, less adjustments for harvesting and transport costs. This scenario is relevant for a farmer who is a surplus producer selling both local and hybrid maize, and for whom local and hybrid maize are perfectly substitutable in consumption. In other words, the first scenario represents the most conventional approach to assessing profitability and probably embodies the least realistic assumptions among the scenarios.

In the second scenario, local maize is valued at a higher implicit price because of its superior storage and processing characteristics. The value of hybrid maize output was reduced by the cost of the insecticide needed to curb storage losses, and the local maize price was increased by a 25% premium to represent the processing losses associated with dentier maize.[26] The assumptions of Scenario II are suitable for a farmer who intends both to consume and sell either variety, but who values local maize more because of its processing and storage characteristics.

In Scenario III, although hybrid maize is still valued at the ADMARC buying price, less transport, harvest, and insecticide costs, local maize is valued with the processing premium and the ADMARC selling price. In other words, the farmer is assumed to produce local maize only for home consumption. The value of the local maize retained is therefore the cost to the household of purchasing maize

26 The 25% differential in flour extraction rates from shelled maize is based on the results of pounding tests comparing MH12, one of the dentier hybrids, with local maize. The tests were conducted by Dr. B.T. Zambezi (1990), Chief Maize Breeder, Chitedze Agricultural Research Station.

for food at ADMARC and transporting it home. In this scenario, the apparent market value of hybrid maize is severely reduced by the implicit value the household places on local maize.[27]

Three sets of cumulative net returns distributions, each set consisting of the distributions associated with the three technologies, were constructed by computing, for each scenario, the value of output less production costs (Figures 9a-9c). Under the first two scenarios, the results are inconclusive with respect to the relative riskiness in net returns associated with technologies. The distributions cross at zero or negative returns, and the areas under the curves are comparable. When a farmer intends to sell both varieties or to sell and consume both varieties, we cannot predict which technology he or she would choose based on relative riskiness of net returns, without additional knowledge about the farmer's risk aversion parameters.

In Scenario III, when local maize is given its greatest value premium for processing and storage characteristics, and the farmer is assumed to grow it only for home consumption, fertilized local maize dominates fertilized hybrid maize at every level of net returns. If the assumptions of Scenario III hold, we can predict that any farmer, regardless of his or her attitude toward risk, would choose to grow fertilized local maize rather than fertilized hybrid maize because the chances of greater net returns are always higher.

The figures demonstrate clearly that assumptions about how farmers implicitly value maize varieties are critical to determining which technology is more attractive to farmers in terms of relative riskiness of net returns. A comparison of the scenarios reveals that, as the premiums are successively added to local maize output, applying fertilizer to local maize becomes more attractive. In the upper part of the distributions, which corresponds to positive returns, the distribution for fertilized local maize gradually diverges from the unfertilized local maize distribution and approaches the distribution for fertilized hybrid maize.

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27 For all three scenarios, the assumptions used to construct input costs are the same. Fertilizer costs were calculated from survey data based on the actual amounts and types applied to the plots and the ADMARC selling prices for fertilizer. Uniform seed rates per hectare were assumed, although hybrid maize tends to be planted at a higher density. Hybrid seed was valued at the ADMARC seed price for hybrid maize, and local maize seed was valued at the ADMARC buying price for maize grain. Labor costs were constructed based on the method of land preparation, the number of times the farmer weeded or fertilized the plot, MOA figures for the typical amount of time required to perform the operations, and the average of the wage rates (converted from in-kind payments, where necessary) reported by farmers for each cluster (Enumeration Area), for each operation. The average of reported rental rates in each cluster was used when land was prepared by oxen. The labor cost assumptions imply that the value of the farmer's labor on his or her own fields is equal to the wage obtainable from working on another farmer's fields. Since many household members occasionally work for *ganyu* and also cultivate their own fields, the assumption seems reasonable.

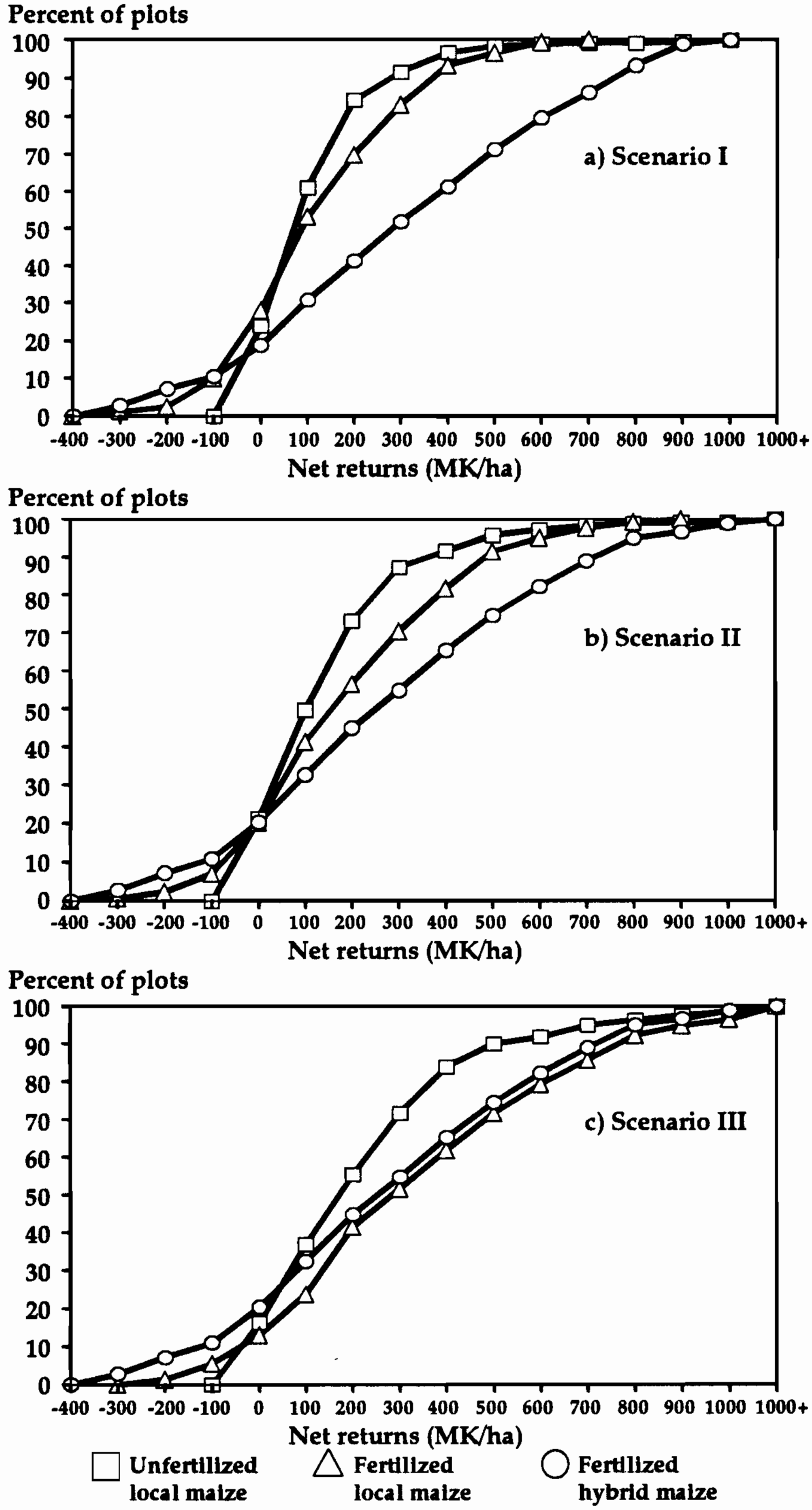

Figure 9. Cumulative net returns distributions for three scenarios, all zones, 1989-90.

Though the probabilities of negative net returns (losses) are similar for all three technologies in any scenario, they are closer for fertilized local and fertilized hybrid maize. In the range of negative returns, the chances of falling below a given value are always less with fertilized local than with fertilized hybrid. For farmers choosing between local, fertilized or unfertilized, and fertilized hybrid maize, "downside risk" is somewhat greater for hybrid maize than for local maize under any valuation assumptions.

When farmers operate with limited resources, producing a small surplus in one year and a deficit in the next, the risk of low or negative economic returns may be of primary importance in their decision making. Such farmers may choose options that minimize the possibility of falling into the lower range of net returns, even when another option provides greater chances for large returns at higher ranges. The problems associated with credit default only strengthen these results.

Finally, the fact that no single technology dominates with respect to riskiness of net returns in most scenarios suggests that farmers may be able to reduce total risk of net returns by a combination of technologies. As suggested above, varietal diversification may enable some farmers to improve their overall net returns prospects.

Summary

The data from this study provide some evidence that, in the future, maize technology recommendations may need to be further tailored to the operating conditions of distinct sets of farmers. To generalize about farmer characteristics by agroeconomic stratum may be useful for some comparative purposes and to signal differences that are likely to affect technological options in each zone.

The CIMMYT/MOA data from the 1989-90 season support the following characterization. Farmers in the Blantyre survey zone are likely to be part-time farmers who, when possible, organize their household resources so that they may benefit from relatively remunerative off-farm employment opportunities. Losing labor to off-farm activities does not necessarily impair their productivity, since it can enable them to hire the labor and purchase the fertilizer they need to coax the optimum amount of local maize from their small fields. Intensive maize production on their small plots, more frequently by women, enables them to secure at least a portion of their annual maize consumption needs. But their overall objective may result in sacrificing a large investment in new seed technology. When they do adopt hybrid maize seed, they tend to adopt it following their own experience and observations, rather than following recommendations, and to produce it with a modest objective of supplying a lucrative green maize market in town, earning some extra cash, or bridging consumption needs with a shorter-season variety. They expect less, and obtain less, from hybrid maize production than a farmer with profit-maximizing objectives. The fact that their local maize yields are also lower, whether fertilized or unfertilized, may be more a reflection of lower total initial nutrient availability in the soil, or the agroclimatic conditions they face, rather than other agronomic practices. Relative to farmers in other zones, they weed frequently, and attempt to enrich the soil with organic matter.

Farmers in the Kasungu survey zone generally operate in a comparatively favorable resource and institutional environment. They seek to capitalize on alternative crop opportunities while maintaining the basic objective of meeting local maize consumption requirements, some of which they are willing to meet by substitution of home-grown hybrid maize. They more frequently grow hybrid maize following recommendations and obtain good yields. They rotate their crops more frequently, and probably incorporate relative profitability of competing crops into their annual land allocation decision. With both their greater liquidity and greater exposure to production alternatives, they nevertheless devote a large proportion of their area to local maize and fertilize only about half of it. The yields they expect to obtain, and obtained in 1989-90, are high relative to yields obtained by Blantyre farmers and far more frequently provide Kasungu farmers with surplus maize.

Farmers in the Mzuzu survey zone are the most likely to specialize in producing maize and maintaining local seed with special traits. They also have the longest experience with new maize technologies, operating extensive maize areas sown to a diversified portfolio of maize varieties. Mzuzu farmers also grow alternative crops, such as millet, which serves an important social function but may be less valuable in terms of cash-earning potential than the tobacco of the Kasungu farmers. Mzuzu farmers are likely to grow hybrid maize as a cash crop when it is profitable to do so, rarely retaining much of the harvest for home consumption. When they do grow hybrid maize, they are more likely to invest in it heavily, drawing in bush or fallow land, hiring oxen teams to prepare the garden, and applying high levels of nitrogen. Occasionally, they obtain yields higher than those recorded on some research stations. Like farmers in each stratum, however, they continue to devote about 60% of the household maize area to local maize produced for home consumption.

The CIMMYT/MOA data reveal the complexity of farmers' technology adoption decisions in Malawi. Although institutional factors, such as credit procedures and input markets, affect adoption probabilities, the CIMMYT/MOA data indicate that, even in the absence of institutional factors and constraints, farmers would choose different technological options because of their multiple objectives and constraints. For example, the conditions under which many Blantyre farmers operate (particularly the scarcity of land and the importance of non-farm sources of income) may mean that, regardless of the greater credit opportunities and a greater range of varieties that can be made available to them, their optimal choices would always exclude commercial investments in new seed technology. Farmers who have adopted hybrid maize have largely done so independently of credit and extension institutions, and it remains to be seen whether, even if given these opportunities, they would choose to use them. Blantyre farmers maximize household income, and specific technical changes may not have a significant effect on their well-being. Because most of the Blantyre farmers do not produce enough to meet household needs, the new flintier releases could significantly affect farm household well-being if the varieties prove widely adaptable to their farming conditions.

Although adoption of flintier hybrids could reduce the average household maize deficit, most Blantyre farmers might still remain deficit producers, and because they have no alternative cash crops to assist them in paying back loans, credit mechanisms are not likely to be attractive. When farmers must sell their food supply to repay loans it is unlikely they will choose to join credit clubs, even if they are given the opportunity. To the extent that Blantyre farmers can organize their household resources to obtain small packages of flinty hybrid maize seed and fertilizer with cash, and to the extent that these packages are available in marketing outlets without credit connections, they may benefit from the new releases.

The Kasungu and Mzuzu farmers tend to have broader and longer experience with maize technologies, and these farmers are more likely to seek to maximize farm profits, even while they allocate land to ensure consumption requirements, because they have the resources to do so. To attain their true production potential, they need the opportunity to choose from among hybrid varieties those that perform best on their fields. Because they are high potential technology adopters, specific technical changes are more likely to improve their performance, and seed rationing or supply limitations can also have a greater negative impact on their production. On the other hand, despite their performance, some of these farmers continue to rely unnecessarily on seasonal credit in financing their operations. Perhaps as a consequence, over time, discontinuities appear in their seed and fertilizer use.

Implications

From an adoption perspective, the relatively high proportion of farmers sowing hybrid maize in the Mzuzu and Kasungu survey areas is an expression of their willingness to test new technologies and their success in growing hybrid maize.

The perseverance of the Blantyre farmers in obtaining new inputs even when they are less favored by credit and supporting institutions is also encouraging. Although credit has been a major vehicle for promoting hybrid maize, hybrid maize farmers are not limited to credit club members in any of the survey zones. In at least some survey areas, improvements in the approach used by extension workers and the "Block Extension System" have undoubtedly supported the dissemination of knowledge about new maize technology to a broader group of farmers. In contrast to these findings, and from a national food security perspective, the land allocation choice that probably results from both a desire to sustain a consumption preference for local maize and a risk-controlling objective of varietal diversification, may be considered by some as discouraging.

The authors believe, and the data suggest, that no single variable determines a farmer's adoption choice in Malawi. To increase aggregate area sown to hybrid maize, the Government of Malawi can choose from several sets of options, including actions that affect the choice of whether to grow hybrid maize or not (*adoption*), and actions that can influence farmers' choice of land allocation to local and hybrid maize (*extent of adoption*). Pursuing a goal of increasing aggregate hybrid maize production may involve a third set of options designed to improve the efficiency of hybrid maize production among adopters by shifting their yield or net returns distributions toward higher values.

Each set of options is associated with distinct national welfare and distributional consequences. A combination of options may be more likely to produce measurable and desirable long-term results. For example, actions that affect adoption opportunities may be primarily institutional. Factors such as credit, timely provision of appropriate seed for a particular locality at the proper planting time, and provision of fertilizer and seed to markets to enable farmers to obtain inputs with cash rather than on credit, can result in a larger number of farmers growing at least some hybrid maize. If all farmers grew hybrid maize on only a small proportion of their land, aggregate hybrid maize output and area would nevertheless increase. The social welfare considerations associated with these actions include household food security, since higher yield potential on some plots can improve the conditions of even the smallest farmers.

Aggregate hybrid maize output and area can also be increased through actions that affect the area hybrid adopters allocate to hybrid maize (that is, the *extent of adoption*). Such actions include current efforts to breed and diffuse flintier hybrids and to educate farmers about storage and processing alternatives for dentier hybrids. Farmers appear to plan their production according to the belief that local maize continues to be superior in processing and storage, which suggests that a flint hybrid is likely to have broader appeal than a dent hybrid. Those who are now adopting may allocate larger portions of their maize area to hybrid maize if that hybrid is more substitutable in consumption. Those who are able to adopt but have not adopted may be more willing to grow a flint hybrid maize than a dent variety.

Because these more technical options primarily affect farmers who are already capable of adoption, they do not have the same distributional welfare implications as the institutional options cited above, although they can improve national welfare. For example, flintier hybrids cannot relieve underlying expenditure constraints or inability to qualify for credit. Even those farmers who can afford to purchase inputs cannot be expected to relinquish their local sources of seed until they can rely on marketing institutions for timely, certain delivery of quality seed meeting their own specifications. Even then, depending on how maize varieties are valued by the farmer, comparison of net returns distributions indicates that varietal diversification may remain an objective that is consistent with reducing total economic risk.

Hybrid varietal diversification can also be accomplished through breeding. Especially in Blantyre, but also occasionally in Kasungu and Mzuzu, hybrid maize growers frequently stated that earlier maturity was an important trait. Certain varieties may also be more suitable to the *dimba* production that supplements household food supplies during the hungry season. At present, however, informal evidence suggests that in most localities the limited range of varieties supplied to the market or through credit leaves farmers with few choices among hybrid varieties. Farmers are rarely aware of differences in traits among hybrids and, until they are, they cannot benefit from diversification potential.

A third set of policy actions involves improving technical and economic efficiency among hybrid producers, through developing recommendations that are more closely tailored to their various operating conditions and concentrating on agronomic practices. As long as overall adoption rates are modest, investments of this type can improve the welfare of only a limited proportion of farmers, although they could increase aggregate output.

Finally, although hybrid maize may respond more to fertilizer than local maize, the procedure of promoting techniques as packages of given size and composition undoubtedly constrains farmers' choices and may reduce the probability of adoption by discouraging experimentation and encouraging heavy, concentrated investment. Hybrid maize may generate yield advantages, under some soil conditions, without fertilizer.

Efforts to provide farmers with packages of varying composition and a wider range of sizes are likely to improve adoption rates. If anything, the data presented in this report show that farmers are willing to try diverse combinations of technological options, and may find them to be consistent with their objectives.

The data presented in this report suggest the need for a flexible policy approach to encourage hybrid maize adoption, which would suit the complexity of farmers' adoption decisions. In choosing their maize technology, farmers seek to meet multiple objectives while facing multiple constraints. Their objectives may include attempting to ensure that they meet their projected consumption needs with the traditionally preferred, flinty variety when yields are uncertain. They also seek to increase their cash-earning potential, from crops as well as non-farm income. Their constraints may include a small amount of total cultivable land to allocate to either maize variety, inability to qualify for credit, and limited cash-earning opportunities for funding purchased inputs.

At this stage, the data are sufficient to confirm that the overall adoption pattern in Malawi does not express farmers' rejection of new technology, but constrained acceptance. As the concerns of the Ministry of Agriculture move from the basic question of whether farmers adopt, to defining which technologies are most suitable for different subsets of farmers, an understanding of the various conditions under which farmers choose to grow hybrid maize may become the more salient information need.

Further Work

This report, the first of a set of reports on maize technology and varietal adoption in Malawi, is intended as a profile of farmer adoption patterns. The findings suggest some plausible hypotheses concerning causal factors, and these hypotheses are tested with econometric analysis in a companion paper.

For example, known agroecological differences between the survey zones, combined with distinct household economic characteristics, appear to be associated with the probability of adoption. Credit and cash resources from other farm output and off-farm earnings, total cultivable land area, farmers' yield expectations, and farmers' experience with new technologies differ by survey zone and are likely to be related to the chances for hybrid maize adoption.

The universal processing and storage preference for flinty maize suggests that, even when farmers adopt hybrid maize, they seek to assure their local maize consumption requirements by continuing to allocate a large portion of their maize area to local varieties. The implicit value of local maize to the household, combined with the risk of falling short of local maize requirements, may lead farmers to allocate more of their cultivated area to local maize than they would if profits were their only consideration. To the extent that they are willing to substitute hybrid maize for local maize in consumption, or if they have sufficient land to cover consumption needs under usual conditions and release some land for hybrid production, the data also suggest that farmers can derive risk-reducing benefits from varietal diversification.

In addition to econometric analysis, further work will include basic analysis of past ASA data to observe changes in maize technology over time and a more detailed study of agronomic practices. A small farmer evaluation survey of the new, flintier hybrids will also be conducted.

Appendix A

Survey Design

The CIMMYT/MOA Maize Variety and Technology Adoption Survey (MVTS) was designed as a module attached to the Annual Survey of Agriculture (ASA), covering a subset of households included in the 1989-90 national sampling frame. In consultation with Ministry of Agriculture officials, CIMMYT chose this design for several reasons: the ASA households are selected with probability sampling procedures; the ASA questionnaires elicit extensive agronomic data related to maize technology; and the ASA enumerators are fully trained, professional field investigators who reside in survey villages. The MVTS included questions designed to provide more detailed varietal information, information on farmers' perceptions and experience with varieties, and supplementary wage and price information used in valuing costs of production, output, and household income. The variables measured in this report therefore represent a combination of those assembled from the routine ASA data, additional variables collected in the MVTS, and variables composed by transforming and combining the complementary data sets.

ASA and MVTS Sampling Frames

Originally designed for the 1980-81 National Sample Survey of Agriculture, the ASA sampling frame is a stratified cluster design, in which the nation's area is divided into approximately 200 agroecological strata, and each stratum (primary sampling unit) is composed of a varying number of Enumeration Areas (EAs, or sampling clusters) composed of roughly equal populations. The strata are contained within eight Agricultural Development Divisions (ADDs), which are administrative and development units responsible for implementing and evaluating the Rural Development Projects (RDPs) in their respective geographical zones. Evaluation Units in the ADDs implement the ASA as well as other, smaller scale surveys requested by the Ministry of Agriculture.

Since 1985-86, for the ASA, Evaluation Officers have implemented a rotating EA sample designed in that year by the National Statistical Office. In each EA, the enumerator responsible for collecting the ASA data lists all households at the beginning of the cropping season (200-300), and a systematic random sample of 20 households is drawn from the list frame. Selection of strata with probability proportionate to size of population and subsampling of clusters of about equal size ensures that the overall probability of including a household in the sample is the same for all households in the population. More densely populated ADDs and strata have a larger number of EAs, sample EAs, and sample households. Changes in population have eroded the self-weighting design over time with subsequent difficulties in developing weighting schemes for computation of aggregates, but the 1989-90 sample was based on a revised stratification and more recent 1987 population census figures.

With limited financial and physical resources to devote to supervising the MVTS and to cleaning and analyzing the data, CIMMYT chose to focus on the major maize-producing regions of Malawi, covered geographically by Blantyre, Liwonde, Kasungu, Lilongwe, and Mzuzu ADDs. Given the broad similarities between agroeconomic conditions in Liwonde and Blantyre, and between Kasungu and Lilongwe, and the considerable amount of past research conducted in Lilongwe and Liwonde ADDs, the Department of Agricultural Research advised CIMMYT to implement the research in Blantyre, Kasungu, and Mzuzu ADDs. The three ADDs represent contrasting agroecological and household economic zones, and since these factors are hypothesized to affect maize varietal adoption and production technology, they constitute the strata for the MVTS. The variation in these factors within each MVTS strata is expected to be less than variation between strata, although Blantyre ADD in particular evinces notable microclimatic and household economic diversity. A few EAs are also similar between strata. For example, maize farming practices in one EA in northern Kasungu RDP, which borders Mzimba District, resemble those found among the Mzuzu EAs.

Given available resources, a total sample size of 420 households was considered the maximum feasible for supervision and for cleaning and analyzing the data within the period of study, while meeting an adequate (for basic statistics) stratum subsample size of 140 households. From each ADD's 1989-90 sample of EAs, excluding some EAs that Evaluation Officers identified as non-representative, seven EAs were drawn by systematic random sampling. Several EAs with a Lakeshore environment were excluded from the Mzuzu list, Dowa East and Ntchisi RDPs were excluded from the Kasungu list because they are atypical of the Lilongwe plain agroecology, and several EAs located near the Kirk Ranges and Mulanje and Thyolo Estates were omitted from the Blantyre list. The proportion of remaining ASA EAs drawn for the MVTS survey was 7/21 in Blantyre, 7/10 in Mzuzu, and 7/25 in Kasungu. The total survey zone therefore represents largely the higher potential, major maize-producing areas within the three ADDs.

In each EA, the 20 ASA sample households were included in the MVTS supplement. In all but one of the seven Kasungu EAs, five of the 20 ASA households had been purposively selected for credit club membership. As noted in the text, the descriptive statistics are presented either for the full Kasungu subsample or the subsample based on only 15 households per EA, depending on whether each statistic differed between the two samples. The major variables that differed between the two samples were (1) probability of credit club membership, (2) probability of sowing any hybrid, (3) value of non-maize output, and (4) aggregate maize area estimates for local and hybrid maize. Most other statistics reported in the tables were not affected significantly.

In one of the survey EAs, a household moved away permanently soon after the survey began. In other EAs, a total of about 12 households moved away later in the season or between the two years of the MVTS survey. The households were not replaced because the purpose of the two-year effort was to observe changes in maize technology between years for the same households.

For the MVTS, the probability of selection of any household within a stratum is equal because of the underlying ASA frame. The probability of selection of MVTS EAs from ASA EAs differs between strata, however, and aggregates formed from the full sample need to be weighted by varying probability of EA selection within strata. The EA sampling fractions for the region under study in the MVTS is 7/21 for Blantyre, 7/10 for Mzuzu, and 7/25 for Kasungu. The sample represents roughly 5,250 households in Blantyre, 2,500 households in Mzuzu, and 6,250 households in Kasungu. The probability of selection of a household is 0.0267 in Blantyre, 0.056 in Mzuzu, and 0.0224 in Kasungu. For aggregation over the MVTS survey zone, appropriate weights would be composed of the inverse probability of selection associated with each stratum divided by the sum of the inverse probabilities of selection for all strata, equalling 0.375 for Blantyre, 0.179 for Mzuzu, and 0.446 for Kasungu.

ASA and MVTS Questionnaire Design and Implementation

The ASA questionnaires consist of four modules, or schedules. The household form contains questions on the demographic composition of the household, hours and type of off-farm employment, hours and type of hired farm labor, the value of remittances, and quantity of livestock owned by the household. Data are gathered in four visits covering the calendar year. A worksheet is used for measurement of all fields and plots operated by the household. The plot survey records basic agronomic information for each plot cultivated by the household as well as objective yield measurements from yield subplots, and is administered intermittently throughout the cropping season. The operator form consists of questions about use of credit and extension services by the household, and is addressed to the operator(s) following harvest.

The MVTS comprised three forms implemented along with the ASA survey. Schedule A requested additional details on the source of seed sown in maize plots, seed retention, and varietal names, and was complementary to the ASA plot form. Schedule B, administered with the quarterly ASA household form, asked about wages paid to hired labor, expenditures on purchased inputs, and requested rough estimates of amounts earned through off-farm employment and livestock sales. Schedule C contained more difficult questions about the operator's experience with maize varieties, perceptions of hybrid and local yields with and without fertilizer, seed selection practices, and varietal consumption preferences. Because the concepts expressed in the questions were subtle, Schedule C was pre-tested separately, translated into Chichewa and Chitumbuka, and implemented at the end of the season.

For the MVTS, Evaluation Field Officers from the ADDs and the CIMMYT researcher visited each enumerator four or five times during the cropping season to check the ASA and MVTS data, participating in some of the interviews, especially for Schedule C. They pre-tested Schedule C with the enumerators and assisted each enumerator in the first four of the 20 interviews. Details of Schedules A and B, which were more easily grasped by the enumerators because of their ASA experience, were discussed individually during the season.

Measurement, Conceptual, and Processing Errors

The interrelationship between the two sets of schedules was both an advantage and a disadvantage in controlling types of survey errors. Often, problems of consistency between the schedules revealed incomplete information or miscoded information at an early point in the survey rounds. On the other hand, the fact that the MVTS and ASA schedules were separately completed meant that combining, aggregating, and transforming the data into useful variables was extremely complex. Although the data were edited both in the field and in the office, a certain amount of inconsistency remains in some of the transformed variables because of the amount of data and matrix manipulation required for processing. A combination of Lotus, dBase, and SPSS was used for these procedures.

The most important measurement and conceptual difficulties in the data relate to the varietal information, fertilizer application levels, and subjective yield distributions. Farmers are not yet fully informed about the differences between composites and hybrids, or the differences among hybrids, so that their knowledge of varietal names is limited. For example, some farmers believed that seed purchased from ADMARC as food can be used as hybrid seed, and stated that they are growing hybrid. Others call any hybrid "Rhodesia" or "41." For seed purchased from ADMARC, enumerators could verify responses by requesting to see the seed packet. For seed that was purchased from other farmers, both the extent of recycling and the actual variety was difficult to ascertain.

On the ASA forms, codes for fertilizer application levels represented only the number of bags, but bags are now offered in several sizes. Codes for types of fertilizer included no details for mixtures. Although both the ADDs and

CIMMYT requested actual kilogram levels, the accuracy on some of the forms is suspect. In transformations, mixtures of two or three types of fertilizer were simply divided into equal amounts of each type. When converted to nitrogen nutrient kilograms, these assumptions can lead to either over- or underestimation of actual nutrient amounts applied. In addition, farmers have difficulty estimating how many bags they applied per plot, rather than how many bags total they applied to their maize. At least in some cases, the total number of kilograms applied to maize is likely to be overstated. If any systematic bias exists in the fertilizer application levels, it is probable that it results from a slight overestimation of bags applied per plot.

Farmers with little or no experience using hybrid maize had considerable difficulty estimating hybrid maize output. The questions elicited a triangular output distribution, which is the simplest form of continuous distribution requiring only estimates of the minimum, maximum, and most frequent (modal) output. A number of farmers also had problems grasping the difference between the concept of highest output, lowest output, and most frequent output, even for local maize. Outputs were estimated by the farmer for a specific plot identified by an ASA number, and farmer estimates were then divided by the area for yield figures. Yield figures were then converted manually from the various types of volumes recorded (oxcarts, storage units, baskets) to weight in kilograms. Errors in conversion or in misidentification of plots are also likely to have occurred. Because farmers with little experience of hybrid maize were less able to respond, and most of the farmers in Blantyre ADD reported estimates in terms of baskets or *nkhokwes* (traditional storage units), the Blantyre estimates are more likely to contain the larger measurement errors. Despite these difficulties, over the full sample, the resulting estimates appear to be fairly consistent with the actual observed pattern of yields.

The income, wage, and price information is also rough, as can be expected in non-commercial agrarian economies since values must be estimated for payments-in-kind, net earnings from beer brewed with gathered firewood and own-produced millet, and similar transactions. Farmers' recall for off-farm work is also sketchy, although quarterly visits curb some omissions, and because enumerators know their households well, they are able to judge the general reliability of statements about earnings.

Sampling Errors and Intraclass Correlation

In general, for a given sample size, clustering produces sampling errors that are higher than those associated with simple random samples for variables that are more homogeneous within the clusters than in the population. Stratification, by contrast, reduces sampling errors relative to simple random samples for variables that are more homogeneous within the strata than in the population.

One design goal of the stratified cluster design is to reduce the inflation of the total sampling error created by similarities among cluster elements by spreading the variance between divergent strata. With respect to the variable of interest, the more heterogeneous the elements within the clusters, and the more homogeneous the clusters within the strata, the smaller the total sampling error.

Estimates of sampling error, or estimated variances in standard computer output, assume simple random sampling procedures. For certain variables, these may differ greatly from estimates calculated for stratified cluster designs. The computations for a stratified cluster design are complex, however, and the statistical tests conducted in this report were based on standard computer output. The level of significance used was nevertheless small for most policy purposes. Even if standard errors have been underestimated and the true dispersion of estimates is larger than appears, many of the key statistics are likely to differ between zones at reasonable significance levels. Further analysis of larger ASA data sets from past years should provide more indication of the reliability of these results.

Appendix B

1990-91 Update

Changes in Varietal Adoption Patterns, 1989-90 and 1990-91

During the 1989-90 cropping season, the percent of farmers sowing hybrid maize differed dramatically by survey zone. About one-third of farmers sowed hybrid maize in Kasungu and Mzuzu, compared to only 14% of farmers in the Blantyre zone. Almost all farmers also grew local maize, and a small percentage grew recycled hybrid maize and identified composite varieties in their fields (Table B1).

The most salient finding during the 1990-91 season was the sharp increase in farmers who planted hybrid maize in the Blantyre zone. Within one growing season, the percentage of Blantyre farmers sowing hybrid maize rose from 14% to 30%. Between the survey zones, in the 1990-91 season, there was no statistically significant difference in the percentage of farmers sowing hybrid maize. The weighted estimate of the farmer adoption rate for all survey zones in this cropping season was 36%.

During this cropping season, however, as in the previous season, the average percent of their maize area that adopters sowed to hybrid varieties was roughly 30% in Blantyre, which is lower than in the other zones. As shown by the 1989-90 data, farmers in all zones tend to devote a large portion of their own maize area to local maize varieties even when they have adopted hybrid maize.

A second apparent change between the cropping seasons is a slight increase in the percentage of farmers growing hybrid maize in Kasungu (which may or may not be statistically significant), combined with an increase in the percentage growing recycled hybrid maize, and an expansion in the average percent of their maize area Kasungu farmers sow to hybrid varieties. Recyclers are composed primarily of two groups—those who defaulted on loans last season and those who obtain seed through purchase, gift, or *ganyu* from another farmer. In this season's round, the former group (defaulters) was particularly evident in several of the survey villages.

The aggregate maize area estimates express these changes in farmers' adoption patterns. Between the two seasons, the estimated percentage of aggregate maize area sown to hybrid varieties almost doubled in Blantyre and Kasungu zones and remained about the same in Mzuzu. The overall estimate for the three zones, weighted by the probabilities of selection between zones, is 18%. Hybrid maize represents an estimated 35-36% of aggregate maize output, which has important implications for national food security.

Table B1. Selected statistics on varietal adoption, 1989-90 and 1990-91

Characteristic	Agreconomic stratum[a] Blantyre	Kasungu	Mzuzu	All strata
Adoption of seed				
1989-90				
Percent farmers growing:				
Local maize	97	99	97	98
Hybrid maize	14 *	33	38	27
Recycled hybrid	4 *	7	9	6
Composite variety	4	4	5	4
Percent of farm maize area sown to hybrid maize by adopters	30 *	35	42	34
1990-91				
Percent farmers growing:				
Local maize	98	96	99	97
Hybrid maize	30	39	40	36
Recycled hybrid	7	22*	10	14
Composite variety	2	1	1	1
Percent of farm maize area sown to hybrid maize by adopters	31 *	50*	41	41
Percent of aggregate maize area				
1989-90				
Local maize	91	84	74	85
Hybrid maize	6	13	22	12
Recycled hybrid	1	2	2	2
Composite variety	1	1	2	1
1990-91				
Local maize	85	67	79	76
Hybrid maize	11	23	19	18
Recycled hybrid	3	9	2	5
Composite variety	1	1	—	1
Hybrid maize as a percentage of aggregate output				
1989-90	18	44	47	35
1990-91	26	41	42	36

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Combined figures are weighted by probability of selection. Strata n=140. Total N=420.

* Indicates statistically significant differences between strata (5 %), pairwise Chi-square or t-test.

The third major finding during the 1990-91 season, illustrated in Table B2, is the apparent decrease in the proportion of total cultivated area that Kasungu farmers planted in maize, from an estimated 82% in 1989-90 to 70% in 1990-91. The data indicate that the increase in area sown in other crops was roughly proportionate in tobacco and groundnuts, but some localities had a large percentage increase in sunflower. The increase in area sown to other crops in Kasungu represents an expansion in cash crops compared to sweet potatoes, cassava, and pulses, but among cash crops the percentage distribution of area is roughly the same as it was in the 1989-90 season.

In Kasungu, the pattern that emerges from Tables B1 and B2 is that, between the two seasons, farmers expanded the proportion of their land allocated to cash crops and reduced their land allocation to maize. At the same time, more farmers sowed hybrid maize, and among adopters the proportion of maize area sown to hybrid maize increased compared to area sown to local varieties. If this apparent shift represents more than a seasonal variation, it suggests that the policy objective of encouraging farmers to sow hybrid maize varieties so they can release maize area for producing alternative crops may be succeeding in at least some parts of Kasungu ADD.

Table B2. Aggregate area sown to maize and other crops, 1989-90 and 1990-91

Characteristic	Agroeconomic stratum[a] Blantyre	Kasungu	Mzuzu	All strata
Percent of aggregate cultivated area[b]				
1989-90				
Maize	96	82	83	87
Other crops	4	18	17	13
1990-91				
Maize	98	70	81	82
Other crops	2	30	19	18
Percent of aggregate maize area intercropped				
1989-90				
Local maize	32	2	16	15
Hybrid maize	31	3	1	13
1990-91				
Local maize	49	5	20	24
Hybrid maize	30	6	6	15

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Combined figures are weighted by probability of selection. Strata n=140. Total N=420.
[b] Defined by primary crop.

Changes in Fertilizer Adoption Patterns, 1989-90 and 1990-91

The major changes in fertilizer use by farmers appear to have occurred again primarily in the Blantyre survey zone (Table B3). Among the Blantyre farmers, the percentage of farmers applying fertilizer to their local maize rose from 44% to 57%, and the percentage applying fertilizer to their hybrid maize increased from 71% to 93%. The consequence is that over the three zones more than 50% of farmers appear to fertilize at least some of their local maize and almost all hybrid growers apply fertilizer. In addition to these encouraging findings, the mean application rates for those farmers who apply fertilizer to hybrid maize appear to be higher in Blantyre this season than last. On the other hand, mean application rates for local maize in Blantyre appear to be lower. Last season, Blantyre farmers who used fertilizer tended to overfertilize their local maize and underfertilize their hybrid maize. This season, the average is under the recommended rate for both types of maize but closer to recommendations for hybrid maize.

Table B3. Selected statistics on fertilizer adoption, 1989-90 and 1990-91

Characteristic	Agroeconomic stratum[a] Blantyre	Kasungu	Mzuzu	All strata
Adoption of fertilizer				
1989-90				
Percent local growers apply	44*	52	58	50
Percent hybrid growers apply	71*	97	97	87
Application rate of adopters (N/ha):				
Local maize	48*	37	37	41
Hybrid maize	64*	86*	111*	82
1990-91				
Percent local growers apply	57	59	52	57
Percent hybrid growers apply	93	96	100	96
Application rate of adopters (N/ha):				
Local maize	32	40	38	37
Hybrid maize	73	66	101*	75
Percent of aggregate area fertilized				
1989-90				
Local maize	39	48	32	42
Hybrid maize	83	98	99	93
1990-91				
Local maize	53	52	37	50
Hybrid maize	94	97	100	96

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.

[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

* Indicates statistically significant differences between strata (5 %), pairwise Chi-square or t-test.

In Kasungu, however, the average amount of nitrogen applied per hectare appears lower for hybrid maize this season than last. This result could express merely some measurement problem or that some farmers found it economically optimal to divert some of their fertilizer from hybrid maize to other cash crops, or both. In terms of the value of total farm income, farmers may be willing to sacrifice some hybrid maize yield for output of other crops. Among the Blantyre and Kasungu survey farmers, the average amount of nitrogen applied per hectare was lower than recommended rates in 1990-91, but in Mzuzu, as in the 1989-90 season, the average application rates are near recommended levels for both local and hybrid maize. In all cases, the data show that mean fertilizer application rates are higher than the modal rates, although they are closer for hybrid maize than for local maize. In other words, the majority of farmers apply less than the recommended fertilizer levels, and a few farmers apply extremely high levels.

The changes in farmer adoption patterns generate a sizeable expansion in the percentage of aggregate local maize and hybrid maize area that is fertilized in the Blantyre zone. Over all survey zones, an estimated 42% of total local maize area and 93% of total hybrid maize area was fertilized in 1990-91, with little change from last season.

Yield Estimates

Several sets of yield estimates, by technology, are presented in Table B4. The objective yield estimates for the 1989-90 season are based on weights harvested from yield subplots laid in each maize plot for each farmer, with multiple samples per farmer. During the 1990-91 season, only one yield subplot was laid per farmer for each variety, so the estimates are probably less reliable. The subjective yield estimates in 1990-91 were obtained by asking the farmer how many bags or oxcarts were harvested for each variety, or by measuring the *nkhokwe*, and dividing the output estimate by the area sown. The expected yields represent farmers' perceptions about average yields over time. These were obtained by calculating the average from the maximum, minimum, and mode elicited from farmers based on their past experience with a variety or their observations. Since farmers in Blantyre had less experience with hybrid maize and fertilizer than farmers in Kasungu and Mzuzu, their subjective yield estimates are less reliable as indicators of their true yield potential. Their yield expectations are good indicators, however, of whether or not they believe it is worthwhile to test seed-fertilizer technology on their own fields.

Combined, the estimates support several possible conclusions. Fertilized and unfertilized local maize yields appear at least as high (and probably higher) in all three survey zones, in 1990-91, by both objective and subjective yield estimates. Since rates of fertilizer application to local maize tended to be the same or lower in 1990-91, weather conditions may explain any differences. Notably, some of the survey farmers in the Blantyre zone were located in the Phalombe disaster area. If these farmers are excluded from the analysis, the yield estimates for the Blantyre zone are even higher.

For the Blantyre farmers, subjective and objective estimates suggest an increase in hybrid maize yields while for the Kasungu farmers, they indicate a decrease. These findings are also consistent with the fertilizer application results reported above. The highest objective yield estimates for hybrid maize are in the Mzuzu survey zone, although the Mzuzu farmers, even more than the other survey farmers, appear quite pessimistic about their actual yields and their potential yields. In any set of estimates, subjective or objective, mean yields are higher for fertilized hybrid maize than for fertilized local maize, and for fertilized local maize than for unfertilized local maize.

Table B4. Objective yield estimates, farmers' expected yields, and farmers' estimated yields, 1989-90 and 1990-91

Characteristic	Agroeconomic stratum[a]			All strata
	Blantyre	Kasungu	Mzuzu	
Objective yield estimates (t/ha)				
1989-90				
Local maize, unfertilized	0.7	0.9	0.7	0.8
Local maize, fertilized	1.2	1.4	1.2	1.3
Hybrid maize, fertilized	2.2	3.0	2.9	2.7
1990-91				
Local maize, unfertilized	0.8	1.2	0.9	1.0
Local maize, fertilized	1.4	1.6	1.6	1.4
Hybrid maize, fertilized	3.1	2.7	3.6	3.0
Subjective yield estimates (t/ha)				
1990-91				
Local maize, unfertilized	0.8	0.8	0.7	0.8
Local maize, fertilized	1.2	1.5	1.9	1.4
Hybrid maize, fertilized	2.8	2.3	2.7	2.6
Expected yields, based on past experience or observation				
Local maize, unfertilized	0.6	1.0	0.7	0.8
Local maize, fertilized	1.1	1.7	1.5	1.4
Hybrid maize, fertilized	1.9	2.9	2.5	2.5

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-91.
[a] Strata correspond to higher potential maize-producing zones in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions. Strata n=140. Total N=420.

Farmers' Preferences for Different Hybrid Maize Varieties

During the 1990-91 season, farmers who had grown hybrid maize during any season were asked which varieties of hybrid maize they preferred. From previous experience discussing maize varieties, the enumerators and researchers knew that many farmers are unable to remember the names of particular varieties and often confuse their traits. Nevertheless, the findings do tend to show a consistency and basic knowledge of traits among the farmers.

Among the Blantyre farmers, the most frequent responses were that 1) they had only grown one variety (NSCM41) and couldn't compare varieties, and 2) they preferred NSCM41. Most of the hybrid maize available in the Blantyre area until recently has been NSCM41, and farmers often call hybrid maize "41." In Kasungu, farmers reported that they preferred 1) R201 and 2) NSCM41, and in Mzuzu, 1) MH12 and 2) R201). Perhaps early maturity is a more important trait to farmers in Blantyre and Kasungu than in Mzuzu, since more of them tend to consume some of their hybrid maize. In Mzuzu, where maize is a cash crop, the highest yielding variety has been the most popular.

For the full sample, farmers' most frequently cited reasons for preferring these varieties are listed, in order of importance, in Table B5. In the past, because the primary vehicle for seed and fertilizer distribution has been the credit club system, farmers have had little choice over which varieties they plant. What the results indicate is that hybrid maize adopters do tend to know, from experience, the major defining traits of these most popular varieties. In the future, with the release of the flinty hybrids, informing farmers about differences in traits among hybrids could speed the adoption process, if farmers are also able to choose which variety they grow.

Table B5. Reasons (in order of importance) most frequently cited by farmers for preferring different hybrid maize varieties

Hybrid	Reason for preference
NSCM41	1. Early maturity
	2. Yield
	3. Poundability
R201	1. Yield
	2. Early maturity
	3. Poundability
MH12	1. Yield
	2. Big grains

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