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The Maize Green Revolution in Kenya Revisited

Hugo De Groote, George Owuor[1], Cheryl Doss[2],
James Ouma[3], Lutta Muhammad[4] and K. Danda[5]

International Maize and Wheat Improvement Centre (CIMMYT)
P.O. Box 1041 Village Market - 00621Nairobi, Kenya
h.degroote@cgiar.org

Abstract

The maize green revolution, which increased maize yields through the use of improved varieties and fertilizer, has stalled since the mid-eighties in Kenya. This paper examines whether the stagnation of yields continued in the 1990s in spite of the implementation of the maize liberalization policies by the Kenya Government. Analysis of farm level surveys from 1992 and 2002 indicates slight increases in the use of improved maize varieties and fertilizer, but a substantial decrease in the intensity of fertilizer use. The econometric analysis suggests that the intensity of fertilizer use has a major effect on yield. The use of improved maize varieties, however, did not affect yield, suggesting that there are local varieties for some areas that do as well as improved varieties. Research is needed to develop improved varieties for some areas, and also needed for the development of alternative affordable soil fertility measures. .

Keywords: *green revolution, maize, adoption, soil fertility, Kenya*

[1] Egerton University, Njoro, Kenya
[2] Yale Center for International and Area Studies
[3] Kenya Agricultural Research Institute (KARI), Embu, Kenya
[4] KARI, Katuman, Kenyai
[5] KARI, Mtwap, Kenya

1. Introduction

The Green Revolution is a series of technical innovations in food production that can lead to a rapid increase in cereal yields and production. It was very successful in Asia where the growth in food production was able to surpass rapid population growth, thus avoiding predicted massive food shortages (Evenson and Gollin, 2003). In Africa, however, the Green Revolution has not had such sustained success. After decolonization, production of export crops continued to increase and technical innovations in maize production (mostly hybrid seed and fertilizer) led to yield and production increases in East and Southern Africa (Byerlee and Heisey, 1997). This maize Green Revolution was particularly felt in Zimbabwe (Eicher, 1997) and Kenya (Hassan et al., 1998b; Karanja, 1993; Hassan and Karanja, 1997), spear-headed by large-scale commercial farms, which made maize development one of the major success stories in African agricultural development (Gabre-Madhin and Haggblade, 2004). In the mid-eighties, however, both maize yield and area, and hence production, stopped growing in East Africa. At the same time, population increased rapidly, leading to a reduction of food production per capita and an increased risk of large food deficits in the future.

Maize is the key food crop in Kenya, constituting 3% of Kenya's gross domestic product (GDP), 12% of the agricultural GDP and 21% of the total value of primary agricultural commodities (Government of Kenya, 1998). Maize is both a subsistence and a commercial crop, grown on an estimated 1.4 million hectares by large-scale farmers (25%) and smallholders (75%), which is more than 30% of arable land. The average annual production of the last 5 years is 2.4 million tons (FAOSTAT, 2004), or for a population of 31 million, 79 kg per person. Consumption is estimated at 103 kg per person (Pingali, 2001), so Kenya is increasingly importing maize. Maize is important for human nutrition; its average daily consumption contains 1010 Kcal, which is 40% of the recommended dose for adults, and 28 grams of protein, which is 62% of adults' recommended dose (Semhi, 1993).

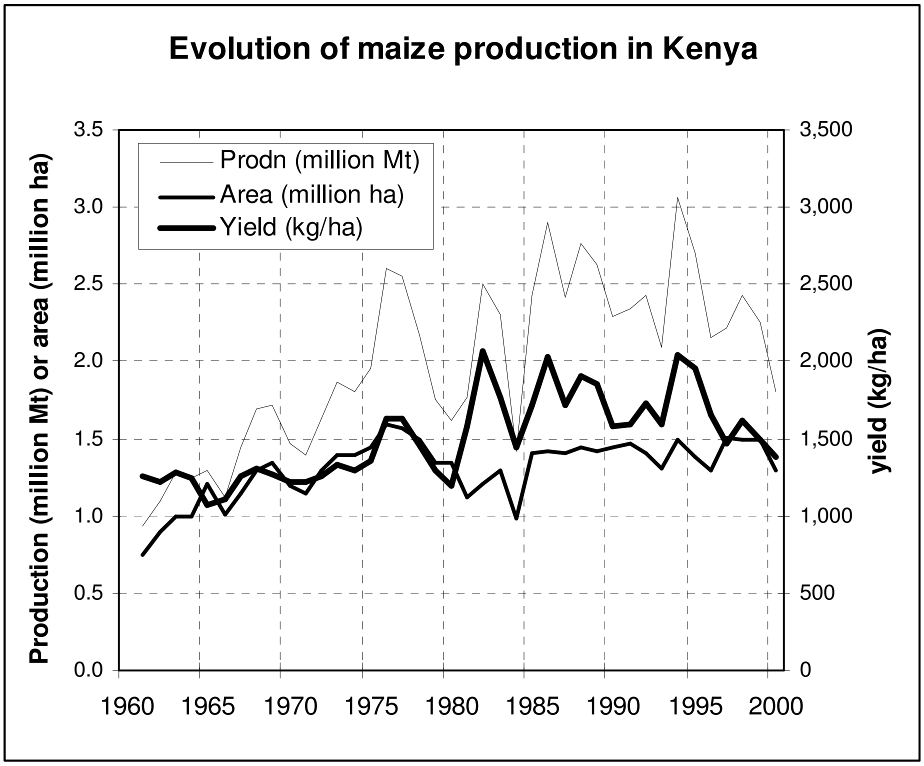
It is critical that Kenya increases its maize production in order to feed its growing population. In the 1990s, Kenya began a process of liberalizing the maize sector in order to increase production. During this time, Kenya was experiencing slow GDP growth with relatively high levels of population growth. The average annual GDP growth from 1990 to 2001 was 2%, while the population growth rate was 2.5%. In 2000-2001, the GDP growth rate per capita was -1% (World Bank, 2003).

In this paper, we examine the policies of liberalization of the maize sector in section 2. In section 3, the possible impacts of liberalization on price risk, availability of public services (credit, extension, and research), and the output and input prices are examined. In section 4, we analyze farm level data to understand the causes and consequences of the use of improved technologies using two farm household surveys (from 1992 and 2002) in Eastern Kenya. The final section concludes and discusses policy implications.

2. Policy environment of maize production in Kenya

Maize production in Africa has been characterized by heavy government interventions dating back to the colonial period. In Kenya, as in other countries with high numbers of European settlers, the maize policy reflected the interests of large-scale commercial farmers. After independence, many of these large farms were taken over by local elites, who enjoyed good links to politicians and policy-makers. During this period, parastatals dominated the agricultural research and extension sectors. New maize varieties were developed by public research institutes, now under the Kenya Agriculture Research Institute (KARI), while seed production was in the hands of the Kenya Seed Company (KSC), a privately structured company with a majority of shares owned by the government. A seed unit within KARI managed quality control and the Ministry of Agriculture did extension of new technologies, and the seed was distributed through the retail network of the parastatal, which was part of the Kenyan Farmers Association (KFA). From the late 1960s to the early 1980s, this system was remarkably effective and produced many popular varieties. Adoption of these new varieties, in combination with improved agricultural practices such as use of chemical fertilizers, led to rapidly increasing maize yield and production, as shown in Figure 1 (e.g. Gerhart, 1975; Karanja, 1993).

Figure 1. Evolution of maize production in Kenya



In the late 1970s, however, progress stalled and maize yields started to decline and reached the current level of 1,500 kg/ha. Maize production per capita, which had risen to over 150 kg per capita in the mid-1970s, has dropped steadily since then to a current all-time low of 70 kg per capita. This is substantially less than the estimated consumption needs of 103 kg per capita, which necessitates regular imports of large quantities of maize. During the 1990s, a consensus emerged, especially in the donor community, that heavy state involvement impeded the development of efficient input and output markets and thus was responsible for the stagnation, and even the decline in agricultural productivity. Consequently, many countries liberalized their agricultural markets, attempting to increase efficiency and the availability of technology to farmers (Gisselquist and Grether, 2000; Pray et al., 2001). In some cases, this liberalization was successful; in 1982 when seed trade was deregulated in Turkey, there were 24 hybrid maize varieties available to farmers, but over the next 10 years, 185 new varieties were released (Gisselquist and Grether, 2000). Kenya has been only moderately successful in implementing policies to deregulate input and output markets and reaping the benefits from them. For example, Kenya's seed sector was deregulated, but the KSC continues to have quasi-monopoly power. Similarly, the process of releasing a variety continues to be time-consuming and expensive.

Modern inputs in the maize sector are primarily seed and fertilizer. The maize seed sector presents many challenges when governments attempt to liberalize it. Maize seed industries, especially in the initial stages, are typically not competitive. Experience from many countries shows an evolutionary process of the industrial structure with a recognizable lifecycle (Morris et al., 1998). During the initial phase of this lifecycle, government dominates research, production and dissemination. In a second, intermediary stage, the private sector forms seed companies to take over seed production and dissemination. In a final stage, these seed companies increasingly take over research activities from the public sector and develop new varieties themselves. This development process is supported by the development of hybrid seed to ensure that research costs are being compensated through yearly seed sales. While liberalization of the seed sector can accelerate this development, it is not a sufficient condition. Proper distribution systems need to be in place, as well as adequate transport infrastructure to decrease the transaction costs (Tripp and Rohrbach, 2001; Tripp, 2001).

Kenya has not met many of these other conditions for successful liberalization of the maize seed sector. The transportation infrastructure is poor and has actually deteriorated over the last 10 years. The formal distribution network of the KFA has also completely been abandoned. A network of small stockists has replaced it, but these stockists face high entrance costs and a lack of available credit. Thus, Kenya has not fully implemented liberalization of this sector, nor does it have the necessary conditions in place for it to reap many of the potential benefits from liberalization.

The mechanism for allowing the participation of private seed companies in releasing new varieties has been opened up, as previously only the KSC could release new varieties. Private seed companies (local as well as international) can now enter their varieties into the National Performance Trials (NPT), managed by KARI for the Kenyan Plant Health Inspectorate Services (KEPHIS), and the results are discussed at the NPT committee meetings. At first, varieties that have at least 20% higher yields than controlled fields can be recommended for intermediate testing, during which a variety can be marketed under certain conditions. After two more good seasons in the NPT they can be recommended for release, the last and definite phase in the approval process. However, some important changes were made over the last two years, and now varieties can be released if they have a particular trait (such as resistance to a particular disease) and have similar yields as current popular varieties. Similarly, if a variety does particularly well in the NPT, a pre-release can be issued after one year. A second year in the NPT is, however, still required for the full release.

The liberalization of the seed sector saw an increase in the number of new firms entering the seed sector. They have been entering the market to produce seed of varieties for the mid-altitudes and transitional zones, but have been slow to increase their market share in the highlands (Nambiro et al., 2004). In the low-potential areas, liberalization did not result in many new firms entering the seed sector, but there has been an increase in alternative seed systems, such as various community based, or farmer to farmer seed production in the dry areas (Muhammad et al., 2002) and in the lowlands (Chivatsi et al., 2002). Most of them, however, depend on external financing and are therefore not sustainable (Tripp, 2000).

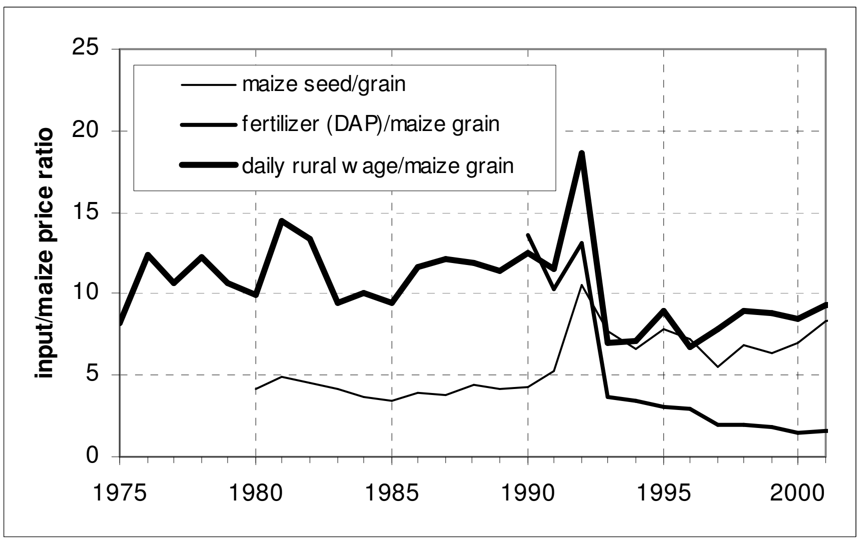
The effect of the liberalization on the fertilizer industry, on the other hand, increased the distribution and availability of this essential input (Omamo and Mose, 2001; Wanzala et al., 2001; IFDC, 2003; Freeman and Kaguongo, 2003). The government is still active in this market, however, and The National Cereal and Produce Board (NCPB), with government support, imported fertilizer for the direct sale to farmers, at reduced prices. A similar program was announced for the 2005 main season. Kenya has only partially reduced state intervention in maize output markets. Controls on internal movement of maize were removed, but imports are still discouraged by import taxes. NCPB still buys maize at prices substantially above the market price (Wangia et al., 2004), even though the quantities are small. The liberalizations have been accompanied by cuts in government support of agricultural services. Government spending on research and extension has been reduced substantially and formal credit to farmers has basically disappeared. Formal credit had been available through the Agricultural Finance Corporation (AFC), but by 1998, only 1% of the loans by the AFC went to small-scale farmers (Kodhek, 1999).

It is critical that Kenya increases its agricultural production, especially maize production, and in order to do so, farmers will have to increase yields on existing maize area. Improved technologies, including improved varieties, increased fertilizer use, or the application of new management techniques will be needed. Some of these are already available, but farmers are not taking full advantage of them. This may be due to the fact that they are not profitable, given the current conditions under which the inputs may not be available at the appropriate time, or farmers may not have the information about these technologies and how to use them.

3. Changes in price structures

The three most important inputs in maize production are seed, fertilizer, and labor. Seed prices relative to maize prices have not changed much over the last 10 years (see Figure 2). There was, however, a steep increase in the early 1990s, when seed subsidies were abolished in the Structural Adjustment Plan, and the KSC was forced to operate at a deficit. After the liberalization, there was a drop in real seed prices in the beginning of the 1990s, but since then real prices have been fairly constant with fluctuations between 6 and 8 (units).

Figure 2. Changes in input price – maize price ratios



It appears that liberalization of the seed sector has only been moderately successful. The market continues to be dominated by the government-owned KSC. In the semi-arid areas, targeted by few companies, many NGOs have conducted seed multiplication projects, but these efforts are not usually sustainable (Muhammad et al., 2003). Yet, the maize seed release mechanism has been relaxed. Two foreign companies have successfully released and marketed varieties for the moist transitional zones, and a few small new national companies have now released many new varieties. However, the release system is still costly and there has been little success in regional integration, so that a successfully variety released in a neighboring country still needs to go through the whole approval process in Kenya. Moreover, the system only considers yield, and not seed production costs, as a factor in approving release. Thus, an improved open pollinated variety (OPV), which is much cheaper to produce and thus, potentially more profitable than a hybrid, but does not yield more than 20%, will not be released, unless it has a particular trait considered highly desirable.

The most popular maize fertilizer is DAP (di-ammonium phosphate). Prices vary by location, since transportation costs may be significant. As Figure 2 indicates, DAP prices relative to maize price have clearly decreased in the 1990s. This finding is in line with the conclusions of previous authors that the liberalization has led to the entry of many small-scale fertilizer distributors, increasing availability and reducing prices (Omamo and Mose, 2001; Freeman and Kaguongo, 2003). As a result, the DAP/maize price ratio was reduced from 3-4 to less than 2.

Another important factor of production is labor. The purchasing power of the daily rural wage has fluctuated over the years between 8 and 19 kg of maize/daily wage. Relatively to the maize price, which has increased, labor has become cheaper over time. In 1970, a day's labor would purchase 12 kgs of maize; by the late 1990s it would only buy 8 kgs of maize. This reduction in labor cost should probably not be linked to the liberalization, but instead to the general economic decline during this period. Several factors play a role here, including the decrease in prices for major export products, and the political turmoil and subsequent strong reduction in donor support.

The liberalization, however, did have a strong negative impact on rural services. The formal agricultural credit system collapsed, and was only partially replaced by informal credit and micro-credit organisms (Owuor et al., 2004). Similarly, the number of agricultural extension officers was reduced substantially, and although numerous NGOs started rural development activities, their staff was small in numbers and also had little technical agricultural training. Funding of agricultural research by the government has also been decreased. During the 1990s very few varieties were released and none were very popular. Opening the seed sector to private companies is starting to show some positive results in terms of the number of new varieties being released.

4. Farm level analysis of maize production

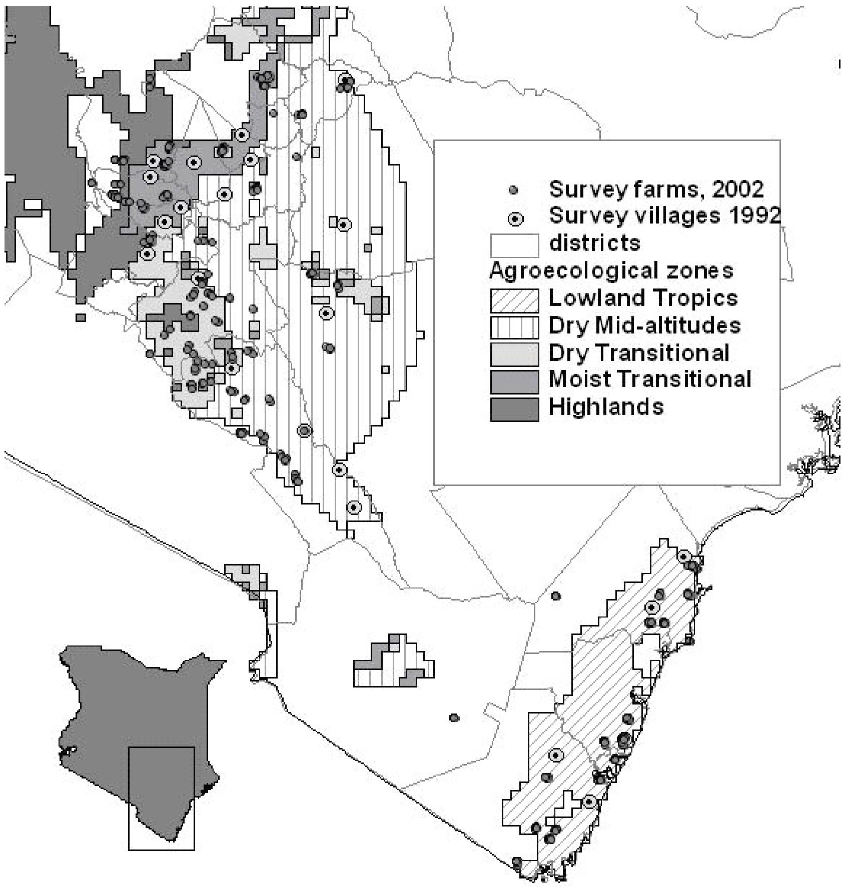
In addition to examining the national policy environment, it is important to understand which farmers are using improved technologies, especially seed of improved varieties and fertilizer. Two separate farm-household surveys were carried out by the International Maize and Wheat Improvement Centre (CIMMYT) in 1992 (Hassan, 1998) and 2002 (unpublished data). The two surveys used different sampling methods, resulting in different sites and farmers. However, analysis of these surveys will provide some indications of which farmers are using new technologies and how the patterns have changed over time.

The 1992 survey covered 1400 farmers and was based on the national sampling frame (NSF) of the National Sample Surveys and Evaluation Program III (NASSEP III) (Hassan et al., 1998a). This sampling frame only included small-scale farmers. In this analysis, the 686 households from Eastern Kenya were included. The 2002 survey used a stratified 2-stage sampling design with agro-ecological zones as strata. The administrative unit "sub-location" formed the first stage, of which 10-20 units were selected in proportion to size, and from each sub-location 10 to 20 farmers were selected. Sample size was determined so as to keep the sampling error below 10% for most of the key variables. In both surveys farmers were asked about personal characteristics, the characteristics of their farm, their use of improved seed and fertilizer, and their access to agricultural services such as credit and extension.

4.1. Overview of the agro ecological zones and the sample farmers

In 1992, CIMMYT and KARI organized a large farm survey in the major agro-ecological zones of Kenya (Hassan, 1998). This study redefined these zones into six major agro ecological zones for maize production.

Figure 3. Agroecological zones in Eastern Kenya, with location of survey sites (villages for the 1992 survey, farms for the 2002 survey)



The Lowland Tropics (LT) is at the coast, followed by the Dry Mid-altitudes and Dry Transitional zones around Machakos. These three zones are characterized by low yields (below 1.5 tons/ha). Although these zones cover 29% of Kenya's maize area, they only produce 11% of the maize. Central and Western Kenya are dominated by the Highland Tropics (HT), bordered at the West and East by the Moist Transitional (MT) zone, which is between mid-altitude and highland. These zones have high yields (more than 2.5 tons/ha) and produce 80% of Kenya's maize on 30% of Kenya's maize area. Figure 3 provides the locations of the 1992 survey (villages are marked on the map) and the 2002 survey (individual farms are identified on the map).

For the analysis of the micro level data, different estimation methods were used according to the nature of the dependent variables. For the use of improved maize varieties or fertilizer, which are binary variables, the Logit model was used. This model has a good theoretical foundation (Maddala 1987, p. 22), and the predicted values can be interpreted as probabilities of using improved technologies, which fall within the 0-1 limits. To analyze the factors influencing intensity of fertilizer use, the Tobit (or censored regression) model is used. Finally, to estimate the impact of different factors on yield, a linear model was estimated using the OLS. A log-linear (Cobb-Douglas) production function would have been preferred, but many farmers use no fertilizer. Though we are interested in the adoption process of new technologies, the data that we have only allow us to estimate current technology use.

To understand which farmers are using improved technologies, we look at four types of variables: farmer characteristics, farm characteristics, agro-ecological zones and institutional environments. We examine the relationship of these variables with the use of improved maize varieties and fertilizer, and the intensity of fertilizer use and yield. Summaries of these variables by zone and period are presented in Table 1 (see Annex).

The farmer characteristics include the age of the head of the household, a dummy variable indicating whether or not the household head had any schooling, and a dummy variable indicating whether or not the head of the household was female. The average age of the household head is similar over the different zones and time periods. We see a decrease in the number of female-headed households and an increase in the level of schooling in the later period. These trends are likely related to the general decline of the economy associated with decreased urban employment opportunities, which brought many men with some schooling back to the farm from urban areas. In addition, the trend towards the formal titling of land has favored men.

The farms surveyed in 2002 were larger, had more cattle and more maize acreage than those surveyed in 1992. This can be explained by two major factors: the difference in sampling procedures and the inclusion of new settlement areas. The sample from 1992 was taken from the NSF of the NASSEP III (Hassan et al., 1998a), which was established by CBS. This frame excludes large-scale farmers, who were defined as having 20 ha or more. The 2002 survey followed a conventional stratified two-stage design, and can be considered representative of the different zones. As a result of randomization, several resettlement areas were included. These areas typically have a larger than average farm size and farmers are more likely to own livestock.

In addition, especially in the coastal lowland areas, there is some evidence that farm sizes are increasing. Ox-plows are increasingly being used in this area, which increases the amount of land that can be farmed. In addition, an increase in the use of tractors in this zone has also occurred. Many farmers in this zone have begun keeping cattle, in part to provide animal traction and also as a means of diversifying their sources of income and food production in years when the cropping is poor. As soil fertility in the zone has declined, farmers are keeping cattle to also provide manure.

Yields have increased over time in all zones, except for the dry mid-altitudes. However, only the 2002 yield in the moist transitional zones comes close to the national average of 1.5 ton/ha. Use of improved maize varieties has doubled at the coast; up to 75% of the farmers now use them. This reflects the increased attention of KSC to the coast, along with the recent release of two popular hybrids, specifically developed for the coastal area. In the dry mid-altitudes, on the other hand, use of improved varieties by farmers decreased by more than half to a quarter, while in the dry transitional zone use of improved varieties stayed constant; around a third of farmers were using them. This reflects the risky nature of maize production in these areas with erratic rainfall and the lack of new varieties adapted to these areas. In the moist transitional zone, there was an increase in the rate of use from an already very high 85% to 98%. Nearly all farmers in this zone now use improved varieties, reflecting the high potential of the zone and the availability of varieties adapted for this area.

Except for the coast, we see a substantial reduction in access to agricultural extension. This is also linked to the reduction in public service employment. Access to credit is generally very low in both time periods: Less than 15% of farmers obtained credit except in the moist transitional zone, where several micro-credit organizations and producer cooperatives have been able to reach farmers. There is also some increase in credit availability at the coast, but this could be due to the inclusion in the sample of farmers from the Mombassa district, which includes the regional capital, meaning that these farmers would have inherently better access to credit. Access to credit also increased slightly in the dry mid-altitude zone.

Proportion of farmers using fertilizer increased in all zones except for the dry mid-altitudes. Fertilizer use is still very low at the coast (12%) and in the dry mid-altitudes (7%), but higher in the dry (54%) and moist (69%) transitional zones. Although the number of farmers using fertilizer has increased, the average amount used has gone down dramatically. Only in the moist transitional zone, do farmers use more than 100 kg/ha. In all other zones the average dose is less than 30 kg/ha. These amounts are substantially less than the recommended dose. In 1992, the economically optimum level of fertilizer use was calculated to be between 40 and 98 kg of N /ha and between 36 and 92 kg of P, depending on the zone. This was based on a price ratio of 5.8 for N and 3.5 for P (Hassan et al., 1998).

4.2. Factors influencing use of new maize technologies

To improve maize production and food security, it is important to understand the factors that influence the use of new technologies. Two very important modern technologies are analyzed here: improved varieties and chemical fertilizers. There are, of course, other technologies, including alternative soil fertility enhancing techniques such as the use of manure, rotation and intercropping with legumes, but these technologies are hard to quantify and the relevant variables in the two surveys were not comparable. First, we use a logistic model to estimate the probability that a household is using improved varieties of maize, and results are presented in Table 2 (see Annex).

We estimated the coefficients for the pooled data set and for each of the individual surveys. In the pooled data estimation, the coefficient on the year dummy variable is not significant for use of improved varieties, indicating that the observed mean differences are explained by the other independent variables. There are, however, substantial differences between zones. Since the coast is the control area, the estimated coefficients of zone dummies indicate that both the dry mid-altitudes and the dry transitional zones are less likely to use improved varieties, and the moist transitional zone is more likely to use improved varieties than the coast zone. Farmer characteristics are also important, as younger farmers are more likely to use improved varieties, although this coefficient is not significant in the 2002 sample. Households that are female-headed are not different from male-headed households in terms of use of improved varieties. The institutional characteristics are also important: both access to credit and access to extension are positively related to the probability of using improved varieties, although the effect is much less in the 2002 sample. Table 3. (see Annex).

The logistic model was also estimated for use of fertilizer, with the same explanatory variables. The coefficient of the time dummy is large and significant, indicating an increase in the number of fertilizer users, which is not explained by the other explanatory variables. The coefficients on zones were significant in the pooled sample and the 2002 sample. This suggests that farmers in the coast zone were less likely to use fertilizer than the farmers in the transitional zones in 2002. Farmer characteristics were not statistically significant, except for schooling, which was positively related with fertilizer use in the 1992 sample. In the 1992 sample, those farmers with a larger area planted with maize and those who owned cattle were less likely to use fertilizer. Access to extension was positively related to fertilizer use in the pooled and the 2002 sample, while access to credit was positively related to fertilizer use in the 1992 sample. Table 4. (see Annex)

Factors influencing fertilizer intensity (kg/ha) were estimated using the Tobit (censored regression) model. Since most farmers are using fertilizer below the recommended levels suggested by the extension service, we can assume that using more fertilizer will improve productivity. The agro-ecological zones have statistically significant effects, which may be due to different access by farmers in different zones to fertilizer and by different responses to fertilizer use. The 1992 sample again shows a negative effect of owning cattle and maize farm size on fertilizer use.

In order to understand which factors increase the maize yield, a linear model was used, with yield (kg/ha) as the dependent variable. The use of improved maize varieties (binary) and intensity of fertilizer use were included as explanatory variables. Of the two technologies, only fertilizer had a significant impact on yields. The amount of fertilizer used is very important and significant, although the yield response is quite low (1.5 kg of maize for 1 extra kg of fertilizer). Using improved varieties, all other factors constant, does not improve yield. This indicates that in areas where farmers still use local varieties, the yield advantage of improved varieties is not significant, holding all else constant. In other words, where they are used, local varieties are comparable to improved varieties, indicating a need for improved modern varieties that are more adapted to these areas. Table 5. (see Annex)

The period of the survey has a significant effect, indicating a positive trend not fully explained by the other variables. Zones are also clearly important, reflecting the differences in agricultural potential, especially in the later period. Farm households that are headed by females have a lower yield, which could reflect labor shortages in crucial periods such as weeding. Finally, in the pooled sample, use of credit has a significant impact on yield, in contrast to extension. This may be due to the fact that receiving extension services is highly correlated with intensity of fertilizer use.

5. Conclusions

Since the liberalization of the maize sector in Kenya, maize yields and production have increased very little. Fertilizers have become more available and cheaper and more farmers use them, but the average quantities used per hectare are now lower than before. The rise of informal and micro-credit availability is also a positive sign, as the estimations indicate that extension and credit was correlated with the use of improved technologies. Nevertheless, the declining fertilizer use is worrisome: Although the number of users increases, the intensity of use is now much smaller and considerably below the recommended levels. Why is it so? One might think of two possible reasons. Either this might reflect the general decline in the economy, which puts more demands on the little cash available or the existing modern seed varieties are less responsive to fertilizers. The liberalization of the seed markets has not yet had much of an effect on the use of improved varieties. The seed industry is still largely a monopoly, few new varieties have entered the market, use of the improved varieties has only increased marginally, and yield effects are small, which reinforces the point that the existing modern varieties are less responsive to fertilizers.

Several policy recommendations can be derived from the results of this study. Since institutional factors such as schooling, extension and credit are clearly correlated with technology use, they should be improved. Although support for government extension services is limited, stronger collaboration with NGOs, who often have the funds, personnel resources for extension services, and the human capital, is indicated. For credit, micro-finance and informal credit and loan associations should be encouraged.

Input markets for fertilizers by now are well developed. Since farmers now use less fertilizers than previously means that there is an urgent need to further research this issue. The findings of Otsuka and Yamano reported in this special issue clearly indicate that farmers in Highlands Kenya tend to use recommended, sometimes even higher levels of fertilizers (organic or inorganic), when the modern seed varieties are responsive to fertilizers. This suggests that the varieties used in Eastern Kenya may not be responsive to fertilizer under the conditions in farmers fields. We would expect that as varieties become available that are responsive to fertilizer and profitable with fertilizer use, farmers will adopt fertilizer. In addition, as noted by Otsuka and Yamano, alternative soil fertility approaches such as using cattle manures are needed. Maize research should also focus on those areas for which improved adapted varieties are not readily available.

Table 1. Means of variables

Group	Variable	Units	Low Tropics (coast)			Dry midaltitude			Dry Transitional			Moist transitional east		
			1992	2002		1992	2002		1992	2002		1992	2002	
Head	Age	Years	47.23	46.83		46.57	51.77	**	47.5	51.27		47.21	45.88	
	Some Schooling	0=no, 1=yes	25	76	***	56	83	***	66	77		56	80	***
	Female Headed	0=no, 1=yes	31	27		45	8	***	38	31		44	22	**
Farm	Own Cattle	0=no, 1=yes	0	33	***	33	69	***	20	81	***	11	73	***
	Sold Maize	0=no, 1=yes	22	14		44	49		4	44	***	5	N.A.	
	Farm Size (Ha)	ha	2.34	4.04	***	3.54	8.19	**	1.52	5.58	***	1.25	1.91	*
Institutional	Access To Extension	0=no, 1=yes	31	40		33	14	***	35	29		51	26	***
	Access To Credit	0=no, 1=yes	3	15	***	12	12		3	10		5	55	***
Maize	Uses Imv	0=no, 1=yes	35	75	***	62	25	***	37	36		85	98	**
	Fertilizer Use, Intensity	Kg/ha	0	14.59	***	19.25	1.03		52.46	29.41	*	191.98	117.44	
	% Farmers using fertilizer		0	12		10	7	*	33	54		56	69	
	Maize Production	Kg/household	578	1012	**	356	1193	**	414	1652	***	370	536	
	Maize Area	ha	1.26	2.2	***	1.5	3.26	***	0.84	3.36	***	0.5	1.02	**
	Maize Yield	Kg/ha	548	942	*	591	405		663	1263	*	1034	1453	*
Sample Size	N	Number of farmers	100	294		180	169		80	83		100	140	

***, **, * Significant difference of means (at 0.1%, 1%, or 5%), for the t-test of equality of means for independent samples (equal variances assumed where appropriate after Levene's test)

Table 2. Factors influencing the adoption of improved maize varieties (dependent variable= binary, using logistic model, pooled and by period)

Type	Variable description	Pooled Data			1992			2002		
		Coefficient	*t*-statistic		Coefficient	*t*-statistic		Coefficient	*t*-statistic	
Time	Year (1992=0, 2002=1)	0.024	0.140							
Zones	Dry Mid-Altitudes	-0.836	- 4.723	***	1.078	3.466	***	-2.281	-8.807	***
	Dry Transitional	-1.187	-5.521	***	0.061	0.169		-1.757	-6.017	***
	Moist Transitional	1.657	5.939	***	2.327	6.108	***	2.365	3.846	***
Head of hh	Age	-0.010	-2.000	**	-0.015	-2.143	**	-0.003	-0.429	
	Some schooling	0.276	1.673	*	0.309	1.272		-0.157	-0.602	
	Female headed	0.111	0.694		-0.072	-0.314		-0.251	-0.988	
Farm	Own cattle	0.168	1.043		0.209	0.685		0.197	0.900	
	Farm size (ha)	-0.022	-1.833	*	-0.05	-1.429		-0.007	-0.636	
Institutional	Access to extension	0.455	3.013	***	0.698	2.996	***	0.007	0.032	
	Access to credit	0.909	3.885	***	1.238	2.367	**	0.569	1.922	*
Constant	Constant	0.679	2.205	**	-0.247	-0.544		1.385	2.910	***
Measures of fit	% Correctly predicted	69.80			68.9			87.9		
	-2 Log likelihood	1243.25			500.301			635.019		
	Cox & Snell R Square	0.201			0.212			0.308		
	Nagelkerke R Square	0.272			0.285			0.422		
Sample size	N	972			444			672		

***, **, * Coefficient significantly different from zero (at 1%, 5%, or 10%),

Table 3. Factors influencing the adoption of fertilizer on maize (dependent variable= binary, using logistic model, pooled and by period)

Type	Variable description	Pooled data			1992			2002		
		Coefficient	*t*-statistic		Coefficient	*t*-statistic		Coefficient	*t*-statistic	
Time	Year (1992=0, 2002=1)	0.756	3.245	***						
Zones	Dry Mid-Altitudes	0.383	1.330		7.902	0.476		-0.4	-1.058	
	Dry Transitional	2.439	8.805	***	9.513	0.573		2.179	6.896	***
	Moist Transitional	3.134	11.782	***	10.2	0.614		2.908	9.381	***
Head of hh	Age	0.004	0.667		0.023	2.091	**	-0.002	-0.250	
	Some schooling	0.199	0.909		0.755	1.961	*	-0.149	-0.528	
	Female headed	0.192	0.946		0.053	0.157		-0.065	-0.241	
Farm	Own cattle	-0.109	-0.540		-1.39	-2.678	***	0.337	1.434	
	Farm size (ha)	-0.027	-1.286		-0.448	-2.800	***	-0.01	-0.526	
Institutional	Access to extension	0.577	3.069	***	0.507	1.527		0.504	2.127	**
	Access to credit	0.078	0.326		1.456	2.348	**	-0.164	-0.594	
Constant	Constant	-3.508	-7.528	***	-11.05	-0.665		-2.128	-3.814	***
Measures of fit	% correctly predicted	81.2			84.8			81.4		
	-2 Log Likelihood	853			237			567.365		
	Cox & Snell R Square	0.26			0.293			0.285		
	Nagelkerke R Square	0.39			0.473			0.411		
Sample size	N	1146			382			672		

***, **, * Coefficient significantly different from zero (at 1%, 5%, or 10%),

Table 4. Factors influencing the intensity of fertilizer use on maize (dependent variable is kg/ha, using censored regression or tobit model)

Type	Variable Description	Pooled			1992			2003		
		Coefficient	*t*-statistic	Sig.	Coefficient	*t*-statistic	Sig.	Coefficient	*t*-statistic	Sig.
Time	Year (1992=0, 2002=1)	57.5	0.163							
Zones	Dry Mid-Altitudes	53.6	1.048		37697.264	2.116	**	-80.895	-1.882	*
	Dry Transitional	352.9	6.627	***	37973.712	2.131	**	190.973	4.727	***
	Moist Transitional	505.1	10.122	***	38085.108	2.137	**	348.368	9.108	***
Head of hh	Age	0.9	1.315		6.209	2.001	**	0.534	1.304	
	Some schooling	15.6	0.434		82.688	0.813		-1.778	-0.058	
	Female headed	-0.5	-1.365		-42.568	-1.386		-0.287	-1.269	
Farm	Own cattle	-49.4	-1.337		-297.239	-2.033	**	13.916	0.495	
	Farm size (ha)	-0.1	-0.216		-62.363	-3.227	***	-0.015	-0.062	
Institutional	Access to extension	57.3	1.751	*	22.713	0.252		43.033	1.583	
	Access to credit	25.4	0.614		219.595	1.273		-12.345	-0.391	
Constant	Constant	-666.9	-9.304	***	-38505.458	-2.161	**	-333.942	-1.413	
Measures Of Fit	-2 Log Likelihood	4161.5			1214.642			2820.000		
	ANOVA Based Fit Measure	0.537		***	13.127			83.855		
	Sigma	352.546	17.156	***	553.3187	52.522		231.545	12.985	
Sample Size	N	1146			460.000			686.000		

***, **, * Coefficient significantly different from zero (at 1%, 5%, or 10%),

Table 5. Factors influencing maize yield (kg/ha, using linear regression model)

	Variable Description	pooled			1992			2002		
		Coefficients	*t*-statistic		Coefficients	*t*-statistic		Coefficients	*t*-statistic	
Inputs	Quantity of fertilizer on maize (kg/ha)	1.5	4.043	***	2.126	6.542	***	1.111	2.128	**
	Farmer uses improved	-92.6	-0.896		101.67	0.941		-270.291	-1.926	*
Year	Year of survey	223.5	1.815	*						
Zone	Moist transitional	618.9	4.046	***	110.375	0.822		956.831	4.317	***
	Low tropics	434.9	3.486	***	210.116	1.568		697.631	4.121	***
	Dry transitional	603.2	3.947	***	79.481	0.548		887.076	4.352	***
Head of hh	Age	-1.5	-0.500		4.991	1.536		-3.773	-0.975	
	Some schooling	-20.7	-0.190		157.953	1.506		-150.467	-1.028	
	Female headed	-206.6	-1.916	*	96.517	0.954		-397.895	-2.734	***
Farm	Own cattle	87.7	0.856		102.783	0.675		123.885	1.006	
	Farm size (ha)	-8.6	-1.807	*	-15.69	-1.207		-7.455	-1.401	
Institutional	Access to extension	38.7	0.397		81.591	0.806		-1.88	-0.015	
	Access to credit	253.9	2.064	**	-13.695	-0.071		243.401	1.629	
	(constant)	409.2	1.837	*	28.093	0.128		786.208	2.590	**
N		844			199			644		
R2		0.092			0.276			0.09		
Standard error of estimate		1276			660			1402		

***, **, * Coefficient significantly different from zero (at 1%, 5%, or 10%),

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