Ex-Ante Evaluation of Drought Tolerant Varieties in Eastern and Central Africa

Genti Kostandini
Department of Agricultural and Applied Economics
University of Georgia
1109 Experiment Street
223 Stuckey Building
Griffin, GA 30223-1797
Tel.: 770-228-7231 x 121, Fax: 770-228-7208
E-mail: gentik@uga.edu

Bradford F. Mills
Department of Agricultural and Applied Economics
Virginia Polytechnic Institute and State University
314 Hutcheson Hall, Blacksburg, VA 24060
Tel.: 540-231-6461, Fax: 540-231-7417
E-mail: bfmills@vt.edu

Elton Mykerezi
Department of Applied Economics
University of Minnesota
218F Classroom Office Building
1994 Buford Ave.
St. Paul, MN 55108
Tel.: 612-625-2749, Fax: 612-625-2768
E-mail: myker001@umn.edu

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009.

Introduction

In sub-Saharan Africa drought is a major source of both production variability and exposure to risk in household income flows. In the early 90's estimated annual drought related losses amounted to 25 million metric tons of rice and 20 million metric tons of maize in tropical areas, and 19 million metric tons of maize in non-temperate areas (Doering, 2005). Sub-Saharan Africa is seen as the core of the global drought and desertification problem (UNESCO, 2003) with at least 60 percent of the region vulnerable to drought and 30 percent highly vulnerable to drought (Benson and Clay, 1998). Predictions suggest that by 2050 some climates in the region will be 10 to 20 percent drier compared to the 1950-2000 averages (Kigotho, 2005). In addition, agricultural sources of fresh water are decreasing in both quality and quantity, causing farmers in irrigated areas to be increasingly categorized as 'partially' or 'poorly' irrigated (Toenniessen, 2003). On a global scale, estimates indicate that 65 percent of the poor households already live in drought-prone marginal areas, where drought related crop losses increase household exposure to poverty (FAO, 1997).

Ex-post measures to reduce the effects of drought in poor countries are costly and provide only short term support. For example, the World Food Program spent $US 665 million in 2003, 85 percent distributed in sub-Saharan Africa to protect vulnerable households in the face of drought and associated crop failure (World Food Program, 2003). Drought resistant varieties, on the other hand, provide long term benefits against drought related losses. Breeding for drought resistant varieties has to date been mainly conducted by the public sector through conventional breeding. The African Maize Stress project, for example, has tested more than two thousand genotypes under drought conditions in Kenya (Bett et al., 2003; Hassan et al., 1998). Transgenic methods have been the major source for enhancing productivity in agriculture for the last two decades and recent studies suggest that there remains substantial room for transgenic methods to improve crop drought resistance in semi-arid regions (CGIAR, 2003; FAO, 2003; Doering, 2005; Lobell et al., 2008). In fact multinational biotech companies such as Monsanto have already developed transgenic drought resistant varieties of maize and wheat, with open field trials of drought resistant maize currently under way in the U.S. and South Africa (African Center for Biosafety, 2007).

As agricultural production is an important source of income for subsistence farmers in developing countries, agricultural technologies and policies that stabilize incomes and reduce production variability stand to reduce the vulnerability of smallholder households to poverty and increase welfare. However a framework does not currently exist to value the economic impact of production stabilizing technologies and policies on small scale producers. But with hundreds of drought resistant varieties in the pipeline, evaluation of the potential economic impact of drought resistant varieties at the household level would provide needed guidance for the allocation of hundreds of millions of dollars of public and private sector funds being devoted to drought research. This paper presents a framework for measuring the benefits of mean-increasing and variance-reducing transgenic and non-transgenic drought resistant varieties of maize, millet and sorghum among small, medium and large farm-household producers in the rainfed regions of Kenya, Uganda and Ethiopia.[1] The framework is easily adaptable to quantify the benefits of other 'yield-enhancing' and 'variability-reducing' technologies in agriculture, such as pest and disease resistant crop varieties which also increase the volatility of agricultural income (Hardaker et al., 2004; Qaim and Zilberman, 2003).

[1] We focus on these three countries as they are important producers of maize, millet and sorghum in Sub-Saharan Africa. In addition their agricultural research systems are relatively advanced compared to other countries in the region, with associated data availability and accessibility.

The framework makes use of drought risk information and spatial crop data to identify rainfed production areas in each country and their exposure to drought risk. Household data are then used to characterize three types (small, medium and large) of maize, millet and sorghum producing households in the rainfed areas of Kenya, Uganda and Ethiopia and to quantify ex-ante benefits of improved drought resistant varieties. The distribution of benefits among small, medium and large farmers and potential profits to the private sector are also documented.

The rest of the paper is structured as follows. Section two describes the spatial framework and data used to characterize agricultural production and agricultural income risk in Kenya, Ethiopia and Uganda. The model used to measure the ex-ante economic impacts of mean yield increases and yield variance reductions is laid out in section three. Section four outlines the data used to generate the ex-ante estimates of farm household impacts. Results are presented in section five, followed by concluding remarks in section six.

A Spatial Framework Characterizing Agricultural Production and Income Risk

Knowledge of the spatial distribution of drought risk can be a helpful tool for assessing the potential impact of drought related research programs. This section presents a measure of drought exposure and describes how it is overlaid with rainfed production in the major regions of Kenya, Ethiopia and Uganda. Drought risk is derived by taking 30 years of actual rainfall and evapotranspiration data as input to a soil moisture model that accounts for both the depth and water holding properties of local soils (Fischer et al., 2002). The drought risk map is then overlaid with maps that delineate maize, millet and sorghum production and planted areas under rainfed conditions on a 10km x 10km pixel resolution in each country.[2] Finally, administrative

[2] Rainfed zones, drought risk maps, and production and planted area data for maize, millet and sorghum were kindly provided by the International Food Policy Research Institute (IFPRI).

maps are used to extract production and planted area in each administrative region of each country.

The results from allocation of rainfed production (metric tones) across country regions in Kenya, Uganda, and Ethiopia (Amhara region) and drought risk levels are presented in table 1. Household data was only available for the Amhara region of Ethiopia and it is the only region analyzed in that country. Most of the maize, millet and sorghum production in Kenya takes place in the Rift Valley and Coastal region under high and medium drought risk conditions. A similar pattern is also found in Uganda, where most of the maize, sorghum and millet production takes place in the Eastern region and is exposed to high and medium drought risk. Cropping patterns in the Amhara region of Ethiopia indicate that most of the production for each crop takes place under medium drought risk.

"TABLE 1 ABOUT HERE"

Measuring Economic Impacts of Mean Yield Increases and Yield Variance Reductions

The economic impact of changes in agricultural productivity and risk on producing households

This paper focuses on measuring the expected benefits from changes in mean yields and yield variance reductions at the household level. Household data for Kenya, Uganda and the Amhara region in Ethiopia are used to create representative producer household types (small, medium and large) as described in the next section. In order to find household level benefits we need to allocate the small, medium and large households to low, medium, and high drought risk zones of each administrative region in each country. Unfortunately, available household surveys did not provide information on the exact location of the household, but only the sub-region which can be exposed to more than one drought risk regime. However, most of the representative households reside mainly in medium-high drought risk zones. Maize, sorghum and millet production and planted area data are available for each drought risk level within each administrative region of each country from the spatial analysis.

Aggregation to the regional-level is based on the weighted shares of maize, millet and sorghum planted acreage of small, medium and large households in each drought risk zone within each region. First to find the total planted area by household type for each drought risk zone, the total planted area of each drought risk zone within each administrative region is divided by the share of the total acreage planted for each household type across all surveyed households for that region. The number of households in each drought risk zone is then found for each household type, the planted area of that household type is divided by the average planted area of the household type. Finally, net regional level benefits for small, medium and large producer households are found by aggregating benefits across adopting households and subtracting losses to non-adopters due to equilibrium price changes.

Benefits of mean yield increases

A partial equilibrium framework based on consumer and producer surplus changes at the market level has been developed to evaluate the potential impact of technologies that increase mean yields (see Alston, Norton and Pardey, 1995). However, this paper focuses on the benefits from income stabilization as well as income increases associated with the adoption of new agricultural technologies at the household level. Thus, benefits of mean yield increases are measured as changes in producer and consumer income for each representative household type in sub-region rainfed areas with a uniform level of drought risk. The division allows us to better specify the potential impact of drought resistant varieties, which may have different responses under different drought risk levels.

Drought resistant varieties may generate yield increases, which translate into a unit cost reduction in producer costs. The producer experiences a change in income from lower production costs, but also a lower price from market induced price response to supply. The consumer experiences a gain in income from the lower market price.

The changes in household producer income can be approximated as:

(1) $\Pr_{ij}.Y = K_j P_j Q_{p\,j} - \Delta P Q_{p\,i}$

(i = small, medium, large: j = low, medium and high drought risk)

where *Pr. Y* is the producer benefit from the crop, P is the new equilibrium price, Q_p is the quantity produced and ΔPQ is the change in the price level times the quantity produced before adopting the technology. K is the unit cost reduction calculated as $K = \left[\frac{E(G)}{\varepsilon} - \frac{E(C)}{1+E(G)}\right] A_t$

where $E\,(G)$ is the expected increase in yield per hectare, $E\,(C)$ is the proportionate change in variable costs per hectare, A_t is the expected adoption rate and ε is supply elasticity.

Changes in consumer income are approximated as:

(2) $Cs.\ Y = \Delta PQ_c$

where *Cs. Y* is the change in consumer expenditure in the market, ΔP is the change in price and Q_c is the quantity consumed. Changes in price after the introduction of the new technology can be easily calculated from elasticities of consumer demand (η), producer marginal cost (ε), and initial prices and quantities sold in each region's drought risk zone. Changes in consumer income are estimated only at the market level.[3]

The development of drought resistant varieties using genetic engineering will most likely arise from private sector investments with IPR protection on seed. Assuming the seed company

[3] This is the same as assuming that each region consists of a representative consumer.

behaves as a monopolist in the seed market, private sector profit is calculated as $\Pi = (P_m - C)\ H$ where P_m is monopoly price seed for one hectare, C is the marginal cost of producing seed to plant one hectare and H is the area planted with the transgenic seed (Falck-Zepeda et al., 2000). Most studies have assumed a constant marginal cost of seed per hectare (Qaim and De Janvry, 2003: Acquaye and Traxler, 2005: Falck-Zepeda et al., 2000). The price that maximizes monopoly's profits can then be found from Lerner's rule, $P_m = C / (1 + \upsilon^{-1})$, where υ is the elasticity of demand for seed. In the case of a seed markup, the K shift is adjusted for changes in unit costs associated with the increased price of seed.

Benefits of yield variance reduction

Yield variance reduction has been a priority of many crop improvement programs (Heisey and Morris, 2006). To measure the benefits of yield variance reductions we follow the Newberry-Stiglitz (1983) framework. The individual producer has a Von-Newman Morgestern utility function of income $U(Y)$ with:

(3) $R = -YU''(Y)/U'(Y)$

where R is the coefficient of relative risk aversion. Producers are risk averse with respect to variations in incomes and changes in yield variations influence income variation. The reduction in yield variance will change the distribution of income from $\tilde{Y}_0$ with mean $\overline{Y_0}$ and coefficient of variation σ_{y0} to distribution $\tilde{Y}_1$ with mean $\overline{Y_1}$ and coefficient of variation $\sigma_{y1.}$ The money value B for this reduction in income variation can be found by equating:

(4) $EU(\tilde{Y}_0) = EU(\tilde{Y}_1 - B)$

Expanding both sides of this equation using a Taylor series approximation, dividing both sides by $\overline{Y_0}\, U'(\overline{Y_0})$ and neglecting terms of order higher than σ^2_{y1} he equation reduces to:

$$\text{(5)} \qquad \frac{B}{\overline{Y_0}} = \frac{\Delta \overline{Y}}{\overline{Y_0}} - \frac{1}{2} R(\overline{Y_0}) \left\{ \sigma^2_{Y1} \left(\frac{\overline{Y_1}}{\overline{Y_0}} \right)^2 - \sigma^2_{Y0} \right\}$$

where $\Delta \overline{Y} = \overline{Y_1} - \overline{Y_0}$ and the first term on the right hand side is what Newbery and Stiglitz (1983) call transfer benefits while the second term is the risk benefit. If we focus solely on yield variance reductions, mean income $\overline{Y_0}$ does not change and producer risk benefits are measured as:

$$\text{(6)} \qquad \frac{B}{\overline{Y}_0} = \frac{1}{2} R \left\{ \sigma^2_{Y0} - \sigma^2_{Y1} \right\}$$

More specifically, adjusting for risk benefits at the household level for each type of household equation (6) can be written as:

(7) $\Pr_{ij}.RB = 0.5 R Y_i s_{ijk} (\vartheta_{ij} \sigma^2_k + \Delta \sigma^2_p)$

(*i* = small, medium, large: *j* = low, medium, high drought risk: *k* = maize, sorghum, millet)

where $\Pr_{ij}.RB$ is the producer risk benefits , R is the relative risk aversion coefficient, Y_i is the total household income, s_{ijk} is the share of the crop income on total income, ϑ_{ij} is the percentage reduction in yield CV, σ^2_k is the squared coefficient of yield CV, and $\Delta\sigma^2_p$ is the change in the CV of price at the market level.[4]

Consumers may also benefit from a yield variance reduction through changes that variance of prices in each zone have on their expenditures. These consumer risk benefits can be measured as:

[4] It is assumed that the yield at the farm level is not correlated with the price at the market level.

(8) $$\frac{B}{\overline{X}_0} = \frac{1}{2} R\left\{\sigma^2_{p0} - \sigma^2_{p1}\right\}$$

where $\overline{X_0}$ is the mean consumer expenditure, $\sigma^2_{p_0}$ and $\sigma^2_{p_1}$ are the squared coefficient of variation of prices before and after the yield variance reduction, respectively, as price variability is the only pathway by which yield variability impacts consumers. Two simplifying assumptions embedded in equations (7) and (8) are that the prices in other markets and producer and consumer income from other sources remain constant.

It is clear that the households are also affected by supply –shock-induced market-level price variance, which should be accounted for in the analysis. To estimate these effects, the areas under the same drought risk level for each region in each country are considered to consist of a representative producer and consumer exposed to market price and quantity variability.
In addition, specific assumptions are needed on the shape of supply and demand curves to find the effects of yield variance reductions on price variability and, thus, producer income and consumer expenditure variability. Results are also sensitive to the specification of the source of risk (Newbery and Stiglitz, 1983). In this study we focus on the impact of technologies that reduce the variance of yields and the source of risk lies on the supply side. We then assume additive supply risk with linear demand and supply curves which are easily constructed using information on price, quantity and demand and supply elasticity. Demand and supply are thus specified as:

(9) $Q_d = \theta - \gamma P$ $(\gamma > 0)$

(10) $Q_s = \alpha + \beta P$ $(\beta > 0)$

where Q_d and Q_s are quantity demanded and supplied, respectively. P is price, θ is a constant and α is a normally distributed random variable with mean μ_α and variance σ_α. Thus, demand is stable and supply fluctuates due to weather, technology and other factors. The yield variance reduction can be incorporated in the analysis as a reduction in the variability of supply (i. e. as a reduction in σ_α). Specifically, if the coefficient of yield variation is reduced by a fraction z and the adoption rate of the technology is A, then, the new supply variability is $(1\text{-}z)A\ \sigma_\alpha$.

Under this framework, changes in the coefficient of variation of price at the market level can be found by comparing the difference on the variation of price with and without the yield variance reduction. Specifically, given demand and supply specifications the variance of price is $Var(P) = \left[\left(\frac{1}{\gamma + \beta} \right)^2 \sigma_\alpha^2 \right]$. Market level changes in the coefficient of variation of prices are simulated by applying a reduction of (1-z) in the coefficient of variation for the zones with the same drought risk level within the regions of Kenya, Uganda and Amhara region in Ethiopia and adoption rates borrowed from other studies in these three countries. Producer risk benefits can then be calculated using equation (7). Consumers also experience changes in the variation of their expenditures from yield variance reductions through changes in the coefficient of variation of price and their risk benefits can be calculated from equation (8).

Data Description

Characterizing representative maize, millet and sorghum producing households

Agricultural production in Kenya, Ethiopia, and Uganda takes place across a range of household farm sizes and the impacts of new drought resistant crop varieties will likely differ across this range. Existing household surveys for each country are analyzed to create three types (small, medium and large) of representative maize, millet, and sorghum producing households based on farm size quantiles in the regions of Kenya, Uganda, and Amhara region in Ethiopia. The following statistics are generated for each household type in each region: farm size, maize income, sorghum income, millet income, the share of maize, millet, and sorghum on the total acreage and total farm income, crop prices, yields, and the share of other major agricultural and non-agricultural income sources in total household income.

For Kenya the most recent survey with information on the yields and prices of maize, millet and sorghum, as well as all income from all other sources is the 2000 Rural Household Survey of Kenya.[5] This data set is used in the model to estimate the benefits of mean yield increase and yield variance reductions for representative households and aggregate them to the regional level. Descriptive statistics on the variables of interest for each representative household in the Central, Eastern and Nyanza region of Kenya are illustrated in table 2.[6] Results suggest that total household income in Kenya increases with farm size in each region and maize is the most important source of crop income across all household types. There are also differences in total household income across regions with households in Nyanza having the smallest income and households in the Central region having the largest total income. Panel data is necessary to derive the variation of yields, incomes and other parameters of interest for each household type in each country. However, panel data is only available for Kenya and a description of the data set can be found in Appendix A.

"TABLE 2 ABOUT HERE"

The 2005/06 National Household Survey from the Uganda Bureau of Statistics is used to create small, medium and large representative households in the four main regions (Central, Eastern, Northern and Western) of Uganda and derive the parameters of interest. The survey

[5] The Coastal region of Kenya did not have enough observations to compute the CVs of the main variables during the four years, however, it had enough observations in 2000, and it is still included in the analysis.
[6] The rest of the descriptive statistics for the other three regions of Kenya (Rift Valley, Western and Coastal region), the four regions of Uganda and the Amhara region of Ethiopia are available from the authors upon request.

covers a 12-month period (from July 2004 until June 2005) and provides detailed information on crop production, consumption, sales, livestock production, livestock products, and each source of household income including gifts and remittances. Descriptive statistics indicate that average total income increases with farm size. Maize income appears to be the most important source of crop income, while sorghum and millet income contribute with similar smaller shares to total household income.

A household survey of Ethiopia with the information needed to create the variables of interest for this study is not available for all administrative regions. However, a complete household survey for 1999/2000 for the Amhara Region in Ethiopia is available.[7] Similar to households in Kenya and Uganda, the average total income of households in the Amhara region increases with farm size. Small and medium sized households earn more income from sorghum than maize, but, maize remains the most important crop planted for large households.

Since no panel data is available for Uganda or Ethiopia, we use the estimated CVs from the Kenya panel for small, medium and large farms to account for the variability of maize, millet and sorghum yields, as well as total income variance.

Expected mean yield increases and yield variance reductions from public and private sector research

The public sector has a long history of breeding for drought tolerant maize in drought prone areas, but new classification and selection methods suggest room for further gains. For example, Banziger et al. (2006) report a 40 percent yield advantage for CIMMYT hybrid drought maize varieties at the 1-ton/ha yield level compared to private sector hybrids for the drought prone

[7] The survey was collected through collaboration of IFPRI, the International Livestock Research Institute (ILRI) and the Amhara National Regional Bureau of Agriculture and Natural Resources.

areas in Eastern and Southern Africa. Betran et al. (2003) found that hybrids performed significantly better than inbreds with average grain yields of 1.14 t/ha compared to 0.15 t/ha for inbreds under severe drought stress. The hybrids also performed better in terms of stability, showing almost half of the variation of the inbred lines selected for drought. Similarly, Seboksa, Nigussie and Bogale (2001) conclude from field trials in Ethiopia that it is possible to develop drought maize varieties with higher yield and greater yield stability across different drought prone environments. Other studies have confirmed these results in drought prone environments of Mexico and Zimbabwe (Betran, Beck, Banziger, and Edmeades 2003; Worku et al. 2001; Tollenar and Lee 2002; Monneveux, Sanchez, Beck and Edmeades 2005).

New drought resistant varieties of maize, millet and sorghum developed through conventional breeding are expected to deliver yields at least equal to those of current varieties during the good years and significantly better yields during bad years. As part of the study, maize, millet and sorghum breeding experts from CIMMYT and ECARSAM were asked to provide estimates on potential mean yield increases and yield variance reductions for maize, millet and sorghum. These expert opinions indicated potential ranges of 10 percent to 50 percent for both yield increases and variance reductions, with higher benefits in the higher drought risk rainfed areas. Based on expert opinion and field trial estimates from the studies mentioned above, and factoring in that farm level performance is generally lower than field trial performance, we assume 18 percent, 13 percent and 10 percent increases in maize mean yields and 20 percent, 15 percent and 10 percent variance reductions in the high, medium, and low drought risk rainfed areas, respectively, in Kenya, Uganda, and Amhara region in Ethiopia.

Private sector involvement in transgenic drought research suggests that higher yields and stability levels can be achieved via transgenic methods which are superior when compared to conventional breeding methods utilized mostly by public sector research. Although information on productivity advantages of private sector transgenic drought tolerant crops is rare prior to their commercial releases, the results from the experimental data that does exist are promising. For example, insertions of drought tolerant genes into maize have generated 10-23 percent higher yields under drought stress when compared to traditional maize varieties (Garg et al., 2002). Monsanto's field trials on drought tolerant transgenic maize varieties in the U.S. show a 23.3 percent increase in maize yield compared to their non-transgenic counterparts (Merret, 2007). In 2007 Monsanto obtained permission to test transgenic drought tolerant maize in open field trials in South Africa with hopes to achieve commercialization as early as 2010 (African Center for Biosafety, 2007). Based on these results we assume that private sector transgenic drought resistant maize varieties achieve mean yield increases of 25 percent, 20 percent, and 15 percent in the high, medium, and low drought risk rainfed areas, respectively, in the three countries. Similarly, yield variance reductions of 25 percent, 20 percent, and 15 percent are assumed in the high, medium and low drought risk areas, respectively.

Sorghum and millet are also important staple crops in Africa where an estimated 300 million people in arid areas rely on them as a source of food (Reuters, 2006). Sorghum and millet are known to perform well in drought prone areas, but opportunities remain for improvement. Public sector selection and breeding efforts have recently generated high yielding and yield stabilizing sorghum drought resistant varieties. Showemimo (2007) tested 20 different genotypes in 5 different locations in the savanna agroecological zone of Nigeria for three years and found average yields of 3.02 t/ha and square yield deviation of 0.07 across the 5 locations. These numbers compare very favorably with average current yield levels of less than 0.8 t/ha and high yield variability across regions and time. Haussmann et al. (2000) carried out a similar experiment in eight macro-environments in the semi-arid Makueni District of Kenya and found that hybrids outyielded their parents lines by an average of 54 percent and showed greater yield stability. Conservative mean yield increases of 18 percent, 13 percent, and 10 percent and yield variance reductions of 20 percent, 15 percent, and 10 percent in the high, medium, and low drought risk areas, respectively, are assumed based on these findings.

Public sector research has also demonstrated significant improvements in millet yields in drought prone areas. For example, Yamoha et al. (2002) showed that integrated crop residue management and crop residue plus fertilizer can result in 1.2 and 2 times higher yields, and greater yield stability compared to the control crops (no residue and no fertilizer). Omanya (2004) conducted on-farm yield trials for improved drought resistant millet varieties during the 2003 and 2004 seasons in Burkina Faso, Mali and Niger. The improved varieties showed 10 percent yield increases compared to the local varieties. Serraj et al. (2004) also point out that marker-assisted selection for drought tolerance in pearl millet has achieved significant improvements in yields. For the purpose of this study we consider a 15 percent increase in mean yields in high drought risk rainfed areas, 12.5 percent increase in medium drought risk areas and 10 percent mean yield increases in low drought risk areas. In addition, variance reductions of 18 percent, 14 percent and 10 percent are employed for the high, medium, and low drought risk areas, respectively, from public sector research on millet. Investments in transgenic sorghum and millet in the private sector have been limited and are not evaluated in the paper.

Adoption rates

Several studies report adoption rates of improved maize, millet and sorghum varieties in Africa. For example Maredia, Byerlee, and Pee (2000) estimated overall adoption rates of 37 percent in

Africa for improved maize varieties with specific adoption rates of 70 percent in Kenya, 60 percent in Uganda, and 21 percent in Ethiopia. The study also reports sorghum expected adoption rates of 19 percent for Uganda, 38 percent for Kenya and 6 percent for Ethiopia. De Groote et al. (2002) also report adoption rates of maize varieties for Kenya and Uganda with 74 percent in Kenya and from 7 percent up to 47 percent across different areas in Ethiopia. Sserunkuuma (2002) reports adoptions of 62 percent for improved maize varieties in Uganda.

Given that proposed maize varieties will be particularly beneficial for drought-prone areas, we assume adoption rates of 50 percent in the high drought risk zones and 40 percent in the medium drought risk zones of Kenya for maize drought resistant varieties from both private sector transgenic research and public sector conventional breeding. Studies on farmer adoption rates of improved sorghum and millet varieties in Kenya show lower rates compared to maize. Thus, we assume adoption rates of 40 percent and 30 percent for millet and sorghum in the high and medium drought risk areas, respectively.

Reported adoption rates of improved maize varieties in Uganda are slightly lower than in Kenya. Therefore adoption rates of maize are assumed to be 40 percent, 30 percent and 20 percent for the high, medium, and low drought risk areas, respectively. For sorghum and millet drought resistant varieties in Uganda, we employ adoption rates of 20 percent, 15 percent, and 10 percent in the high, medium, and low drought risk zones, respectively. Based on the reported adoption rates for maize in Ethiopia, a 25 percent adoption rate of drought tolerant maize varieties is assumed for the high drought risk zones of the Amhara region and a 20 percent adoption rate is assumed for medium drought risk zones. Finally, ex-ante adoption rates of 10 percent and 8 percent are assumed for drought tolerant sorghum and millet in the high and medium drought risk zones of the Amhara region in Ethiopia, respectively. Adoption rates of small, medium, and large farms are considered to be the same within the drought risk zones of the three countries, as Doss et al. (2003) analyzed twenty two micro level adoption studies in Kenya, Ethiopia and Uganda and found that farm size is not correlated with adoption of new improved varieties.

Seed costs

Seed cost studies usually assume a constant marginal cost per hectare (e.g. Hareau, Mills and Norton, 2006; Qaim and De Janvry, 2003). Juma (2008) reports maize seed costs of $US 8 per hectare in Kenya for the local varieties and $US 56 per hectare for hybrid seed. Private sector seed cost in Kenya were reported to be $50 per hectare and $35.5 per hectare in 2001 for maize hybrid seeds from the private companies KSC and Pioneer, respectively (Nambiro, de Groote and Kosura, 2001). Ugandan farmers pay around $30 per hectare for hybrid maize seed (Larson and Mbowa, 2004). Qaim and De Janvry (2003) assume a constant marginal cost of $25 per hectare for Bt cotton seed in Argentina. Based on these studies we assume a constant marginal cost of $35 per hectare for transgenic drought resistant maize seed in Kenya and $30 per hectare in Ethiopia and Uganda.

Risk aversion coefficients at the household level

Studies have found that risk benefits are sensitive to the magnitude of the coefficient of risk aversion (Ligon and Schechter, 2004; Di Falco and Chavas, 2006; Chetty 2006; Isik, 2002). For example, Chavas and Holt (1996) estimate a coefficient of relative risk aversion R of 6.07 for soybean and corn farmers in the US. Di Falco and Chavas (2006) use an R of 2 and state that this is a moderate level of risk aversion. Brennan (2002) uses values of 2 and 3 for poor farmers.

Other previous studies on developing countries have found values of *R* between 0 and 7 with a median around 1 (Arrow, 1971: Binswager 1981). Barret et al. (2004) estimate a minimum *R* of 1.28 for the rice farmers in Madagascar. Chetty (2006) establishes a new method to estimate *R* and places an upper bound of $R < 2$. Based on this evidence we use a relative risk aversion coefficient of $R = 1.2$ for small, medium and large farmers and $R = 1$ for consumers.

Demand and supply elasticities

Supply and demand elasticities used in this study are borrowed from previous work in Ethiopia, Kenya and Uganda. A Kenya maize supply elasticity of 0.68 and a demand elasticity of -0.4 are estimated by Kiori and Gitu (1992) are employed in this study. Sserunkuuma (2003) estimated maize supply elasticities in the range of 0.22 to 0.41 and demand elasticities in the range of -0.05 and -0.1 for Uganda. Therefore, we assume a supply elasticity of 0.31 and a demand elasticity of -0.075 for maize in Uganda. In his study in Ethiopia, Abrar (2002) found an elasticity of supply of 0.08 for maize. Based on these findings, for Ethiopia we assume a maize demand elasticity of -0.4 and a supply elasticity of 0.08. For Kenya, Uganda and Ethiopia, in the absence of other country specific studies on supply and demand elasticites of sorghum and millet we employ an elasticity of supply of 0.35 and an elasticity of demand of -0.30 as suggested in Gabre-Madhin et al. (2002) for crop supply and demand elasticities in developing countries.

Results

Two types of results are presented in this section for the regions of Kenya, Uganda and the Amhara Region of Ethiopia. First, we present the benefits from mean yield increases and variance reductions at the household level for each household type in each region. Second, we present aggregated benefits at the regional level for the rainfed zones under each drought risk level in each country's regions. All results are reported in $US dollars.

Benefits from mean yield increases and yield variance reductions at the household level for the representative maize, sorghum and millet producing households in Kenya are presented in table 3. Aggregated producer and consumer benefits at the regional level are shown in table 4.

"TABLE 3 ABOUT HERE"

As expected, benefits from public research mean yield increases at the household level are greater in maize compared to sorghum and millet, since households plant larger areas with maize. Household benefits are also on average greater for large farms, since they dedicate more acreage to each crop. Public sector research appears to deliver slightly larger benefits from mean yield increases when compared to private sector research for each producer type. Risk benefits from yield variance reductions at the household level are considerable in the high drought risk region of Kenya, especially for maize in the Eastern and the Rift Valley regions. Risk reduction benefits are also considerable for millet and sorghum producers in Nyanza and Rift Valley regions. Although large and medium farms show greater risk benefits than small farms, the later still earn significant benefits. A similar distribution pattern is found for risk benefits from yield variance reductions for transgenic maize from private sector research. For the private sector, risk benefits from yield variance reduction are greater than benefits from mean yield increases. Private sector research on drought generates greater producer benefits compared to public sector research benefits across all household types in Kenya when considering both, mean yield increase benefits and risk benefits.

Aggregated producer benefits in table 4 reveal large benefits for many regions. Small farms gain less than medium and large farms since the overall maize acreage of medium and large farms is greater. Most of the benefits from maize and sorghum drought research accrue to large farms in the Coastal-High Drought risk region, whereas millet drought research benefits accrue to medium sized farms in the Eastern-High drought risk region. Producers and especially consumers in the Costal-High drought risk zone gain the most from maize public sector drought research. Producers and consumers in the Rift-Valley-Medium drought risk zone gain most of the benefits from millet drought research, while most of the benefits from public sorghum drought research are allocated to producers and consumers in the Coastal-High drought risk zone. Consumers benefit slightly more than producers from sorghum and millet drought resistance research across all regions. Total annual benefits from public sector research in maize, sorghum and millet drought tolerance research across all regions in Kenya are $41 million, $2.3 million and $1 million, respectively.

"TABLE 4 ABOUT HERE"

Private sector benefits to maize consumers and producers are distributed similarly to public sector benefits. One noticeable finding is that private sector drought research in maize generates greater total benefits for producers and consumers when compared to the public sector research, mainly because of higher yield variance reductions. Consumers and producers benefit $43 million, with another $20 million of profits to the private sector from biotechnology research on maize drought tolerance.

The same ex-ante analysis is also conducted for Uganda in each of its four administrative regions. Household level benefits from mean yield increases and yield variance reductions from drought research in maize in table 5 suggest that large producers in the Eastern-Medium drought risk region benefit the most from mean yield increases. Surprisingly, large producers in the Western-Low drought risk region benefit the most from mean yield increases in sorghum and millet. In all cases large producers gain more from drought research on mean yield increases because they dedicate more acreage to each crop compared to small and medium producers.

"TABLE 5 ABOUT HERE"

The lower panel of table 5 illustrates the representative households' risk benefits for each region. In general, risk benefits increase with farm size. However, in a few instances risk benefits of small farms are larger than those of medium sized farms suggesting that the income for that crop is a relatively more important source of income for small farms. This is the case in the small millet and sorghum farms in the Northern-High drought risk region. Public sector drought resistant research on maize generates slightly greater farm level benefits than public sector transgenic drought resistant research.

Aggregated producer and consumer income changes from yield increases and yield stabilization for public sector research in maize, millet and sorghum and private sector research in maize are presented in table 6. Results suggest that the distribution of gains from sorghum and millet drought resistant varieties is roughly equal between consumers and producers, however, consumer gain substantially more than producers from drought resistant maize varieties. Consumers in the Eastern-Medium drought risk region benefit the most from maize and millet drought research. Risk benefits from yield variance reductions are an important component of total benefits. In fact, maize producers gain significantly more from yield variance reductions compared to mean yield increases, and consumers' risk benefits from stabilization of maize yields are on average greater than those from mean yield increases. Sorghum and millet producers and consumers still earn considerable risk benefits, however, their benefits are smaller than income gains from mean yield increases. Overall potential benefits of $36 million, $3.5

million and $4 million are generated from public sector research in maize, sorghum and millet respectively.

"TABLE 6 ABOUT HERE"

A similar pattern of benefit distribution between producers and consumers emerges for the benefits from private sector research in maize. Overall, transgenic maize generates $37 million for Uganda producers and consumers, which is slightly greater than public sector research benefits, plus an additional $5 million is generated as profits to the private sector.

Representative producers' potential gains along with consumer and private sector benefits from mean yield increases and yield stabilization for Amhara region in Ethiopia are shown in table 7. These estimates suggest that sorghum farmers benefit the most from improved drought tolerant varieties. Typically, those farmers specialize in sorghum production and plant larger areas of sorghum compared to the average planted area of maize and millet. Millet and sorghum producers in the high drought risk areas gain more on average than producers in medium drought risk areas. Farm level risk benefits from yield variance reductions through public research in maize, millet and sorghum as well as risk benefits from private sector research are smaller than the benefits from mean yield increases, with most benefits accruing to large farms. As expected, farms located in the high drought risk areas of Amhara benefit more than the ones located in the medium drought risk areas because of higher potential yield variance reductions.

"TABLE 7 ABOUT HERE"

Aggregated benefits from mean yield increases and yield variance reductions suggest that maize producers in the Amhara-Medium drought risk region gain a total of $4.7 million from public sector research on mean yield increases and yield variance reductions in maize and consumers gain $5 million. Both, producers and consumers in the high drought risk zones of the

Amhara region gain substantially less because of smaller planted maize areas. Sorghum and millet producers and consumers in the areas exposed to medium drought risk earn smaller benefits of $1.5 million and $0.4 million from public drought resistant research in sorghum and millet, respectively.

Private sector research on transgenic drought resistant maize is expected to generate greater total benefits than public research with $4.5 million gains to producers, $6.2 million to consumers and an additional $3.4 million profits to the private sector. However, public sector research generates more benefits to producers and consumers from mean yield increases compared to private sector research. Although potential mean yield increases from public sector research are smaller compared to their private sector counterparts, the seed mark up charged by the private sector increases production costs and results in lower overall gains to maize producers. Aggregated producer benefits from mean yield increases and yield variance reductions suggest that most of the gains accrue to large producers in the medium drought risk areas of Amhara. Small, medium and large millet producers in the high drought risk zones gain less compared to maize and sorghum producers because of a substantially smaller planted area in that region.

A set of sensitivity analysis is conducted on the most important parameters used in this study.[8] Specifically, sensitivity analysis is conducted on mean yield increases, yield variance reductions, adoption rates, and demand and supply elasticities. All these parameters increase and decrease by 50 percent from the initial values used in the initial estimation.[9]

---

[8] The analysis is conducted only on the parameters used in the Eastern- Medium drought risk region and the Eastern-High drought risk region of Kenya since the same methodology is applied to the regions of Uganda and Ethiopia. Detailed tables for sensitivity analysis are available from the authors upon request.

[9] For example, if the initial mean yield increase in maize is 20 percent, results are generated for mean yield increases of 30 percent (50 percent increase from the initial value) and 10 percent (50 percent decrease from the initial value).

Representative household benefits, and aggregate level producer and consumer benefits increase by roughly one half from increases of 50 percent in both mean yields and adoption rates suggesting that benefits increase (decrease) proportionally with increases (decreases) in mean yield and adoption rates. Similarly, increases by 50 percent in adoption rates and yield variance reductions generate household and aggregate risk benefits' increases of one half in the initial risk benefit estimates. Consumer risk benefits also increase almost proportionally with further increases in yield variance reductions and adoption rates. Private sector profits also increase (decrease) roughly by one third with increases (decreases) in farmer adoption rates.

The next set of sensitivity analysis is conducted on demand and supply specifications. Findings suggest that when supply elasticity is reduced by 50 percent risk benefits to representative producers as well as at the aggregate level increase by more than a half while consumers risk benefits increase by more than five times on average. When demand becomes more elastic (by one half) consumer risk benefits are smaller on average by less than a half and producer risk benefits are slightly smaller than the initial estimates. Private sector profits are not sensitive to crop demand and supply elasticities but they are sensitive to the seed demand elasticity. For example, increases in the seed demand elasticity from -2 to -3 (by 50 percent) reduce profits to the private sector by half and increase benefits to producers and consumers.

Concluding Remarks

This study suggests that substantial ex-ante benefits can be generated from mean yield increases and yield variance reductions from public drought research on maize, millet and sorghum, as well as private sector transgenic drought research on maize, for producers in the rainfed areas of Kenya, Uganda and the Amhara region in Ethiopia. Furthermore, large potential profits exist for private sector firms from their transgenic maize drought resistant varieties and consumers in these developing countries. Total producers' and consumers' estimated ex-ante benefits from mean yields increases and yield variance reductions in Kenya, Uganda and the Amhara region of Ethiopia suggest a total of $86 million, $7.5 million and $5.5 million of benefits from potential adoption of drought resistant maize, sorghum and millet, respectively, from public sector research on drought. Aggregated regional level benefits to maize producers and consumers from transgenic drought tolerant maize mean yield increases and yield variance reduction total $90 million while the private sector is estimated to gain $28 million in profits.

Producer risk benefits at the aggregate level comprise almost 20 percent of the total drought research benefits to producers, consumers and private sector in maize, millet and sorghum. These results suggest that estimated ex-ante benefits from yield variance reductions can be an important part of drought related research with potential benefits similar to those from mean yield increases, especially in the medium and high drought risk areas where yields vary substantially from year to year. Household level gains provide important insights on potential research impacts across different household types. Results suggest that large producers in the rainfed regions of Kenya, Uganda and the Amhara region in Ethiopia benefit the most from drought research in maize, millet and sorghum farmers since they plant larger areas with these crops. However, small and medium maize, millet and sorghum also gain substantial benefits from both mean yield increases and yield variance reductions. These results have implications for equity objectives of agricultural research suggesting that policy makers should also seek alternative ways to increase the well-being of small farmers in the marginal areas. This type of framework can be easily adapted to other cases where policy makers seek regional level as well as household type level benefits of income stabilizing technologies and policies.

Overall, private sector maize drought research seems to be the most beneficial, however, transgenic drought resistant varieties have yet to pass regulatory approvals before they reach the seed markets in developing countries. Meanwhile, public sector research on drought resistance appears to be very promising for the farmers in the drought prone areas of the ASARECA region.

Appendix A. Panel Data description

Four datasets were used to construct the panel and estimate the parameters needed for Kenya; The Rural Household Surveys of Kenya in 1997, 1998, 2000 and also the Rural Indicators Survey in 2002, both collected from a collaboration of Egerton University and the Tegemeo Institute/MSU. A total of 1540, 612, 1609 and 1768 households were interviewed in 1997, 1998, 2000 and 2002, respectively, of which 454 households were interviewed during all four years. The datasets of 1997, 1998 and 2000 provide detailed information on crop production, livestock production, livestock products, sales, prices, on-farm income, off-farm income and remittances, while, the 2002 survey includes only crop production and crop sales. The CVs of these variables of interest during the four years are computed for each household type in each of the five main regions as shown in table 8. Variation of crop yields at the household level is computed as kilograms harvested per amount of seed planted (instead of kg/ha) because the planted area was not reported for each crop individually. The CVs of yield are computed for each individual household and then averaged to create the representative households' CVs in yield for each farm type in each region. The same procedure is used to obtain the CVs for the rest of the variables. CVs of total household income during the four years surveyed range between 0.38 and 0.64 and, except for small producers in the Nyanza region, are higher for small farms than medium and large farms, suggesting that poorer households face higher relative income fluctuations. The household data reveals that maize is the most important crop for Kenyan households with shares of 5.6 up to 23 percent in the total household income. Sorghum and millet income on the other hand contribute less with a minimum of 0.3 percent and a maximum of 7.0 percent in total income across all households surveyed. Maize yield CVs range between 0.5 and 0.7 and in most cases are higher among small farms. Sorghum and millet yields also vary substantially.

References

Abrar, S. 2003. "Estimating Supply Response in the Presence of Technical Inefficiency Using the Profit Function: An Application to Ethiopian Agriculture." Working paper. University of Leicester, UK.

Alston, J.M., Norton, G. W., and P.G. Pardey. 1995. Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Ithaca, NY: Cornell University Press.

Acquaye, A.K.A., and G. Traxler. 2005. "Monopoly Power, Price Discrimination, and Access to Biotechnology Innovations." AgBioForum 8: 127-133.

African Centre for Biosafety. 2007. Monsanto's Genetically Modified Drought Tolerant Maize In South Africa. Accessed on line September 2007 at: http://www.biosafety-info.net/file_dir/30470589466cc4d9c5c2e.pdf.

Arrow, K. J. 1971. Essays in the Theory of Risk Bearing. North Holland Publishing CO.: Amsterdam.

Bänziger, M. Setimela, P. S. Hodson, D and V. Bindiganavile. 2006. "Breeding for improved abiotic stress tolerance in maize adapted to southern Africa." Agricultural Water Management 80(24): 212-224.

Barret, C. B., Moser, C. M., McHugh, O. V., and J. Barison. 2004. "Better Techonology, Better Plots, or Better Farmers?: Identifying Changes in Productivity and Risk Among Malagasy Rice Farmers." American Journal of Agricultural Economics: 86(4): 869-888.

Benson, C. and E. Clay. 1998. "The Impact of Drought on Sub-Saharan African Economies." World Bank Technical Paper No. 401. 80 pp. The World Bank, Washington, D.C.

Betran, F. J., Beck D., Banziger, M. and G. O. Edmeades. 2003. "Genetic Analysis of Inbred And Hybrid Grain Yield under Stress and Nonstress Environments in Tropical Maize." Crop Science 43: 807-817.

Bett, C., De Groote, H., Diallo, A., Muasya, W., and K Njoroge. 2003. "Participatory Plant Breeding for Drought Resistant Maize Varieties in Eastern Kenya." 7th KARI Biennial Scientific Conference, 2000 - syngentafoundation.org

Binswager, H. P. 1981. "Attitudes towards Risk: Theoretical Implications of an Experiment in Rural India." The Economic Journal 91: 867-890.

Brennan, D. 2002. "Savings and Technology Choice for Risk Averse Farmers." Australian Journal of Agricultural and Resource Economics 46(4): 501-513.

CGIAR. 2003. "Applications of Molecular Biology and Genomics to Crop Tolerance and Abiotic Stresses. A Discussion Document."

Chavas, J. P. and M. T. Holt. 1996. "Economic Behavior Under Certainty: A Joint Analysis of Risk Preferences and Technology." The Review of Economics and Statistics 78(2): 329-335.

Chetty, R. 2006. "A New Method of Estimating Risk Aversion." American Economic Review 96, 1821-1835.

De Groote H., C. Doss, S. D. Lyimo and W. Mwangi. 2002. Adoption of Maize Technologies in East Africa –What Happened to Africa's Emerging Maize Revolution? Paper presented at the FASID Forum V,"Green Revolution in Asia and its Transferability to Africa", Tokyo, December 8-10, 2002.

Doering, D. S. 2005. "Public-Private Partnerships to Develop and Deliver Drought-tolerant Crops to Food-Insecure Farmers." CGIAR.

Di Falco, S., and Chavas, J. 2006. "Crop Genetic Diversity, Farm Productivity and the Management of Environmental Risk in Rainfed Agriculture." European Review of Agricultura Economics 33: 289-314.

Doss, C. R., W. Mwangi, H. Verkuijl, and H. de Groote. 2003. Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies. CIMMYT Economics Working Paper 03-06. Mexico, D.F.: CIMMYT.

Falck-Zepeda, J.B., Traxler, G., Nelson, R.G., 2000. "Surplus Distribution from the Introduction of a Biotechnology Innovation." American Journal of Agricultural Economics 82: 360–369.

Falcon, W. P. and C. Fowler. 2002. "Carving up the Commons – Emergence of a new International Regime for Germplasm Development and Transfer." Food Policy 27: 197-122.

FAO. 2003. "Which Road Do We Take"? Harnessing Genetic Resources and Making Use of Life Sciences, a New Contract for Sustainable Agriculture."

FAO. 1997. "Report of the Study on CGIAR Research Priorities for Marginal Lands." Santiago, Chile. Accesses on line at: http://www.fao.org/Wairdocs/TAC/X5784E/x5784e02.htm.

Fischer, G., H. Velthuizen, H. V., Shah, M., and F. Nachtergaele. 2002. "Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results." RR-02-02. Institute for Applied Systems Analysis (IIASA).

Garg, A. K., Kim, J. K., Owens, T. G., Ranwala, A. P., Choi, Y. D., Kochian, L. V., and R. J.

Wu. 2002. “Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses.” Proceedings of the National Academy of Sciences, USA 99, 15898-15903.

Gabre-Madhin E., Barrett C. B., and P. Dorosh. 2002. “Technological Change and Price Effects in Agriculture: Conceptual and Comparative Perspectives.” International Food Policy Research Institute (IFPRI) Washington, DC.

Hardaker, J. B., Huirne, R. B. M., Anderson, J. R., and G. Lien. 2004. Coping with Risk in Agriculture. 2nd ed. CABI Publishing.

Hareau, G. G., Mills, B. F., and G. W. Norton. 2006. “The Potential Benefits of Herbicide-resistant Transgenic Rice in Uruguay: Lessons for Small Developing Countries.”Food Policy 31: 162-179.

Hassan R. M., Njoroge K, Njore M, Otsyula R. and Laboso A. 1998. Adoption Patterns and Performance of Improved Maize in Kenya. In: Hassan, RM. (ed.). Maize technology and transfer: aGIS application for research planning in Kenya. New York NY: CAB International.

Haussmann, B. I. G., Obilana, A. B., Ayiecho, P. O., Blum, A., Schipprack, W. and H. H. Geiger. 2000. “Yield and Yield Stability of Four Population Types of Grain Sorghum in a Semi-Arid Area of Kenya.” Crop Science: 40:319-329.

Heisey, P.W., and M. L. Morris. 2006. Economic Impact of Water Limited Conditions on Cereal Grain Production. In: Ribaut, J. (Ed.), Drought Adaptation in Cereals. The Haworth Press Inc., New York.

Isik, M. 2002. “Resource Management under Production and Output Price Uncertainty: Implications for Environmental Policy.” American Journal of Agricultural Economics 84: 557-571.

Juma, J. 2008. “The Cost of Evading Costs.” The African Executive. 09-16 April. Accessed at: http://www.africanexecutive.com/MODULES/MAGAZINE/ARTICLES.PHP?ARTICLE=856#.

Kigotho, W. 2005. “Decades of Drought Predicted for Southern Africa.” SciDev.Net. (2 June)

Kiori, G. and K. Gitu. 1992. “Supply response in Kenya agriculture: a disaggregated approach.” Ministry of Planning and National Development Technical Paper 92-11. Nairobi, Kenya.

Larson, D. W., and S. Mbowa. 2004. “Strategic Marketing Problems in the Uganda Maize Seed Industry”. International Food and Agribusiness Management Review 7(4): 86-93.

Ligon, E., and L. Schechter. 2004. “Evaluating Different Approaches to Estimating

Vulnerability." Working paper. University of California, Berkley.

Lobell, D. B., Burke, M. B, Tebaldi, C., Mastrandrea, M. D., Falcon, W. P. and R. L. Naylor. 2008 " Prioritizing Climate Change Adaptation Needs for Food Security in 2030". Crop Science 319: 607-610.

Maredia, M. K. Byerlee, D. and P. Pee. 2000. "Impacts of Food Crop Improvement Research: Evidence from sub-Saharan Africa." Food Policy 25: 531-559.

Merret, N. 2007. 'GM Food Industry Eyes Growth in the East'. Food Navigator. Accessed on line March 2008 at: http://www.foodnavigator.com/news/printNewsBis.asp?id=74788

Monneveux, P., Sanchez, C., Beck, D. and G. O. Edemeades. 2005. "Drought Tolerance Improvement in Tropical Maize Source Populations: Evidence of Progress." Crop Science 46: 180-191.

Nambiro, E., de Groote, H., and W. O. Kosura. 2001. "Market Structure and Conduct of the Hybrid Maize Seed Industry: A Case Study of the Trans Nzonia District in Western Kenya." Seventh Eastern and Southern Africa Regional Maize Conference, 11th-15th February, pp.474-479.

Newbery, D.M.G., and J. E. Stiglitz. 1981. The Theory of Commodity Price Stabilization: A Study in the Economics of Risk. Clarendon Press, Oxford.

Omanya, G. O. 2004. "Evaluation of Pearl Millet Resistant Varieties with Farmers in West Africa." Paper presented in the Conference 'Rural Poverty Reduction through Research and Development', October 5-7, Berlin.

Pingali, P. L., and G. Traxler. 2002. "Changing Locus of Agricultural Research: will the Poor benefit from Biotechnology and Privatization Trends?." Food Policy 27: 223-238.

Qaim, M., and D. Zilberman. 2003. "Yield Effects of Genetically Modified Crops in Developing Countries." Science 299: 900-902.

Qaim, M., and A. De Janvry. 2003."Genetically Modified crops, corporate pricing strategies, and farmers adoption: the case of Bt cotton in Argentina." American Journal of Agricultural Economics 85: 814–828.

Reuters. 2006. "GM Sorghum to Feed Africa's Starving." Accessed online March 2008 at: http://www.int.iol.co.za/index.php?click_id=68&art_id=vn20060331030908122C825789&set_id=.

Seboska, G., Nigussie, M., and G. Bogale. 2001. "Stability of Drought Tolerant Maize Genotypes in the Drought Stresses Areas of Ethiopia", Seventh Eastern and South Africa Regional Maize Conference, 11-15 February, pp. 301-304.

Serraj, R., Hash, C.T., Yadav, R. S. and F. R. Bidinger. 2004. "Recent Advances in the Marker-Assisted Selection for Drought Tolerance in Pearl Millet." New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep – 1 Oct 2004.

Showemimo, F.A. 2007. "Grain yield response and stability indices in sorghum (Sorghum bicolor (L.) Moench)." Communications in Biometry and Crop Science 2 (1): 68–73.

Sserunkuuma, D. 2002. "The Adoption of Improved Maize Varieties in Uganda." A Paper Prepared for the Symposium on Green Revolution in Asia and its Transferability in Africa held on December 8-10, in Tokyo, Japan.

Toenniessen, G. H., O'Toole, J. C., and J. DeVries. 2003. "Advances in Plant Biotechnology and its Adoption in Developing Countries." Current Opinion in Plant Biology 6: 191–198.

Tollenaar, M. and E. A. Lee. 2002. "Yield Potential, Yield Stability and Stress Tolerance in Maize." Field Crops Research 75: 161-169.

UNESCO. 2003. "Water for a Thirsty Planet." A World of Science 1(2): 1-5.

Yamoah, C. F., Bationo, A., Shapiro, B. and S. Koala. 2002. "Trend and Stability Analyses in Millet Yields Treated with Fertilizer and Crop Residues in the Sahel." Field Crops Research 75: 53-62.

World Food Program. 2003. Annual Performance Report.

Worku, M., Zelleke, H., Taye, G., Tolessa, B., Wolde, L. Abera, W., Guta, A. and H. Tuna. 2001. "Yield Stability of Maize (Zea mays L.) Genotypes Across Locations." Seventh Eastern and South Africa Regional Maize Conference, 11-15 February, pp. 139-142.

Table 1. Maize, Millet and Sorghum Production under Rainfed Conditions (Mt)

Kenya Administrative Regions

	Central	Eastern	Nyanza	Rift Valley	Northeastern	Western	Coastal
Maize Production under Rainfed Conditions (Mt)							
Medium Drought Risk	47,508	19,266	150,691	514,599	-	-	-
High Drought Risk	28,377	196,580	-	164,945	256	-	522,456
Sorghum Production under Rainfed Conditions (Mt)							
Medium Drought Risk	16,625	1,132	2,654	22,046	-	619	-
High Drought Risk	241	6,653	-	8,170	153	-	49,778
Millet Production under Rainfed Conditions (Mt)							
Medium Drought Risk	163	1,188	9,719	14,714	-	10,003	-
High Drought Risk	149	6,500	386	1,611	11	-	807

Uganda Administrative Regions

	Central	Eastern	Northern	Western
Maize Production under Rainfed Conditions (Mt)				
Low Drought Risk	115,191	-	-	17,362
Medium Drought Risk	12,070	82,771	140,311	113,657
High Drought Risk	33,898	312,654	159,482	11,020
Sorghum Production under Rainfed Conditions (Mt)				
Low Drought Risk	7,603	5,737	-	16,396
Medium Drought Risk	2,453	26,686	158,794	47,970
High Drought Risk	3,705	54,704	9,468	-
Millet Production under Rainfed Conditions (Mt)				
Low Drought Risk	24,807	-	-	12,695
Medium Drought Risk	5,605	209,518	179,503	75,252
High Drought Risk	-	-	8,225	6,992

Ethiopia - Amhara Region

	Maize	Sorghum	Millet
Medium Drought Risk	1,504,189	645,901	95,492
High Drought Risk	16,292	57,310	147

Table 2. Characteristics of Maize, Sorghum and Millet Producing Households in Kenya in 2000 in the Central, Eastern and Nyanza Region

	Central (172 obs.)			Eastern (231 obs.)			Nyanza (263 obs.)		
	small	***med***	***large***	***small***	***med***	***large***	***small***	***med***	***large***
Avg. Maize Inc.	5,114	10,181	12,343	16,088	8,188	19,054	6,660	9,143	13,576
st.dev.	3,865	7,170	7,221	101,324	6,632	21,048	15,180	7,992	13,848
Avg. Sorghum Inc.	220	n.a.	326	815	871	3,137	1,335	1,972	3,232
st.dev.	n.a.	n.a.	n.a.	765	1,011	3,019	1,290	2,158	3,790
Avg. Millet Inc.	n.a.	n.a.	n.a.	554	692	2,198	885	1,829	1,782
st.dev.	n.a.	n.a.	n.a.	395	343	2,396	890	2,326	1,405
Avg. TOTAL Inc.	123,993	259,118	351,997	166,468	198,651	342,804	56,157	124,611	158,365
st.dev.	77,151	225,358	240,406	169,330	153,602	314,038	65,657	266,924	203,376
Avg. Maize inc. % of TOT. INC.	4.56	6.15	5.17	5.25	7.33	9.36	13.96	16.68	11.46
st.dev.	3.16	5.50	4.20	10.29	8.33	9.74	13.49	15.84	9.23
Avg. Sorghum inc. % of TOT. INC.	0.17	n.a.	0.28	0.82	1.10	2.24	6.08	6.46	5.00
st.dev.	n.a.	n.a.	n.a.	0.66	1.54	2.24	9.40	9.38	6.73
Avg. Millet inc. % of TOT. INC.	n.a.	n.a.	n.a.	0.48	0.36	0.60	1.64	1.49	1.53
st.dev.	n.a.	n.a.	n.a.	0.21	0.11	0.48	2.40	2.09	1.28
Avg. Maize Cons. % of TOT. INC.	7.69	6.59	4.33	10.01	9.38	9.54	52.40	32.64	16.66
st.dev.	8.45	6.55	2.99	15.08	8.69	9.16	114.24	40.91	13.66
Avg. Millet Cons. % of TOT. INC.	0.59	0.08	0.09	0.51	0.20	0.27	10.62	5.58	3.38
st.dev.	1.95	0.09	0.14	1.49	0.17	0.38	29.84	13.14	6.79
Avg. Sorghum Cons. % of TOT. INC.	0.57	0.08	0.09	0.60	0.52	0.83	13.40	9.23	6.04
st.dev.	1.92	0.09	0.14	1.45	0.76	1.51	31.48	15.15	7.84
Avg. Maize Yield (kg/kgseed)	79.15	73.04	80.21	70.33	63.70	47.13	65.28	47.63	56.82
st.dev.	51.40	46.87	76.95	74.17	49.53	42.98	154.98	45.49	52.89
Avg. Sorghum Yield (kg/kgseed)	2.00	n.a.	40.00	120.00	35.26	56.75	36.55	46.02	57.70
st.dev.	n.a.	n.a.	n.a.	135.65	30.33	74.98	41.23	70.50	70.60
Avg. Millet Yield (kg/kgseed)	n.a.	n.a.	n.a.	21.50	18.94	49.64	18.41	21.29	20.41
st.dev.	n.a.	n.a.	n.a.	5.74	9.57	44.13	17.02	16.26	14.62
Avg. Maize Price (KSH/kg)	14.45	16.32	13.00	13.87	12.98	11.83	12.82	12.64	13.26
st.dev.	2.54	10.54	2.98	4.25	3.83	2.64	2.92	3.21	2.78
Avg. Sorghum Price (KSH/kg)	27.03	n.a.	n.a.	n.a.	7.20	6.83	11.01	15.37	11.19
st.dev.	n.a.	n.a.	n.a.	n.a.	n.a.	3.04	3.55	10.08	3.15
Avg. Millet Price (KSH/kg)	n.a.	n.a.	n.a.	n.a.	22.22	32.50	19.71	21.55	19.72
st.dev.	n.a.	n.a.	n.a.	n.a.	n.a.	24.75	6.73	5.88	6.76

Notes: KSH- Kenyan Shillings (1 $US dollar = 74 KSH)

Table 3. Kenya- Annual Representative Producer Household Benefits ($US)

Representative Producer Household Benefits from Mean Yield Increases ($US)	Maize-Public			Sorghum-Public			Millet-Public			Maize-Private		
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Medium	2.6	6.1	7.0	1.0	1.4	2.7	1.0	6.6	1.0	2.3	5.4	6.2
Central- High	2.6	6.2	7.2	1.5	2.1	4.0	1.1	7.1	1.1	2.5	5.9	6.8
Eastern-Medium	3.7	5.6	20.6	0.9	1.0	1.9	1.1	7.0	1.1	3.3	5.0	18.2
Eastern-High	4.9	7.4	27.1	1.2	1.4	2.7	1.3	8.7	1.3	4.6	7.0	25.7
Nyanza-Medium	4.4	8.3	12.8	3.3	4.0	5.2	2.3	3.3	7.5	3.9	7.3	11.3
Rift Valley-Med.	3.8	7.5	18.4	1.4	1.9	2.6	0.9	3.3	3.7	3.3	6.7	16.3
Rift Valley-High	4.3	8.5	20.8	2.1	2.8	3.9	1.1	4.1	4.6	4.0	8.1	19.7
Coastal-High	3.3	4.8	43.4	0.4	0.8	2.0	-	-	0.9	3.1	4.6	41.2
Western-Medium	3.0	4.6	12.5	2.1	3.8	5.3	1.7	3.9	5.2	2.7	4.1	11.1
Representative Producer Household Benefits from Yield Variance Reductions ($US)												
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Medium	2.0	6.0	5.7	0.2	1.5	1.4	1.1	1.8	0.6	2.7	8.0	7.6
Central- High	2.8	8.3	7.9	0.5	2.5	2.5	1.8	2.9	1.4	3.5	10.4	9.9
Eastern-Medium	4.8	5.5	16.1	0.4	1.2	3.1	0.5	1.1	0.3	6.4	7.3	21.5
Eastern-High	6.6	7.7	22.4	0.8	2.2	5.1	0.7	1.4	0.4	8.3	9.8	28.3
Nyanza-Medium	3.3	9.3	6.7	2.8	4.5	4.4	0.3	0.3	0.9	4.5	12.4	8.9
Rift Valley-Med.	4.8	12.8	21.6	0.1	0.7	0.7	2.0	1.4	2.3	6.4	17.1	28.8
Rift Valley-High	6.7	17.4	29.8	0.3	1.0	1.1	3.1	2.5	4.0	8.5	22.0	38.0
Coastal-High	3.9	4.0	40.1	0.5	1.0	3.4	-	-	0.8	4.8	5.0	50.1
Western-Medium	5.6	9.2	15.0	0.4	1.5	0.9	0.8	4.2	2.2	7.4	12.2	19.9

Table 4. Kenya – Aggregate Benefits (thousand $US)

Aggregate Producer Household Benefits from Mean Yield Increases (thousand $US)

	Maize			Sorghum			Millet			Maize Private		
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Med.	42	79	44	4.3	13	42	0.1	0.5	0.2	43	79	44
Central- High	40	76	42	0.1	0.3	1.1	0.2	0.7	0.3	42	79	44
Eastern-Med.	6	8	45	0.2	0.6	2.1	1.0	4.6	1.7	6	8	45
Eastern-High	98	136	733	2.2	6.7	22	8.2	39	14	102	141	763
Nyanza-Med.	102	173	187	2.7	2.8	2.1	10.0	9.7	25	103	175	189
Rift Valley-Med.	144	353	1,079	12.6	27	42	7.7	26	44	145	356	1,090
Rift Valley-High	41	101	308	5.8	12	19	2.9	9.8	16	43	105	321
Coastal-High	203	351	2,825	12.8	51	192	-	-	6.0	211	365	2,939
Western-Med.	54	104	298	0.3	0.7	1.1	0.1	0.2	0.5	55	105	301

Aggregate Producer Household Benefits from Yield Variance Reductions (thousand $US)

	Maize			Sorghum			Millet			Maize Private		
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Med.	71	164	75	0.2	8.4	40.7	0.2	0.3	0.2	94	219	100
Central- High	87	203	93	0.1	0.2	1.2	0.4	0.5	0.6	109	253	116
Eastern-Med.	16	17	74	0.2	0.5	6.4	0.8	1.3	0.7	22	23	99
Eastern-High	267	284	1,215	2.5	6.0	71.6	7.2	11.4	7.8	337	361	1,535
Nyanza-Med.	164	412	206	4.3	5.8	3.4	2.6	1.9	5.9	219	549	274
Rift Valley-Med.	392	1,270	2,691	1.9	8.2	20.6	32.1	20.2	49.7	522	1,693	3,586
Rift Valley-High	129	412	884	1.3	3.8	9.9	14.1	10.4	25.2	164	521	1,128
Coastal-High	483	581	5,231	27	28	588	-	-	9.7	603	725	6,531
Western-Med.	214	435	753	0.1	0.2	0.4	0.1	0.4	0.4	285	579	1,003
Total	2,553	5,158	16,782	79	176	1,065	88	137	208	3,105	6,336	20,108

Consumer and Private Sector Benefits from Drought Resistance Research (thousand $US)

	Maize		Sorghum		Millet		Maize Private		
	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Π
Central-Med.	309	10	73	35	1	0.4	238	14	429
Central- High	321	13	2	1	1	1	274	16	382
Eastern-Med.	111	5	4	2	9	1	85	7	168
Eastern-High	1,963	127	64	27	78	9	1,680	179	1,988
Nyanza-Med.	866	443	9	222	55	1	667	547	1,135
Rift Valley-Med.	2,958	42	100	9	94	44	2,278	55	5,276
Rift Valley-High	913	113	60	37	37	75	781	150	1,260
Coastal-High	6,859	41	328	24	8	45	5,869	62	7,585
Western-Med.	857	46	3	3	1	0.5	660	60	1,782
Total	15,157	840	643	360	284	177	12,532	1,090	20,005

Notes: Cs. Y – Consumer benefits from mean yield increases; Cs. RB – Consumer risk benefits; Π – Private sector profits.

Table 5. Uganda – Annual Representative Producer Household Benefits ($US)

	Maize-Public			Sorghum			Millet			Maize Private		
Representative Producer Household Benefits from Mean Yield Increases ($US)												
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Low	4.3	9.1	22.5	2.2	4.2	14.9	2.8	5.2	12.4	2.0	4.3	10.6
Central- Medium	4.9	10.4	25.8	2.8	5.4	19.2	3.8	7.0	16.8	4.0	8.4	20.8
Eastern-Medium	10.9	23.7	54.2	8.7	16.8	21.9	9.4	10.7	16.5	8.8	19.1	43.7
Northern-Medium	7.5	13.5	21.4	8.3	12.0	17.4	5.3	11.5	16.3	6.1	10.9	17.3
Northern-High	8.9	15.9	25.3	10.0	14.5	21.0	5.4	11.7	16.6	8.0	14.4	22.9
Western - Low	3.6	7.0	18.5	7.9	11.1	23.6	10.8	14.5	24.4	1.7	3.3	8.8
Western-Medium	4.1	8.0	21.3	7.5	10.5	22.3	7.2	9.7	16.4	3.3	6.5	17.1
Representative Producer Household Benefits from Yield Variance Reductions ($US)												
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Low	2.4	3.6	6.6	0.5	1.7	3.5	1.2	2.0	0.4	3.5	5.3	9.8
Central- Medium	4.9	14.3	13.9	1.1	3.5	7.1	1.9	3.1	0.7	6.5	9.7	18.5
Eastern-Medium	8.6	14.3	31.1	2.0	3.3	5.4	1.5	2.0	0.7	9.7	15.6	34.6
Northern-Medium	2.9	6.1	8.0	4.2	3.2	5.1	4.3	1.8	2.8	4.5	9.2	12.3
Northern-High	6.4	12.4	17.7	8.5	6.3	10.1	6.2	2.9	4.5	8.0	15.4	21.9
Western - Low	2.7	3.0	5.1	1.0	1.3	2.4	1.5	1.1	1.8	4.0	5.3	7.6
Western-Medium	6.0	7.2	13.6	3.8	4.2	7.5	2.3	1.6	2.7	8.0	9.5	18.0

Table 6. Uganda – Aggregate Benefits

Aggregate Producer Benefits from Mean Yield Increases (thousand $US)

	Maize			Sorghum			Millet			Maize Private		
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Low	12	30	102	0.4	2.6	8.5	4.1	6.6	24	13	31	105
Central- Medium	8.9	21	73	0.6	4.1	13	1.7	2.8	10	12	28	96
Eastern-Medium	118	249	617	36	93	145	104	132	371	156	328	813
Northern-Medium	42	85	155	50	128	202	45	131	229	56	112	204
Northern-High	55	110	201	12	12	18	3.4	9.7	17	75	150	274
Western - Low	2.1	4.8	15	4.6	7.2	21.1	3.7	5.7	9.4	2	5	15
Western-Medium	27	61	187	26	42	122	45	68	112	36	81	247
Aggregate Producer Benefits from Yield Variance Reductions (thousand $US)												
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Central-Low	32	55	138	0.1	2	4	4	5	2	48	82	206
Central- Medium	39	131	175	1	5	10	2	2	1	52	89	232
Eastern-Medium	415	669	1,574	17	36	72	34	50	30	466	731	1,754
Northern-Medium	73	171	257	52	68	118	75	42	80	113	257	397
Northern-High	180	389	636	20	11	17	8	5	9	224	482	788
Western - Low	7	9	19	1	2	4	1	1	1	11	17	28
Western-Medium	177	242	532	27	34	83	29	23	37	235	321	704
Total	1,189	2,228	4,681	249	447	838	360	484	933	1,499	2,714	5,863

Consumer and Private Sector Benefits from Drought Resistance Research (thousand $US)

	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Π
Central-Low	652	454	14	5	41	12	209	678	397
Central- Medium	508	504	22	10	17	7	334	667	237
Eastern-Medium	4,858	8,738	328	160	724	54	3,191	8,738	2,042
Northern-Medium	1,391	1,562	455	281	484	395	913	2,593	725
Northern-High	2,159	3,524	52	27	36	46	1,674	4,359	812
Western - Low	97	78	39	28	22	6	31	116	60
Western-Medium	1,361	2,023	227	322	270	107	894	2,670	644
Total	11,026	16,883	1,137	833	1,594	627	7,246	19,821	4,917

Table 7. Ethiopia – Amhara Region – Annual Individual and Aggregate Benefits

	Maize-Public			**Sorghum-Public**			**Millet-Public**			**Maize- Private**		
	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large
Representative Producer Benefits from Mean Yield Increases ($US)												
Amhara - Medium	8.3	9.5	19.6	8.1	13.4	26.6	5.2	7.0	12.7	6.4	7.4	15.2
Amhara - High	6.9	7.9	16.2	12.5	20.8	41.2	6.9	9.3	16.9	5.9	6.8	14.0
Representative Producer Benefits from Yield Variance Reductions ($US)												
Amhara - Medium	2.2	3.9	7.2	4.6	10.8	11.4	0.6	1.6	1.1	3.0	5.2	9.6
Amhara - High	4.3	7.5	13.8	7.2	16.1	17.5	0.9	2.3	1.6	5.3	9.4	17.1
Aggregated Producer Benefits from Mean Yield Increases (thousand $US)												
Amhara - Medium	423	900	1,891	89	93	132	7	14	35	337	717	1,506
Amhara - High	7.9	17	35	14	14	20	0.02	0.03	0.08	7	15	31
Aggregated Producer Benefits from Yield Variance Reductions (thousand $US)												
Amhara - Medium	132	434	807	107	157	118	2	7	6	176	577	1,073
Amhara - High	6	19	35	16	23	18	0.004	0.02	0.02	7	23	43
Aggregated Total	569	1,370	2,768	226	288	288	9	21	41	527	1,332	2,653

Consumer and Private Sector Benefits from Drought Resistance Research (thousand $US)

	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Cs. Y	Cs. RB	Π
Amhara - Medium	647	4,212	372	223	66	28	425	5,587	3,335
Amhara - High	12	111	58	51	0.15	0.10	9	138	80
Total	659	4,323	430	274	66	28	434	5,725	3,415

Table 8. Characteristics of Maize, Sorghum and Millet Producing Households in Kenya.

	Central (90 obs.)			**Eastern (92 obs.)**			**Nyanza (97 obs.)**			**Rift Valley (64 obs.)**			**Western (111 obs.)**		
	small	***med***	***large***	***small***	***med***	***large***	***small***	***med***	***large***	***small***	***med***	***large***	***small***	***med***	***large***
Avg. Maize Inc.	7,324	12,624	13,001	9,551	10,310	22,893	7,218	10,133	18,715	24,703	49,435	91,989	7,725	33,810	65,117
CV	0.55	0.54	0.51	0.67	0.54	0.58	0.63	0.61	0.58	0.65	0.65	0.58	0.59	0.56	0.51
Avg. Sorghum Inc.	n.a	n.a	326	869	1,087	2,313	2,134	2,160	3,747	757	1,262	1,810	1,498	1,846	3,896
CV	n.a	n.a	n.a	0.68	0.67	0.55	0.55	0.85	0.67	0.69	0.97	0.48	0.48	0.38	0.65
Avg. Millet Inc.	n.a	n.a	n.a	609	1,524	1,946	2,303	3,008	2,174	1,040	3,211	3,956	2,660	9,068	5,529
CV	n.a	n.a	n.a	n.a	n.a	1.09	0.86	0.52	0.59	0.54	0.69	0.77	0.94	0.71	0.49
Avg. TOTAL INCOME	161,195	241,172	299,575	181,038	176,082	301,126	67,259	120,406	179,188	122,112	198,380	563,800	74,072	177,122	314,799
CV	0.40	0.38	0.39	0.47	0.40	0.53	0.58	0.64	0.53	0.57	0.47	0.49	0.59	0.46	0.38
Avg. Maize inc. % of TOT. INC.	7.44	7.66	5.95	7.40	9.10	11.46	17.51	13.83	17.94	23.00	24.11	20.77	13.47	20.73	21.48
CV	0.54	0.52	0.44	0.63	0.55	0.59	0.56	0.67	0.51	0.49	0.49	0.54	0.59	0.58	0.50
Avg. Sorghum inc. % of TOT. INC.	n.a	n.a	0.28	0.68	1.24	1.30	6.97	3.19	3.83	0.78	0.80	0.46	4.29	1.00	1.46
CV	n.a	n.a	n.a	0.46	0.67	0.85	0.62	0.78	0.68	0.43	0.31	0.53	0.58	0.46	0.64
Avg. Millet inc. % of TOT. INC.	n.a	n.a	n.a	0.67	1.44	0.99	8.82	4.06	1.26	1.65	1.87	1.16	5.79	3.52	1.78
CV	n.a	n.a	n.a	n.a	n.a	1.34	0.85	0.48	0.64	0.82	0.72	0.80	0.71	0.76	0.57
Avg. Maize Cons. % of TOT. INC.	10.13	7.59	10.96	8.84	10.54	11.54	37.54	24.73	18.40	27.99	14.50	8.93	29.29	18.02	13.91
CV	0.42	0.53	0.51	0.63	0.51	0.72	0.58	0.63	0.59	0.59	0.98	1.31	0.41	0.85	0.84
Avg. Millet Cons. % of TOT. INC.	0.13	0.09	0.04	0.27	0.28	0.24	7.85	3.21	0.75	1.27	0.96	0.81	3.76	1.89	1.22
CV	0.80	0.47	0.85	0.44	0.60	0.64	0.90	0.79	0.65	0.64	0.63	0.86	0.54	0.79	0.69
Avg. Sorghum Cons. % of TOT. INC.	0.13	0.09	0.06	0.20	0.49	0.56	8.32	3.91	2.85	0.96	0.57	0.25	3.60	0.60	1.00
CV	0.80	0.47	0.87	0.40	0.70	0.92	0.77	0.87	0.74	0.52	0.58	0.77	0.64	0.69	0.94
Avg. Maize Yield (kg/kgseed)	74.1	76.9	60.3	75.9	56.9	56.0	57.7	54.1	53.8	97.2	128.8	123.7	56.8	95.4	94.9
CV	0.53	0.54	0.49	0.65	0.54	0.63	0.57	0.59	0.53	0.51	0.67	0.50	0.70	0.60	0.46
Avg. Sorghum Yield (kg/kgseed)	n.a	n.a	n.a	400.7	80.5	61.0	38.0	35.8	66.9	15.0	37.0	48.2	40.1	34.7	127.3
CV	n.a	n.a	n.a	0.40	0.53	0.66	0.58	0.82	0.59	0.17	0.68	0.56	0.59	1.20	0.57
Avg. Millet Yield (kg/kgseed)	n.a	n.a	n.a	63.2	65.6	49.6	34.6	19.9	50.1	22.1	29.3	36.6	44.5	65.1	85.8
CV	n.a	n.a	n.a	n.a	n.a	0.21	0.60	0.52	0.76	0.95	0.55	0.58	0.19	0.76	0.51
Avg. Maize Price (KSH/kg)	11.4	13.6	11.8	12.1	12.1	11.3	22.4	12.3	12.1	9.3	10.7	11.2	10.2	11.1	11.4
CV	0.17	0.20	0.43	0.19	0.24	0.20	0.29	0.18	0.17	0.18	0.21	0.20	0.12	0.22	0.21
Avg. Sorghum Price (KSH/kg)	n.a	n.a	n.a	17.7	8.7	9.2	11.1	13.1	11.4	15.0	12.2	14.9	20.1	15.8	14.2
CV	n.a	n.a	n.a	n.a	0.42	0.15	0.46	0.60	0.19	n.a	n.a	0.71	0.45	n.a	0.37
Avg. Millet Price (KSH/kg)	n.a	n.a	n.a	12.7	20.0	12.2	15.9	19.9	22.4	n.a	19.9	23.1	20.4	19.3	53.0
CV	n.a	n.a	n.a.	n.a	n.a	0.32	0.49	0.37	0.07	n.a	0.30	0.19	n.a	0.25	0.51

Notes: KSH- Kenyan Shillings (1 $US dollar = 74 KSH)