FOOD SECURITY RESEARCH PROJECT

FRAMEWORK AND INITIAL ANALYSES OF FERTILIZER PROFITABILITY IN MAIZE AND COTTON IN ZAMBIA

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EXECUTIVE SUMMARY

BACKGROUND

In Zambia, fertilizer and maize have long been paired in government policy as a major tool for improving smallholder production and welfare. Increasing productivity in maize, the principal grain crop, as well as in cotton, an important cash crop, is seen as a way to achieve economic growth in rural areas. Recent research has been evaluating the role of markets and the distribution systems in input supplies for Zambia. In the increasingly monetized economy, farmers' adoption of productivity enhancing inputs relies heavily on the profitability of those inputs.

OBJECTIVES AND METHODS

The main question which this research originally sought to answer was whether or not inorganic fertilizers are generally profitable used alone on maize, or with pesticides on cotton, for small farmers in Zambia. Rather than give a definitive answer for each Zambian farmer, the authors developed a framework for analysis and applied that framework to locations with sufficient information. Using simple value/cost ratios, researchers estimated the potential profit of fertilizer for those sites. Then, using the distributions of response rates of the crops (incremental yields) found in the trials and output prices based on regional price series, the probabilities are estimated for VCRs, using a minimum of VCR of 2.0 for profitability. The results for selected locations and input applications are then presented, as examples and indicators of fertilizer profitability in Zambia.

FINDINGS

The results show that inorganic fertilizer applied to maize and cotton in Zambia can be quite profitable in Region II, but there are conditions in which the applications can be risky, mostly due to high variability in response rates, as in Regions I and III. The critical components in that variability are climatic conditions and soil fertility; and crop management practices, related to timing of seeding and input application, overall soil fertility actions, density of seeding, choice of varieties, and the use of weeding/herbicides and pesticides.

For maize, researcher results demonstrated high profitability in Region I and II for the low and medium dose levels, below the recommended application rates, but risk of losses was still present in most cases. Where soils are relatively rich, the fertilizer profitability is low for higher doses, since plants can get much of what they need from the soils already, so the incremental yield is fairly low with fertilizers. Where soils are poor and the missing nutrients are those in the fertilizers, the results can be highly profitable, as may be the case in parts of Region I, although the rainfall risks are great. This is partially reflected in the high variability in results shown in the distributions of the VCRs, since rainfall variability was included in the years are data used here.
High dose levels of more than 400 kg per hectare combined top and basal dressings were not profitable in Region III, even with the lower fertilizer price, although in some cases, the traditionally recommended level of 300-400 kg per hectare was profitable in Region III. The lowest dose level was most profitable in Mansa.

For cotton, fertilizer profitability was enhanced by the use of pesticides at the rate of 15 sprays per season, yet the variability in results suggests that level of pest infestation plays a role in whether the sprays result in a significant increase in yields in any given case. Combining high dose rates and high pesticides can be profitable, but overall profitability of fertilizers on cotton is relatively low.

CONCLUSIONS

The analysis was conducted with geographical regions, but that does not mean that all farmers in a region will have the same results. In addition, the analysis used mainly on station trial results with hybrid varieties for maize and a combination of on station and on farm results for cotton, such that performance may be better than in farmers' fields. Ideally, each farmer will evaluate the profitability in their own case. Extension agents and farmers can use their local input/output price ratio as an indicator of the minimum amount that the crop must increase to payback the fertilizer price and then make their own assessment, moving away from the generalized recommendations.

Farmers may be better off focusing their efforts on eliminating the inefficiencies or improving overall crop management practices, than in increasing fertilizer use. In areas in which climate and soil conditions are unfavorable or high risk for cropping maize or cropping cotton, it is not recommended to invest in more than small quantities of inorganic fertilizer, without incorporating other risk mitigating practices, as found in conservation farming technologies, for example. Crop suitability mapping at Mount Makulu may be useful for identifying alternative crops, as well.

POLICY IMPLICATIONS

Any lowering of input cost or increase in output prices will improve the VCR of that input and lower the I/O ratio, thereby encouraging use. Government investment in transport and communications infrastructure is one key area in which the government can help reduce the costs of fertilizer and increase producer prices for outputs, making fertilizer use more profitable for farmers (Ministry of Agriculture and Cooperatives, Agricultural Consultative Forum, and Food Security Research Project, 2002). Temporary subsidies on fertilizers have been used in the past and have not always led to long term use by farmers, possibly related to the profitability issues covered here.

Investments in research and extension are critical for productivity growth. More information is needed on the sources of risk and the ways to minimize it while improving productivity. Much more work is needed on other crops and crop management systems. Fertilizers are a critical element in agricultural productivity growth, but their value is limited when other factors are constraining output. Developing that knowledge with farmers and also increasing extension efforts with farmers will help to create a knowledge base of farmers concerning their soils, their varieties, their markets, and their options will enhance productivity in a sustainable way.

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FRAMEWORK AND INITIAL ANALYSES OF FERTILIZER PROFITABILITY IN MAIZE AND COTTON IN ZAMBIA

1. INTRODUCTION

Policy makers in Zambia have long viewed fertilizer access as a critical component in poverty alleviation and economic growth. Current policy debates revolve around subsidizing fertilizer, either by ensuring import of fertilizer or providing credit to the private sector distributors, or through government-sponsored smallholder credit schemes, for smallholder farmers to improve crop yields and thus incomes. A key assumption has been that all smallholder farmers would benefit from fertilizer use and that in the long run, fertilizer use, especially on maize, would provide a lever to improve the food security of all farmers. There are various aspects of the question that should be addressed, including the relative benefits of a fertilizer program as compared to other technology packages or investments. The then Ministry of Ministry of Agriculture, Food and Fisheries (MAFF, now the Ministry of Agriculture and Cooperatives, MACO) and the Food Security Research Project (FSRP) have evaluated the organization of the fertilizer markets and distribution systems, developing recommendations on how the public and private sectors might enhance efficiency in the systems (Govereh, et al. 2002). One key aspect that remains to evaluate is the farm-level profitability of fertilizer use, particularly under market conditions for small-scale farmers. Using inorganic fertilizers to increase productivity and total agricultural production will be viable in the longer run only of farmers find the technology profitable for adoption.

2. OBJECTIVES

To inform policy makers on farm level profitability, this study identifies the key components determining profitability and then sets up a framework to evaluate the probability of farmers to obtain profitable results with fertilizer use on maize and cotton. While the authors had initially set out to provide profitability guidelines throughout the country, the objectives had to be altered to present selected cases from research sites in Zambia for which data were sufficient.

Maize is the most important crop in Zambia, in terms of area cultivated and value of production, and is the crop receiving the most fertilizer from smallholders currently, so it is the main focus of this study. Cotton has also been included, for several reasons. In other countries, such as Mali, cotton is successfully fertilized, with good results. As a cash crop, cotton sales provide farmers a cash income to enable fertilizer purchases. In Zambia, cotton companies are looking for ways to improve productivity and total production of cotton, and may be in a position to facilitate fertilizer supplies for farmers, should fertilizers be profitable.

Assessing farm-level profitability includes determining the factors that most strongly affect profitability. Farmers may have control over some of the factors, such as varietal choice and complementary management practices, but many of the components in profitability are not controlled by the farmers such as rainfall and other weather conditions. Farmers may be able to at least influence other aspects, such as soil quality and prices. This study will identify major factors and indicate some of the risk in profitability due to those factors. The objective is to estimate not optimal profitability (the best results if farmers used all the recommended cropping practices, including hybrid seeds, excellent timing, recommended weeding, organic matter inputs, etc.), but rather profitability given likely farmer practices and outcomes.

Farmers and their environments vary widely in Zambia. The country has been divided into broad agro-ecological (AEC) regions, based mainly on rainfall, and the analysis uses those designations to disaggregate the results. Input and output prices vary geographically as well, so analysis dis-aggregated by these broad AEC regions is appropriate.[1] However, in practice, responses and response rates will vary from farm to farm, dependent on soil conditions and farmer skills and assets, so an easy way to assess profitability is given with farmers estimating their own response rates. Thus this report seeks to develop a methodology for researchers and agronomists that can be used locally when locally-specific input prices, output prices, yields, and expected response rates are available. The actual results of the analysis will be indicative of the likely profitability of fertilizers in the areas for which sufficient information exists.

There is an important issue that will not be resolved in this work. The overall profitability of the crop, whether maize or cotton, will not be assessed. Previous MAFF work on crop suitability mapping was designed to indicate the regions where maize and cotton, among other crops, could best be grown in Zambia, and areas that are not considered suitable for that crop. In some areas, fertilizers may be profitable (i.e., the additional crop produced with

[1] This work was not able to disaggregate further by administrative boundaries, such as districts and camps, due to data and time constraints. In areas with extensive agricultural research, more detailed work can be done and more site-specific recommendations completed.

fertilizers is worth more than the costs of the fertilizer), but the crop itself is not profitable when all the other costs and benefits are included. This is what the crop suitability mapping was designed to evaluate and in general, fertilizer trials are not conducted in the regions considered unsuitable for a crop. For that reason, we do not analyze fertilizer profitability in region III for cotton since cotton cropping is not recommended there.

3. BACKGROUND

3.1. Agro-ecological (AEC) Regions in Zambia

Zambia is a large country with variable climate, soils, and growing conditions. Lungu and Chinene (1993) use three major agro-ecological regions, classified using rainfall, length of growing season, and temperature, based on the work of Veldkamp (1987) and others.

Region I is characterized by low rainfall (less than 800 mm per year), in the dry areas of the Gwembe Valley, Lusemfwa Valley, and southern Luangwa Valley in Southern, Eastern and Central Provinces, as well as the semiarid plains of Western and Southern Provinces. The growing season is relatively short, generally from 80-120 days. As elaborated by Damaseke (draft 2000), there are a variety of soil types in the region:

1. Loamy and clay soils with coarse to fine loam top soils (most appropriate for agriculture in this region);
2. Reddish coarse sandy soils either medium to very strong acidity found in pan dambo areas;
3. Poorly drained sandy soils occurring on the western side of Zambezi River in Western Province; and
4. Shallow and gravel soils (not suitable for cultivation due to shallow depth).

In their report, Lungu and Chinene (1993) state that "Given the environmental limitations in Region I, it would appear that mono-cropping of drought tolerant crops like sorghum, pearl millet, cassava, and cowpeas is the only viable cropping system" (p.23). Both cotton and maize are grown in this region, but as the evidence shows, there are risks.

Region II is located through the middle belt plateaus of the country through Western, Central, and Eastern Provinces, and a bit of Northern Province. Some of the most fertile agricultural soils are located in Region II, which has 800-1000 mms of rainfall annually and a growing season between 100-140 days, with no threat of freezes. Four soil types in this region were described by Damaseke (draft 2000) as follows:

1. Moderately leached clayey to loamy soils with medium to strong acidity (low nutrient reserves and a low water holding capacity);
2. Slightly leached clayey soils, red to reddish in colour with slight to medium acidity (heavy texture, erosion problems on slopes);
3. Coarse sandy loams in large valley dambos with medium to strong acidity and poor drainage; and
4. Sandy soils on Kalahari sands (strong acidity in some cases, coarse textured top soils, low water holding capacity and low nutrient reserves).

While there is still a threat of periods with low rainfall, causing drought, this region is considered to have the highest agricultural production potential in the country.

Region III: This is the region of highest rainfall in Zambia, with more than 1000 mms per annum, averaging 1000-1500 mm annually, with a growing season of 120-150 days. It includes most of Northern, Luapula, Copperbelt, and Northwestern Provinces, and some parts of Central Province. Soil acidity and texture are major determinants for optimal crops and fertilization needs (Ministry of Agriculture 1991).

Regarding soils, Damaseke notes the following:

> The soils of region III are generally highly weathered and leached and are characterised by low pH of less than 4.5 and have very low reserves of primary minerals. They are normally deficient in phosphorus, nitrogen and some micronutrients. The low soil pH and the associated high levels of aluminum and manganese are often toxic to plants.(Draft 2000).

Damaseke (2000) cites the following soil types:

1. Red to brown clayey to loamy soils with very strong acidity;
2. Shallow and gravel soils occurring in rolling to hilly areas;
3. Clayey soils, red in colour and moderately to strongly leached (fewer limitations to crop production than the other soils in the region);
4. Poorly to very poorly drained flood plain soils of variable texture and acidity;
5. Coarse sandy soils with very strong acidity found in pan dambos on Kalahari sands; and
6. Soils of the rift valley with variable textures.

Clearly some of these soils have chemical limitations. With the temperatures, the rain and cloud cover, this is generally not a region suitable for cotton cultivation (Soils Survey Unit, 1987) and there are pest and soil problems with maize, limiting the potential.

We will be dividing the analysis based on the three AEC regions detailed above.[2] This will help to control for some sources of variability in yields, and is the first step in developing more site specific recommendations. Cross-regional maize varietal yield trials from 1985/86 demonstrate the need for this. Across 9 varieties with three possible planting dates, Region I average yields were 4717 kg ha-1, with 7238 kg ha-1 in Region II and 4822 kg ha-1 in Region III (Gumbo, 1988, page 99, after correction in table). Variability in these mean results is high. Looking at the means, we find a coefficient of variation (CV) of 42% for Region I whereas Region II has a CV of only 22% and Region III has a CV of 13%.[3] This example exemplifies the high variability in yields, particularly in Region I.

[2] There are some cases in which the identified region may not correspond with the location name give. For example, in the tables, "Mochipapa" is labeled as Region I. MAFF researchers have explained that while the Mochipapa research station is physically in Region II, it is the administrative base for Region I efforts, with sites off the station. Thus, a report might indicate Mochipapa for the research site simply because the researcher is based there, yet the research was conducted in another site that is in AEC Region I. For example, Masumba is a Region I research site, although the researchers for that site are based at Msekera. In some cases, the researcher indicated 'Msekera' yet Region I, while some researchers indicated 'Masumba'. This confusion was resolved by accepting the AEC region identified by the lead researcher of the trial when classifying the trials in their reports. This confusion could be avoided by having specific research site in the database.

[3] Currently we cannot estimate the true variability in these samples as we do not have the primary data for each of the varieties in each region and have based this simply on the reported means across varieties by planting date.

Table 1: Fertilizer Recommendations for Maize Based on Initial Soil Fertility Status

Fertility status	Fertilizer N Kg/ha	Fertilizer P_2O_5 Kg/ha	Fertilizer K_2O Kg/ha	Fertilizer S Kg/ha
Low	160-180	70-100	30-40	20 min.
Medium	120-140	40-60	10-20	20 min.
High	80-100	20-30	0	20 min.

Source: Gumbo, 1988.

3.2. Fertilizer Recommendations on Maize and Cotton

Current MAFF recommendations for inputs can be found on a chart seen in many MAFF offices: "General Fertilizer Recommendations for Major Crops in Zambia". For maize, the general recommendation is 200 Compound D or C and 200 Urea per hectare, resulting in 112kg N, 40 kg P_2O_5 , 20 K_2O, and 20S. For cotton it is 200 Compound R or C and Solubar 8, resulting in 40kg N, 40kg P_2O_5, 0 K_2O, 20 kg S and 1.6 kg B. These general recommendations are based on small-holder cultivation, with yield expectations of 3-4 tons maize per hectare. The maize recommendation for commercial farmers is higher, with 300 kg of Compound D and 300 kg of urea or ammonium nitrate, with expected yields of 6.5 tons per hectare or higher of maize.

These however are not the only set of recommendations available to extension agents and farmers. Another 1989 bulletin recommended the following for maize on well fertilised rotated land: 160kg N, 70, P_2O_5 and 35kg K_2O ha^{-1} (Dept Agriculture of Zambia 1989). In other work, Gumbo (1988) proposed three different levels of fertilization based on the initial soil fertility, recognizing that higher fertility land needs lower levels of inorganic inputs.

To meet these recommendations, there are various fertilizers available in Zambia. The nutrient composition for the main fertilizers are detailed in Table 2.

In Northern Province, the Ministry of Agriculture issued revised Learning Improved Methods of Agriculture (LIMA) crop recommendation in 1991 (Ministry of Agriculture 1991) for small farmers. Those recommendations were for 50 kg per lima (200 kg ha^{-1}) of basal fertilizer in the form of Compound D, and 50 kg per lima (200 kg ha^{-1}) of urea, the same as earlier recommendations, just taken down to the lima basis.[4] This recommended dose, along with other practices, is expected to yield 6 to 8 bags per lima (about 2400-3200 kgs per hectare).[5] If the fertilizer arrives late, the Ministry recommends cutting the dose of each in half and applying just once.

In the 1980s and early 1990s, LINTCO recommendations for cotton in Zambia were to apply 200 kgs Compound D as basal fertilizer and 50kgs Urea as top dressing (Sikazwe, et al. undated).

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[4] A lima is 0.25 hectares or 2500 square meters.

[5] This estimate of potential yield includes other management practices, not just the fertilizers (Ministry of Agriculture, 1991).

Table 2: Fertilizer Composition					
	Nutrients				
Fertilizer	N	P20	K20	S	B
Compound A	2	18	15	10	0.1
Compound V	4	18	15	8	0.1
Compound C	6	18	12	8	0.1
Compound D	10	20	10	9	0
Compound X **	20	10	5	9	0
Compound R	20	20	0	9	0
Urea	46	0	0	0	0
Ammonium Nitrate	34	0	0	0	0
Calcium Ammonium Nitrate (CAN)	26	0	0	0	0
Ammonium Sulphate	21	0	0	24	0
Single Super P	0	20	0	12	0
Triple Super P	0	44	0	0	0
Potassium Chloride	0	0	60	0	0
Potassium Sulphate	0	0	50	18	0
Solubar	0	0	0	0	20
Partially Acidulated Phosphate Rock (PAPR): SAB-PAPR-50	0	20.2	0	12	0
Source: Lima crop recommendations Northern Province, 1991. Ministry of Agriculture, Zambia. (p.6)					
except PAPR from SPRP Annual Report 1992; Solubar and Compound A from Lungu and Chinene 1993.					

More recent sets of recommendations include crop management practices, such as the conservation farming recommendations (CFU, 1997). Since these involve a set of combined practices, just looking at the fertilizer alone would not be advisable or give a valid assessment of the practices. Current work by the Golden Valley Research Trust (GART) with the Zambian National Farmers Union Conservation Farming Unit and FSRP seeks to assess the short-term profitability of such combined recommendations, and with time could evaluate the medium and long term prospects appropriate with those recommendations.

In the literature, there are many approaches to developing recommendations that are more site-specific. Among the more recent methods, Benson (1999) wrote about Malawian maize

recommendations that take into account the prices for farmers both as producers and as consumers and destination use of the crop grown, to determine the economically efficient application rates of fertilizers, based on maximum returns. Palhares de Melo, et al (2001) created a decision tool that uses qualitative evaluation by researchers for approximate reasoning as to the recommended fertilizer application rates, based on soil characteristics and analysis. Fuzzy set theory provides the basis, but by relying solely upon initial soil status as determined in chemical analysis, the recommendations have no economic basis. It provides another way to approach developing recommendations that could be modified to incorporate economic criteria and risk elements.

3.3. Previous Profitability Analyses and Farmer Yields

There have been some previous analyses conducted on fertilizer use in Zambia. In 1987, Veldkamp (1987a) developed an abbreviated financial evaluation of returns to input packages, including inorganic fertilizer. He estimated that farmers would gain yield of 390 kg/ha with a medium input level package of one 50-kg bag of Compound X and the use of hybrid seed. Farmers would gain 1100 kg/ha with a high input package that included the medium input package and increased it by one bag of either compound D or X, as well as one bag of ammonium nitrate and applications of aldrin and endosulfan. This analysis is the type used in developing the crop suitability mapping, as mentioned previously and in the Data section below, based on soils, climate, and expected yields.[6] Full crop budgeting, including fertilizers can be found in various documents, but the evaluation of fertilizer profitability is best completed using the partial budgeting approach found here.

Samazaka (1996) looked at fertilizers applied to cotton and found value cost ratios (VCRs) of 3.6 to 4.8 under conditions of response rates of 9.1 to 12.2 kg cotton seed for each kg input. These response rates are generally higher than those found in other trials and so higher VCRs are estimated by Samazaka than found here.

This report focuses on researcher trials for results, but there is information available on actual farmer yields with and without fertilizer. The 1998/99 Post Harvest Survey (PHS) (CSO/MAFF/FSRP) in Zambia reports for small and medium scale farmers, including yield and fertilizer use quantities. Of the farmers who apply fertilizer, the average application rate on maize is 237 kg/ha on maize, slightly lower than the recommended doses noted above (between 300-400). Looking at yields, as Figures 2 and 3 and Table 3 indicate, in the 1998/99 PHS, on average, in the three provinces where fertilizer use is most common and numbers are sufficient to have confidence in the results, farmers using fertilizer have higher yields (1942 kg/ha versus 1331 kg/ha for non-users, a significant difference), but the variability in the data can be seen in the figures. There are farmers using fertilizer and getting low yields: some farmers are not using fertilizer and yet get high yields in each of the regions.

Since these data are not from controlled trials with comparable crop management practices across the farmers, we cannot use them to determine a response rate from fertilizer. That is one of the problems in using on-farm data: high variability and lack of control for management practices, soils, and other factors that affect the response to fertilizers. Another problem is sample size. In AEC Region I for 1998/99, only 3 farmers in sample of 197 maize farmers there used fertilizers, far too small a sample to draw conclusions. Does this low use in AEC I reflect the lack of profitability in the zone or lack of suppliers in the zone? These farm data cannot tell us, but research data can be used to evaluate what the crop responses to fertilizer might be, and the incentives of farmers to use it.

[6] Further work combining the estimates from the crop suitability mapping on yields and response rates and the profitability analysis here will be valuable, when current local input and output prices can be used.

Table 3: **Maize Yields of Farmers Using and Not Using Fertilizers: 1998/99 and 1999/2000**

Agro-ecological zone	1998/1999			1999/2000		
	Farmers using fertilizer on maize (% of all farm hhs)	Maize yields without fertilizer (kg/ha)	Maize yields with fertilizer (kg/ha)	Farmers using fertilizer on maize (% of all farm hhs)	Maize yields without fertilizer (kg/ha)	Maize yields with fertilizer (kg/ha)
AEC 1	2%	1155	2825	11%	1103	1433
AEC 2	25%	1264	1920	29%	1370	2108
AEC 3	28%	1335	1941	23%	1138	1831

Source: Post Harvest Survey, 1998/99 and 1999/2000, weighted to reflect population estimates. Note: AEC 1 in 1998/99 had only 3 valid cases for farmers using fertilizer.

4. METHODOLOGY

4.1. Partial Budgeting and Profitability

Profitability can be measured by a value cost ratio (VCR) which is the ratio of (Benefits - Cost) to (Costs). VCRs based upon partial budgeting methods estimate the incremental cost of the fertilizer and incremental benefits with the fertilizer, rather than the total costs and value of production without and with the fertilizer (CIMMYT, 1988). This is valuable when evaluating the returns to investing in fertilizers, but it will not give an evaluation of the crop itself.

Thus, to estimate the profitability and risk of fertilizer applications on maize and cotton, it was necessary to evaluate benefits, using output prices and responses of the crop. Response rates are the amount of increased output received from a discrete technical input. In this case, the response rate is the increased output received per kg of input used.[7] The costs should include the price of the fertilizer and any transaction costs to obtain it, as well as costs of application.

Since farmers do not know exactly how their own crop will react to inorganic fertilizers in a given year, the response rates must be estimated, based upon assumptions about the distribution of results from agronomic data. For the response rates, there were 116 "trials" (both on-farm and on-station) on maize included, although some of the "trials" were multiple year and multiple sites, so the data involve far more that 116 observations. For cotton, 195 "trials" were involved, both on-farm and on-station. Unfortunately, the data found in the reports are often just the averages over several plots, several varieties, or several seasons. In a few cases the standard deviation is reported and in recent years, means testing for differences is conducted. For this preliminary work, we have chosen to use the averages. When available (particularly for the on-farm work), we have included the observations in the analysis, but that is mainly for cotton, for which the farm results are reported. Maize has been the focus of extensive research, but in recent years that research has evaluated conservation farming and other multiple input/management technologies, rather than the more limited inorganic fertilization trials of the past.

While reporting for the research trials has improved over time, there is often insufficient information to aggregate the results as systematically as needed. For example, the variety is not always included in the summary reports available to us. In some cases, results were averaged over several varieties. For maize, almost all trials used hybrid cultivars, with greater yield potential than the open-pollinated varieties (OPV) or the second and third generation hybrids often found on Zambian farms. Ideally, results would be reported controlling for varieties, but this was not possible here.[8]

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[7] Some analysts also estimate the response rate per unit of nutrient but here we will use per unit of input, since fertilizers sometimes combine nutrients. Where two or more fertilizers are used, it is the combined quantity of inputs that is used.

[8] The management information system INFORM-R established MAFF/Mt. Makulu under the Soils and Crops Research Branch will assist in overcoming some of the information gaps on trials if researchers fully fill out reporting forms.

The trials evaluated here often involved a combination of different levels of several nutrients, and in the case of cotton, number of pesticide sprays. Cotton is highly susceptible to various pests and fertilizer response is conditioned by the effect of pests, so results are broken down for different levels of pest control, as well as fertilizer applications. In Zambia, maize rarely receives inputs other than basal and top dressing fertilizers in the small holder cultivation system. Given the combinations of inputs, estimating a response rate to a given nutrient, such as nitrogen, was not possible. It was possible to calculate the yield improvement (if any) for the amount and type of input(s) applied. As would be expected, the lower rate applications of an input tend to have higher marginal value than increasing quantities, such that the first 100 kg of urea will have a higher VCR than the second 100 kg of urea. Here, averages were compared, rather than the incremental changes. To highlight optimal choice of doses, the incremental is important, but requires more detailed information from trials with several levels of input used.

For cotton, Chitah et al. (1992) cite several problems. Most of the agronomic research on cotton was conducted from 1960 to 1975, based on fertilizer applications. However, small farmers were not using weed and pest control methods currently being used and, as they state, “this would have reduced considerably the efficiency of any fertilizer application” (Chitah et al, 1992, p.35). More recent evidence shows such variability that it is hard to determine the relationship between pesticide application and fertilizers, so developing the recommendations for cotton is problematic without further investments in research.

There are trials on lime (an inorganic input to mitigate soil acidity), but we do not have a full set of such trials. Trials are focused in regions with high acidity, such as Luapula and Northern Provinces. Even with a full set of trials, lime would need a special analysis over time, since the effects are not confined to a single season. Since we also need to develop a price series on lime and the costs of lime to the farmer are heavily dependent upon local transport charges, we have not evaluated it here. As Lungu (1987) notes for maize in particular, the use of nitrogen based fertilizers, particularly at high rates of application, on acidic soils may have negative consequences on yields over time, so lime may be very important.

4.2. Price Analysis

The analysis was conducted to reflect the most recent cropping year, 2000-2001 and we have attempted to estimate appropriate prices for farmers this year, looking backward to when they would have purchased fertilizers, and looking to when they have or will be selling, according to the PHS results.

Wholesale maize grain prices tend to follow similar trends throughout the country with high seasonality. Seasonality patterns are similar for the major markets, although somewhat dampened in Ndola (Copperbelt Province) and Mongu (Western Province), both markets in non-maize producing regions. Highest prices tend to be in Jan-Mar and lowest prices from May -August, as would be expected given cropping and marketing. Note that seasonality was estimated using real maize wholesale prices from AMIC (deflated using the non-metropolitan CPI deflator) for the period mid 1994-early 1999 (when the times series were fairly complete for major markets). We looked at the PHS to see when the majority of maize sales occurred. Farmers reported selling in every month, but the months reported most frequently for “when sold most of crop” were July - October in both 1997/98 and 1998/99.

There are gaps in price series for maize for 2000-2001, hindering efforts at developing a price forecasting model. So we assumed that the most recent prices available at the time of estimation (Feb. 15, 2001) would reflect current conditions, stocks, etc., as well as expectations of the crop to be harvested. We chose the most recent observation for a **wholesale** market, and that was Kasama market for Feb 15, 2001. We then estimated the average seasonal indicator for the July -October prices, for each market, over the 1994-1999 period. The average prices from 1994-1999 for each market were compared to the Kasama average price, to estimate the average difference between Kasama and the other markets. Thus, multiplying the most recent Kasama wholesale price by the local seasonal indicator and the Kasama-local market indicator, we get a projected price for this harvest season for each location. The high price is based on prices being 20% higher than the projected average. Farmers who hold back their maize and sell more after October realize a higher price for their maize. In the PHS, farmers selling about 75% of the total marketed maize indicated that the month in which they sold the largest amount of maize was June, July, August, September, or October (the peak post-harvest market period). About 25% of the maize marketed was held by farmers who indicated that they sold the largest amount of maize in a non-harvest month. In the analysis, maize prices were allowed to have a distribution with a 75% probability of being the estimated average price for peak season, and a 25% probability of being the high price (20% above the market season average price). We did add 100 Kwacha per kg transport costs to for maize (or cotton) sold. Simulations were conducted, assuming no correlation with other prices or responses.[9]

Given the lack of time series data on cotton prices, the estimated average price from a staff member of the Cotton Development Trust is used, and then based on the geographic dispersion of prices quoted by industry for 1998/99, a market price is estimated for each major market. For example, if the Mansa market price in 1998/99 was 10% above the national average price (from industry) for 1998/99, the Mansa price was estimated to be 10% above 750 (low price) or 10% above 800 (high price) Kwacha/kg. Note that the industry-quoted price for Chipata was generally higher than the prices stated by farmers in 1997/98 and 1998/99, so the projected PHS price was used, rather than the projected industry price. In other regions (where data are available) and the prices are qualitatively similar, we used the projected industry price. For the simulations, high and low prices were assumed to occur with equal probabilities (10% each) and the average 80% of the time, with no correlation with other variables in the simulation.

For fertilizer prices, we have used the AMIC observed prices for December 2000, and then computed a price 20% higher (for the high cost option), and added transport costs from market to field of 100 Kw/kg for all markets, according to the kgs of fertilizer (not nutrients). Clearly, in each location different farmers will have different transport costs to get the fertilizer from the market to the farm. It is assumed that the transport costs from Lusaka or other origin to the market are included in the fertilizer price. For the analysis, separate simulations are run, based on a low fertilizer price and a high fertilizer price. The separate results are then compared.

[9] See a further discussion of this issue in the following section.

Urea, compound D, and ammonium nitrate prices are all assumed to be the same, although there are differences which come and go between the prices of the commodities. Currently, urea and compound D tend to be close in price. Ammonium nitrate tends to be lower in price. As differences in the prices of inputs become significant, the actual composition of the fertilizer package will be important in the profitability analysis. Each of the dose rates used includes nitrogen and phosphate nutrients.

Regarding the transaction costs for both inputs and outputs, here we have started the basic analysis with a simple inclusion of 100 Kwacha per kg for the transport costs, and not included the other transaction costs or application costs (for the input) or harvesting costs (for the output). A more refined analysis would detail these, by location. Since these activities are generally conducted by household labor, it is not clear that they would enter into the farmers choice decision, but a detailed analysis should include them.

4.3. Key Components in Sources of Variability in Profitability Analysis

As noted in Damaseke 2000, the biophysical efficiency of fertilizer (the response rate on per kg input or nutrient basis) depends upon the nutrients in the fertilizer, initial soil conditions and fertility, weather, and crop management practices of the farmer. Varietal choice affects the response rate as some varieties have greater genetic potential to respond to specific nutrients. Varietal breeding work conducted by a MAFF scientist (Dr. C. Mungoma) identifies maize cultivars that do well under both high and low nitrogen availability conditions, so that farmers in Zambia will have varieties that are relatively productive even under nitrogen stress (Mungoma 2000). However, use of seed retained from hybrids reduces the overall yield potential of the crop, as well as the response rate. Timing of all activities, including application of the fertilizer, will affect the fertilizer productivity, since the crop needs nutrients during various stages of growth. Soils with high amounts of nutrients will also have low response rates, since the plants without fertilizer are still able to gain many of the needed nutrients and grow well. For example, Golden Valley trials show maize yields without any fertilization of 1.8 to 2 tons per hectare. In the profitability analysis, that means that fertilizer use is less profitable for farmers on soils with a high level of initial nutrients than on soils with depleted nutrients.

The response rates used in this analysis were the average response per hectare for the dose, compared to either no fertilizer application, or in a few cases, to a very low dose of fertilizer application. The marginal response rates were available for some cases, indicating the response rate for the increase from one dose to another, but the difficulties of comparison between different trials has motivated us to use the overall average response rate here.

Prices for both inputs and outputs are important in profitability. In this analysis, the prices for inputs were controlled in separate simulations in order to assess the effects of policy. As mentioned previously, included in the price of inputs was a nominal transport cost which did not vary regionally. Any transaction cost will increase the actual cost of the input beyond the sales price and will reduce profitability. A large reduction in transport costs to the market should be reflected in a price reduction of the commodity and this is evaluated with the price simulations.

As noted previously, we assumed that there was no correlation between output prices and yields. In general, when there are adverse climatic conditions, yield (and thus response to fertilizers) is constrained. If market supplies are thus reduced, we expect higher market prices for the reduced supplies. There are two basic reasons for excluding correlation here. To include that correlation in this analysis would mean that all cases of low yield are associated with poor production year and higher output prices, which we do not find to be the case. The spread of yields in a given year in a given location indicates that yield is not necessarily correlated across farms in a region. Secondly, in years of drought or excessive rainfall, you do find all farms with poor productivity, but government policy particularly for maize may result in bringing in food aid supplies or subsidized imports, such that the market maize prices do not rise as much as the scarcity would suggest that it should. For these two reasons, further work on whether market prices will compensate for lower yields would be valuable.

Input/output price ratios (I/O ratios) are a good indication of the breakeven result needed to at least pay back the ticket price of the fertilizer. For example, if a farmer applies 300 kg of urea, paying 40000 Kwacha for each 50 kg bag (i.e. 800 Kwacha/kg) and he/she expects the maize price to be 400 Kwacha/kg, he/she will need to get 2 kg of maize for each kg of fertilizer applied in order to have recovered the ticket price of the fertilizer. In terms of a response rate, to breakeven on the investment, there must be a response rate of 2.00 maize grain for each 1 kg input. In bags, for every 6 bags (50 kgs) of fertilizer, the farmer must harvest at least 12 additional 50-kg bags of maize to pay the ticket price of the fertilizer, when the I/O equals 2.

Evaluating the profitability of the fertilizer use only gives a partial picture. As mentioned in the discussion of the objectives, a major question remains as to whether or not the crop itself is profitable. Fertilizer use may be profitable but the total production costs may exceed the total value of the crop, such that the crop is not profitable. In those cases, fertilizer use may reduce the losses, rather than make the crop profitable.

5. DATA

5.1. Fertilizer Trials and Responses

D. Simumba of the Biometrics Unit at Mount Makulu put together an inventory of fertilizer trials on maize and cotton in recent years, based on the database of that unit and information from additional sources. Information was recorded on maize and cotton trials for the past 30 years. Most of the trials were on-station trials with a few conducted on-farm. It is not possible to survey all of the trials conducted in Zambia, but an attempt was made to identify key results from selected trials. The documents by Gumbo (1988) and by Lungu and Chinene (1993) provide a basis for this work as well as the Annual Reports for the Soils and Crops Research Branch within MAFF. The basic information was tabulated for each of the trials, indicating whether or not it was on-station or on-farm. If on-farm, either farmers or researchers may control the trial, as indicated by researcher-managed or farmer-managed in the trial type column. In many places in the world, researchers find more responsiveness and higher overall yields in on-station trials because the researchers attempt to control all outside factors and they use their own best practices. Many of the reports available only give summary information on the trials, such as number of plots, mean yield and standard deviation. Actual observations were rarely available, limiting the capacity to conduct hypothesis testing.

The research stations at Mount Makulu and Misamfu are the main sites for trials, particularly since 1985. Researchers selected these sites as representative of Agro-ecological Regions II and III, respectively. The Adaptive Research Planning Teams (ARPT) work has contributed much of the information here for on-farm results. The Soil Productivity Research Programme (SPRP) based at Misamfu Regional Research Centre was reorganized in 1986 and documents from the 1986-1996 period provide excellent results for this work (including Lungu, 1987). As mentioned earlier, researchers at Mount Makulu have developed Crop Suitability maps for some crops, including maize and cotton, based primarily on climate, soils, and agronomic data. The maps show that Region III (mostly in Luapula, Northern, Northwestern, Copperbelt and Western Provinces) is not appropriate for cotton, due to high rainfall and other factors related to soil and climate. The suitability maps for maize show that much of the country has high or medium potential for maize. Region I with its arid climate, as described below, had relatively few trials and so our ability to discuss results for Region I will be limited. Wherever possible, we have sought the original research documents, as they contain the greatest amount of information and data, however both Simumba (2000)[10] and Damaseke (draft 2000) point out the limitations of research documentation in Zambia.

Another confounding factor for interpretation and estimation of response rates is the use of data from long-term fertility trials. Some of the trials results found came from long term trials and those will not be used here. Just as farmers tend to use similar practices from year to year, researchers on station attempt to see the effect of a practice in the long term. In long term trials, the lack of a nutrient over a long period may make fertilizers including that nutrient appear very profitable, because the plant will respond well to relieving that constraint.

[10] Simumba is currently working at Mount Makulu with INFORM-R, to facilitate access to research results.

Similarly, as was mentioned above, research stations, by using good agronomic practices, may have a lower response to nutrients if the soil has been fertilized over the years, with both organic and inorganic. For some nutrients or minerals, the effects may be realized over time, such that only long term fertility trials will be appropriate to capture the effects. Lime is an example for which an analysis of a single year will not demonstrate the returns to the investment, as the effects occur gradually over time. Single-year partial budgeting is not appropriate with lime. Here the analysis is primarily on nitrogen- and phosphorus-based fertilizers for which a single year analysis is more appropriate as nitrogen is a volatile input and very important for maize and cotton growth, while phosphorus supplies are needed at specific times in the plant growth cycle.

Some of the data used come from trials that involved several different varieties, hybrid as well as open-pollinated varieties, or a range of planting densities or other factors. In these cases, the results were averaged across the treatments or varieties. Future work, controlling for varieties, would be more precise, but there were not always significant differences across treatments.

5.2. Maize and Fertilizer Prices

Price data come from several sources. The staff of the Agricultural Marketing Information Centre (AMIC) have provided maize and fertilizer price series from 1994 - 1999, as well as current prices (AMIC 2001). Maize wholesale prices from AMIC were used, as described in the methodology section. As a check on AMIC prices, farm-level prices for fertilizers were also estimated from the PHS. A brief look at PHS fertilizer prices compared to AMIC retail fertilizer prices shows that the prices for 1997/98 and 1998/99 of PHS are similar to average AMIC prices. An exact match would not occur because PHS prices are for different months across the year, depending upon when the farmers purchased the fertilizer. We do not know what month and the extent to which transport to the farm or farmer organization is included. The AMIC prices are for major markets and are collected twice monthly, at least, from formal retail sources. So data collection methods are very different between PHS and AMIC. A better comparison could be made if the month of purchase was entered as a variable in the PHS, as well as information on payment of transport costs, including what was paid and which party in a transaction paid it.

Note that some of the incremental cost associated with fertilizer use and crop sales are not included. The transport costs are included as a fixed 100 Kwacha per kg and future work would change that to reflect farmers' costs. The application costs of the fertilizer treatments (primarily the opportunity cost of the farmer's time spent applying) is not included here, and in extended research both it and the transport costs would have to be evaluated at the farm level. For the I/O ratio, farmers should include these in the price estimate for a more realistic view.

5.3. Cotton Prices

Cotton price data are not collected by AMIC and no other agency was found to collect it in a systematic fashion. The Post Harvest Surveys (PHS) conducted by the Central Statistical Office indicate that farmers most frequently "sold most of crop" in June -August in 1997/98 and 1998/99, highly seasonal, as expected. The PHS cotton prices for 1997/98 and 1998/99, were compared to the cotton prices from Lonrho and Clarke for selected places and years (from Jones and Thom), and an estimated cotton price between 750-800 Kwacha/kg for the 2000-2001 season was obtained from Mr. Chisenga of the Cotton Development Trust. In general the PHS prices were 5-15% lower than the industry quoted prices for cotton, where the comparison is possible.

6. RESULTS FOR MAIZE

Before entering into the profitability analysis as such, it is valuable to take a look at Table 4 which shows the comparison of Input/Out Price ratios (I/O ratios) in Column B and the range of response rates of kg output per kg input observed in Columns C, D, and E, depending upon the fertilizer applied.[11]

This table shows the comparison the input/output price ratio and the response rates observed in trials on station and on farm for maize. The input/output price ratio can be considered a breakeven response rate since it indicates how many kilograms of maize are needed to pay for each kilogram of input. A relatively high ratio means that the fertilizer must be more productive to be profitable. In Northern and Northwestern, the high I/O ratios stem from high fertilizer prices, whereas in Southern, the low maize prices result in high I/O ratios.

Table 4: **Response Rates to Fertilizers in Maize Trials**

	Breakeven response rate	**Observed response rates (kg maize/ kg input)**		
Province	**Input /output price ratio (urea/maize)**	**Urea response rates**	**Compound D (or X) response rates**	**Urea and Comp. D response rates**
(A)	(B)	(C)	(D)	(E)
Eastern	3.6	36995	3.0-6.8	6
Central	3.2	36956		37156
Lusaka	3.4			
Southern	4.7	2-12.5	2-3.6	36934
Western	2.5			37135
Northwestern	4.4		2-7.5	1.5-9
Northern	4.3		9	
Luapula	3.9	37142		2.5-8
Copperbelt	3.2			

Notes: Based on Projected maize price and Dec 2000 urea price (AMIC) for the major market town. Response rates are kg maize from each kg of the indicated output. This is an "observed" point ratio rather than the simulated price ratios in the results in Tables 3-4, Annex tables 1-2. Source: MAFF and other documents. Estimates by FSRP.

[11] Note that these response rates are per kg of input to compare and evaluate breakeven points for responses. Also, these response rates are different from those in the other tables because they evaluate only trials with the noted nutrients added. The following tables in the document are aggregated across the nutrients.

6.1. Region I

In Region I, fertilizer trials were reported only for results that were identified as region I by Mochipapa researchers. The I/O ratio is fairly high, 2.43 or 3.34 depending upon whether the fertilizer price is 40000 Kwacha or 55000 Kwacha per 50-kg bag (Table 5 and Annex Table 1). This is due to low maize prices locally and means that at a minimum, the maize must yield 2.5 to 3.5 kg for each kg of fertilizer used, just to pay for the fertilizer. Mochipapa results show VCRs above 2 for the low and medium dose rates, with 35% of the cases at the medium dose level having VCR above 2 even in the high fertilizer price simulations (Figures 2-3). The VCRs dip below 2 for the higher dose rates, but as Figures 4 and 5 show, there is dispersion of results, with some cases of very profitable use of fertilizer. The difference between the high and low fertilizer price changes the VCRs but for the lower input levels, does not result in high probability of actual losses with fertilizer input, and there is a high probability of VCRs over 2.

For the high input level, there is a risk of losing the investment in fertilizers, with 30% probability of a VCR less than one with the high fertilizer price. If the fertilizer price is low, there is only a 5% probability of a VCR less than one, and about 20% probability of VCR over 2, so farmers should profit (Figures 4 and 5). For the highest dose rate, the mean VCR with a low fertilizer price is 1.1 and there is only about a 30% probability of a VCR greater than 1.0, so use at this level would not be recommended on profitability criterion.

In this region, the farmers have the highest probability of profitability by using the lower dose of fertilizer, but the high (but not highest) dose level can be profitable for some farmers. This would mean that up to 250 kgs of fertilizer (100 kg Compound D and up to 150 kgs urea) would generally be a good investment for those farmers without severe yield constraints.

6.2. Region II

Region II results were initially somewhat surprising. Given that it is considered to be the most suitable region for maize, the researchers expected a high proportion of profitable results, since growing conditions are generally good. As can be seen in Table 5, the VCR results for maize vary widely in Region II, from a mean VCR of 2.5 in Msekera with a low dose rate and low fertilizer price to 0.4 in Golden Valley for a high dose and high fertilizer price (see Annex Table 1 as well). Figures 6-9 also demonstrate the variability with the low and high input levels.

There are various reasons for this. In the case of Golden Valley, the generally high quality of the soil was noted by Gumbo (1988) as a reason for relatively low response rates to fertilizer application for both maize and cotton on station. High fertilizer use on station over time will result in more nutrients being available from the soil even for the control plots, as indicated by the yields of over 4 tons without fertilizer. At the low fertilizer price and low dose, while the average VCR is below 2, 15-20% of the cases showed a VCR above 2, indicating that there is potential profitability in this region. The Golden Valley results rely mainly on results from 1990/91.

Table 5: Profitability Results for Fertilizer on Maize in Zambia

AEC region	Location	Input dose level	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Responses	Response rates	Maize price
			VCR	I/O ratio	VCR	I/O ratio	kg output per hectare per dose	kg output per kg fertilizer	Kwacha per kg
I	Mochipapa	1	3.4	2.4	2.6	3.3	1251	12.5	345
I	Mochipapa	2	2.7		2		2003	10	
I	Mochipapa	3	1.7		1.3		2515	6.3	
II	Golden Valley	1	1.5	1.8	1.1	2.5	367	3.7	460
II	Golden Valley	2	1.2		0.9		578	2.9	
II	Golden Valley	3	1.4		1.1		1415	3.5	
II	Msekera	2	2.5	2.8	1.9	3.8	1843	11.3	296
II	Msekera	3	2.3		1.7		3376	10.4	
II	Msekera	4	1.8		1.4		4031	8.3	
III	Mansa	1	3.3	2	2.5	2.8	940	9.4	414
III	Mansa	2	1.1		0.8		639	3.2	
III	Mansa	3	1.1		0.8		1285	3.2	

AEC region	Location	Input dose level	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Responses	Response rates	Maize price
III	Mwinilunga	3	1.3	1.9	1	2.6	700	3.5	434
III	Mwinilunga	4	1.1		0.8		1500	3	
III	Misamfu	3	2.4	3.3	1.8	2.4	1801	9	344
III	Misamfu	4	1		0.7		1800	3.6	

Notes:

Mwinilunga and Misamfu trials reflect the response to the addition of AN and Urea to a control with 200 AN. Msekera reflect changes from a base dose of 163 kg/ha urea (or 75 kg/ha AN), increasing by 163 urea for each level. All others are based on controls of 0 fertilizer.

Dose rates:

Dose level 1 : 100-150 kg/ha (most common dose: 100 kg urea)
Dose level 2: 175 - 300 kg/ha (most common dose: 100 kg/ha urea and 100 kg/ha Compound D)
Dose level 3: 350-450 kg/ha (most common dose: 200 kg/ha urea and 200 kg/ha Compound D)
Dose level 4: 475-600 kg/ha (most common dose: 150 kg/ha urea and 500 kg/ha Compound D)

The results from Msekera may be more indicative of the farmers results in AEC Region II. The base case in the Msekera trials was not a ‘no fertilizer” case, but rather already had 163 kg/ha urea, so the results are reported for the next 3 dose levels, with respect to that low dose level. Table 5 and Figures 10-13 demonstrate the profitability of medium levels of fertilizer, with a maximum VCR of 2.5 for the medium dose level and low fertilizer price. In this area, even with a fertilizer price of 55000 Kwacha per bag, the probability of a VCR over 2 is high (about 33%), in spite of an estimated I/O ratio of 3.8. The results for the highest level of fertilizer demonstrate the declining profitability of the use of increasing quantities of fertilizers, found throughout the country, although 20% of the cases have VCRs over 2.0 when the fertilizer price is low.

6.3. Region III

In AEC Region III, the Mansa results indicate that while the low levels of fertilizer use are profitable, higher levels tend to be unprofitable. The I/O ratio is somewhat low, with about 2 kgs of maize needed to pay for each kg of fertilizer (when fertilizer costs 40000 Kwacha per bag) and about 2.8 kg of maize to pay when the fertilizer price is high. Given that Mansa fertilizer prices tend to be higher than those in other regions, the I/O ratio of 2.8 is probably closer to farmers reality, as indicated by the higher I/O ratio in Table 4.

Maize prices in Mansa also tend to be higher than the national average. The response rates are good enough here to have a high probability of profit with the low application rates, with a 60% probability of obtaining a VCR over 2.0 even when the fertilizer price is high (Figures 14 and 15). With the medium and high fertilizer doses, the results are much less favorable, indicating that the risk of losses is high. Using the low fertilizer price, there was a 50% probability of a VCR less than one with the medium dose level, a 55% probability of VCR<1 with the high dose level, and 85% probability of VCR<1 with the very high dose of fertilizer (Figures 16 and 17). This may be related to the high rainfall conditions in this region and the possibility of highly acidic soils. High urea applications on these soils may exacerbate the acidity problems.

In Misamfu, in spite of having a fairly high I/O ratio, the VCRs indicate that fertilizer use is, on average, profitable for farmers at the high input level. Figures 18, 19 and 20 demonstrate that there is a probability of low returns to fertilizer use there, so farmers with usually low yields would want to evaluate whether soil acidity, other soil quality, or management practices are responsible for the low yields, and design fertilizer and other inputs correspondingly. Mwinilunga with its high I/O ratio also has low response rates, such that very few simulations indicated profitability at these input levels (Table 5 and Figures 21 and 22) . Evaluation of constraints is also needed here.

6.4. Summary

The ambiguity in maize results for many areas reflects in part the high variability in fertilizer performance, due only in part to climatic factors. Even the on-station trials suffer from management difficulties when supplies arrive late and weeding cannot be done according to plan due to budget constraints and logistics. There are cases of strong profitability in Region II and for the low and medium input levels in Regions I and III. As stated by researchers in

Tanzania working on maize fertilizer efficiency, "development practitioners might fruitfully put more emphasis on raising smallholder farmers close to efficiency levels through extension and education programs that are aimed at improving the use of available fertilizers" (Hawassi, et al 1998).

7. RESULTS FOR COTTON

The variability in results found in maize is also found in cotton, both on research stations and on farms. In general, the cotton results reflect the lower response rates generally found with cotton as opposed to maize, for most nitrogen-based fertilizer (Yanggen et al, 1998).   Since the prices for pesticides were not obtained and the cost not used, comparing VCRs across the pesticide application rates may not be appropriate. These results clearly need refinements. Planting density is also important in yields, along with pest and weed control.

7.1. Region I

For Region I, the results show high variability as demonstrated by the distributions of the VCRs (Table 6, Figures 23-25[12] , and Annex Table 2). The figures show the results for Lusitu which are qualitatively similar to the results from Masumba, with one exception. In Masumba, all three dose levels were combined with the three pesticide levels and it was the lowest fertilizer dose level, combined with 15 pesticide sprays, that gave the best results, with decreasing profitability as the fertilizer dose increased (Annex Table 2). Only the high protection regime with the high fertilizer dose showed profitability for the fertilizer application in Lusitu. The rate of pest infection will influence whether it brings a significant difference in results, so farmers must assess the needs for the high protection levels. Masumba demonstrates this, as it has profitable results for the no pesticide regime, with low fertilizer inputs, (Annex Table 2) and over 40% of the cases had VCR over 2 in the simulations. In the presence of pests, fertilizers will be less effective as the plant is under stress. The low I/O ratios mean that the response need not be very high to attain profitability in this region, or at least recover basic costs, yet risks remain.

7.2. Region II

Three sites in Region II are included here: Keembe, Magoye, and Petauke. The Petauke results are primarily from on-farm research, while Magoye and Keembe results are mainly from on-station trials.

Region II results indicate a higher probability of not losing money on fertilizers since most average VCRs are over 1 (Table 6). However, the high fertilizer doses with the high pesticide sprays achieved average VCRs above 2. The example of Petauke (Figures 27 and 28) shows the high dispersion of VCRs. For the low input level, 5 pesticide sprays , and low fertilizer price, the VCRs range from 6 down to -2 (actual loss of yield with application), averaging 1.63. The same graph for Keembe (Figure 26) shows much less dispersion, with VCRs ranging from 0.90 to 2.55, with a mean of 2.08. The results from Magoye parallel those of Keembe, with high probability of profitability only in the case of the high fertilizer dose and 15 pesticide sprays during the season (Figures 29-32).

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[12] Figures are not included for each level and each fertilizer price combination. Looking at the statistics indicates the similarity between some results for a given region, and usually only one figure will be presented when results are quite similar. In some sites, not all combinations were conducted in trials.

Table 6: Profitability Results for Fertilizer on Cotton for Selected Places in Zambia

AEC region	Location	Input dose level	Pesticide application rates (number of sprays in season)	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Average Responses	Average Response Rates	Output price
				VCR (average)	I/O ratio	VCR (average)	I/O ratio	kg cotton per hectare	kg cotton per kg fertilizer	
I	Lusitu	1	0	0.3	1.2	0.2	1.6	82	0.4	694
I	Lusitu	1	5	0.1		0.1		39	0.2	
I	Lusitu	2	5	0.3		0.2		173	0.5	
I	Lusitu	3	5	0.5		0.4		401	0.7	
I	Lusitu	3	15	2.4		1.8		1415	2.5	
II	Keembe	1	0	1.1	1.2	0.8	1.7	308	1.6	750
II	Keembe	1	5	1.6		1.2		478	2.5	
II	Keembe	2	5	1.0		0.7		581	1.5	
II	Keembe	3	5	1.3		1.0		1157	2.1	
II	Keembe	3	15	1.5		1.2		1355	2.4	
II	Magoye	1	0	1.5	1.2	1.1	1.6	413	2.2	694
II	Magoye	1	3	0.4		0.3		118	0.6	
II	Magoye	2	3	0.1		0.1		50	0.1	
II	Magoye	3	3	0.4		0.3		348	0.6	

AEC region	Location	Input dose level	Pesticide application rates (number of sprays in season)	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Average Responses	Average Response Rates	Output price
				VCR (average)	I/O ratio	VCR (average)	I/O ratio	kg cotton per hectare	kg cotton per kg fertilizer	
II	Magoye	3	15	2.2		1.7		1909	3.4	
II	Petauke	1	5	2.08	1.01	1.56	1.39	330	2.6	803
II	Petauke	2	5	1.40		1.05		452	1.2	

Notes: [1] This observation was made by Pons (1989) and is an average over several years, but the original documents were not found to support this. Pons also reported high values for this combination of treatments over the 1984/85-1987/88 seasons for Magoye, Golden Valley, Masumba and Monze.

Only selected sites and selected fertilizer dose-pesticide application rate combinations are seen here. See Annex Table 2 for more results.

Dose rates:

Dose level 1: less than 200 kgs of fertilizer applied (most common: 150 kg of Compound D and 37.5 kg of urea; Petauke, 100 Compound D and 25 urea);

Dose level 2: 250 - 375 kg fertilizer applied (combined urea, compound D and others) (most common: 300 kg of Compound D and 75 urea; Petauke, 200 Compound D and 50 urea); and

Dose level 3: 400-550 kg of fertilizer applied. (Most common is 450 kg of Compound D and 112.5 kg of Urea)

In Petauke, the on-farm trials did not include the full range of options. Farmer practices of 5 sprays per year were used and only the low and medium fertilizer levels were included. The lower dose demonstrated higher average VCR but with the wide dispersion noted above.

Keembe results are disappointing, with poor profitability in general. A low fertilizer dose with only 5 pesticide sprays turns in profitable results in about 15% of the cases, if the fertilizer price is low. This is in spite of I/O ratios of 1.2 for the low fertilizer price and 1.7 for the high price. Some of the trials reported here are from 1985/86, which was not a very good cropping year, so that may account for the poor results. Even the base yields in these trials were not very high.

Magoye results from the on station trials had much less variability, but not very high profitability, probably due to the relatively high amount of nutrients already available in the soil, as noted by Pons (1989). For instance, on-station trials in Magoye had yields in 1987/88 of close to 2 tons without fertilization (Pons 1989). With a relatively high level of nutrients in the soil, the inorganic nutrients produce less of an increase in yields. This is similar to going from high levels of input application to very high levels, with decreasing marginal productivity of the inputs as other constraints enter the picture.

Petauke results shows the wide range of VCRs that can be expected across farmers. Some of the on-farm trials had very good results with high VCRs yet other trials had negative results. Unfortunately, the data for the on-farm trials do not always include the degree of protection (number of sprays, type of product, etc.) so there are difficulties in interpretation of the results. Samazaka (1996) reported high response rates and consequently high VCRs, similar to the farmers with good results in Petauke, so there is great potential for profitability in this region with cotton.

7.3. Summary

As noted in Yanggen et al. (1998), cotton in Sub-Saharan Africa has relatively poor yield response to inorganic fertilizers, mediocre profitability (VCRs between 0 and 3.1 in Eastern and Southern Africa) and yet very good input/output price ratios. They cited research by Carr indicating that when rainfall levels are low, high fertilizer doses should not be recommended. In places with soil acidity and high rainfall, there are also problems. This is reflected in the highly variable results in Region I. In 1987/88, rainfall was relatively good, and many of the results reported here were from those trials, however 1986/87 was a low rainfall year, and had very poor results, with yields actually lower for fertilized fields. Region II results reflect the profitability of the lower dose levels when combined with protection, in cases where pests are present.

Region III is not included here as it has been judged by MAFF to be unsuitable for cotton, with rare exceptions, and farmers recognize this as evidences by the Post-Harvest Survey 1998/99 with very few farmers growing cotton there.

8. INPUT/OUTPUT PRICE RATIOS: A TOOL FOR EXTENSION WORKERS AND FARMERS

One easy tool that has been used by extension workers is the input/output price ratio. This ratio gives the breakeven point for fertilizer profitability and can be locally specific, responding to market conditions. When expressed in terms of bags of maize for bags of fertilizer, it helps farmers evaluate their own case. Since the FRA distribution system pegs the paying back of fertilizer loans in bags of maize, farmers are already familiar with the idea.

For instance, take Farmer Tembo, who uses one 50-kg bag of Compound D and one 50-kg bag of urea that each cost 40000 Kwacha per bag. He expects a maize price of 36000 for a 90-kg bag of maize, which is 400 Kwacha per kilo. If he receives those prices, that fertilizer must increase his production by at least 80000 Kwacha, or 200 kilograms (2.2 90-kg bags of maize). However, if the maize price is only 300 Kwacha per kg (27000 per 90-kg bag), he must obtain at least 267 kg of maize, almost 3 full bags of 90-kg of maize just to pay back the price of the fertilizer.

This simple analysis does not include some of the additional costs involved in the fertilizer (transport, credit, application costs), but it demonstrates a direct relationship between maize and fertilizer prices. Many people would not invest money in something that only pays back its own cost, preferring to invest where the profit is at least 2 times the cost. If Farmer Tembo cannot obtain a yield increase of at least 4-6 bags (depending upon the maize price), he may be better off investing in other things.

9. CONCLUSIONS AND RECOMMENDATIONS

This analysis was designed to contribute to the dialogue on fertilizer policy. The main question which this research originally sought to answer was whether or not inorganic fertilizers alone (or with pesticides in the case of cotton) are generally profitable for small farmers in Zambia. However, as the research progressed, it was clear that the available data from research trials was insufficient for a detailed geographically representative analysis of profitability that would be accurate and useful at the farm level. Thus, the authors developed a framework for analysis and applied that framework to locations with sufficient information. The estimated profit of fertilizer for those sites is evaluated for risk from differing response rates and prices. The results for selected locations and input applications are then presented.

This analysis is not based on the potential profitability with controlled management practices, known soil fertility, and optimal conditions, but rather on what was observed in maize and cotton trials, on station and on farm. In areas for which the crop suitability is considered high, the results presented here may be seem pessimistic, but as is explained in the text, on station conditions may pose special conditions. It should be noted that fertilizer can be very profitable on the most depleted soils, depending upon the nutrient constraints and soil conditions present. When good yields are obtained without additional inorganic fertilizers, as on some research stations, the response may not be sufficient to guarantee profitability. This should not be the case in most smallholder farmers fields in Zambia, however, for farmers rarely maintain high input levels over time. Looking at actual farmer production information from the Post-Harvest Survey, we find that there is a significant difference between farmers' maize yields when comparing those who use fertilizer to those who do not, but these PHS data are not designed to indicate the response rates of the fertilizer used, nor to truly determine the application rate of the fertilizer on specific fields.

When fertilizer prices are high and the maize or cotton prices are low, greater agronomic efficiency of the fertilizer is needed to ensure profitability. This research used two fertilizer prices, one low (corresponding to a subsidized fertilizer price) and one higher (closer to what might be a market fertilizer price). Output prices were allowed more flexibility, representing a distribution of prices that farmers might see. The resulting I/O ratios in some regions are low, such that even a small increase in yield justifies fertilizer investment. However, in some areas, I/O ratios are above 4 and the risks are much higher that fertilizers will not increase the yield sufficiently to re-pay the investment in them. Extension agents can help farmers by making these comparisons and explaining the link between the price ratios and the productivity of the fertilizer.

As was noted earlier, this profitability assessment of fertilizers does not reflect all of the costs and returns to the crop, but rather the basic incremental costs and returns from the fertilizer application. In some cases, fertilizers may be "profitable" (increasing revenues more than costs) but that may mean reducing losses for an unprofitable crop, rather than increasing positive profits. Further work with crop suitability mapping, incorporating current prices, would help to answer the overall crop profitability question.

Regarding the research, as other authors have noted (eg. Lungu 1987, Simumba 2000), the documentation on research could be more thorough and often research trials are suspended before the results can be known and with insufficient records available for those who come next. The investment by the Ministry of Agriculture in sustaining and reinforcing the data collection, documentation, maintenance, and dissemination will help ensure that the resources used in agricultural research are wisely spent and the value added through continued analysis is obtained.

The results show that inorganic fertilizer applied to maize and cotton in Zambia can be quite profitable, but there are conditions in which the applications can be risky, mostly due to high variability in response rates. The critical components in that variability are climatic conditions and soil fertility; and crop management practices, related to timing of seeding and input application, overall soil fertility actions, density of seeding, choice of varieties, and the use of weeding/herbicides and pesticides. Farmers may be better off focusing their efforts on eliminating the inefficiencies or improving overall crop management practices, than in increasing fertilizer use. In areas in which climate and soil conditions are unfavorable or high risk for cropping maize or cropping cotton, it is not recommended to invest in more than small quantities of inorganic fertilizer, without incorporating other risk mitigating practices, as found in conservation farming technologies. Crop suitability mapping at Mount Makulu may be useful for identifying alternative crops, as well.

The analysis was conducted with geographical regions, but that does not mean that all farmers in a region will have the same results. Each farmer will need to evaluate the profitability in their own case. For farmers with typically low yields of 500 kg/ha of maize and less for cotton, even in good rainfall years, the investment in fertilizer may not be very profitable, unless the main cause of low yields is lack of the nutrients contained in the inorganic fertilizer. Such low yields may indicate possible crop management problems that go beyond what inorganic fertilizer can overcome. Such farmers may need more extension assistance on crop management rather than just bags of fertilizer. Shifting to other crops, introducing soil or water conservation measures, obtaining new cultivars, developing better pest control and weeding measures, including lime applications for acidity, or other actions may be more valuable for those low yield farmers.

Extension agents and farmers can use their local input/output price ratio as an indicator of the minimum that the crop must increase to payback the fertilizer price and then make their own assessment, moving away from the generalized recommendations. Box 1 presents this in a simplified fashion. Tools for diagnosis of problems with soil nutrients will be valuable for farmers, such as soil testing and development of indicators (for example, leaf color for determination of nitrogen scarcity in specific cultivars).

For cotton, fertilizer profitability was enhanced by the use of pesticides at the rate of 15 sprays per season, yet the variability in results suggests that level of pest infestation plays a role in whether the sprays result in a significant increase in yields in any given case. This also speaks to the need to work with farmers to evaluate pesticide needs and ensure proper application of what might be necessary, associated with evaluation of fertilizer.

Response rates and input and output prices determine the VCRs for both cotton and maize production. This research did not evaluate the importance of transport costs, either for inputs or for outputs, and their role in fertilizer profitability. However, it can be noted that any lowering of input cost will improve the VCR of that input and lower the I/O ratio, thereby encouraging use. Government investment in transport and communications infrastructure is one key area in which the government can help reduce the costs of fertilizer, making it more profitable for the farmers to use (Govereh et al. 2002). Government action to subsidize output prices as a way to improve the returns to fertilizer will be much more costly. Reducing the costs of fertilizers will lead to higher demand for fertilizer with the higher profitability.

This research is not designed to provide a definitive answer to fertilizer profitability for each farmer, but to provide some guidelines for the analysis and examples of its use. The cases presented do, however, raise a question about the idea that fertilizer is profitable everywhere for everyone, raising incomes for all farmers in Zambia, when applied on maize and cotton. In the variable conditions found in Zambia, both in terms of economic and bio-physical environments, the more farmers understand about soil fertility management and the relationships between management practices and profitability, the more profitable the entire cropping system.

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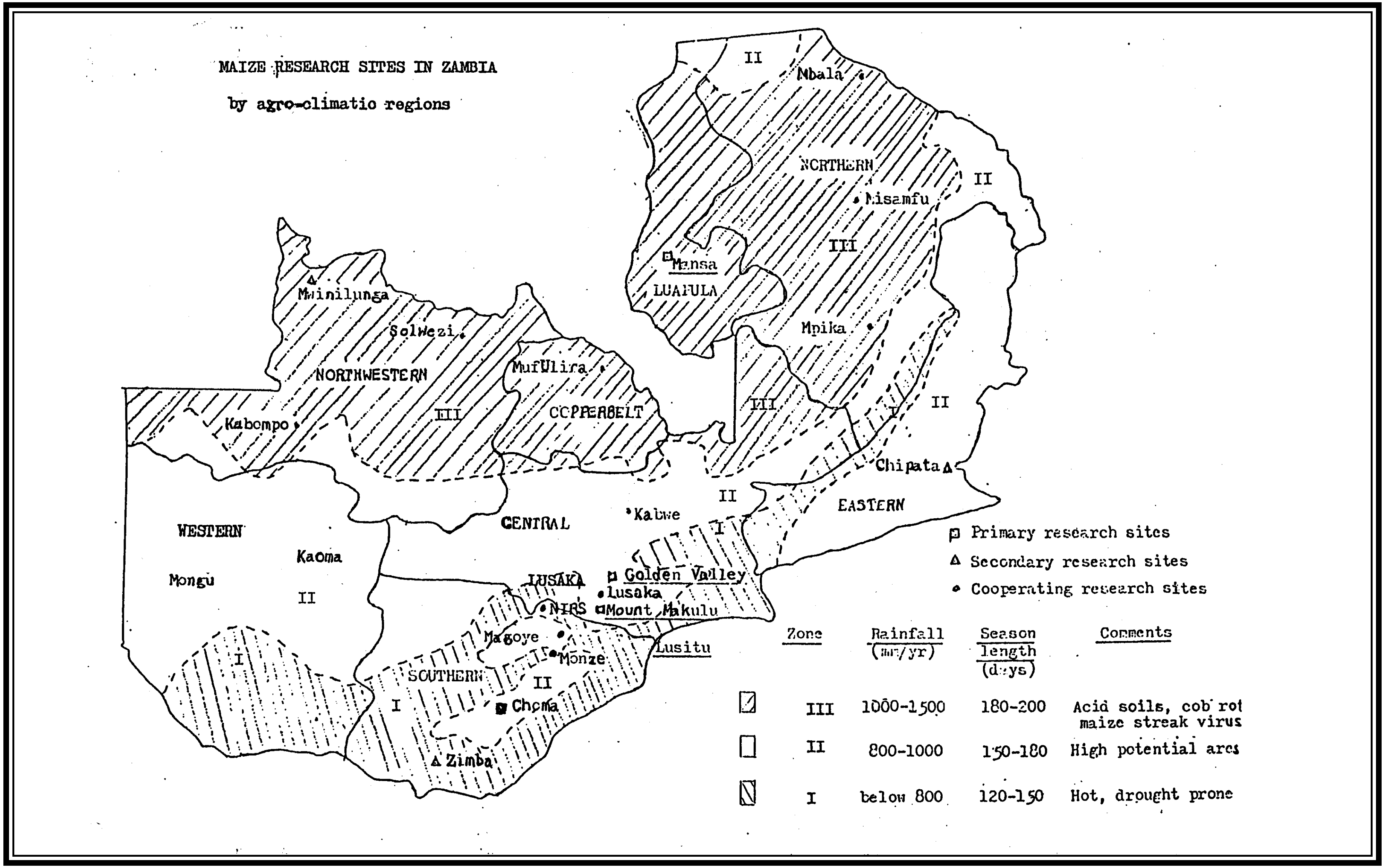
ANNEX OF FIGURES

Figure 1: Map of Maize Research Stations, Demonstrating Agro-ecological Zones



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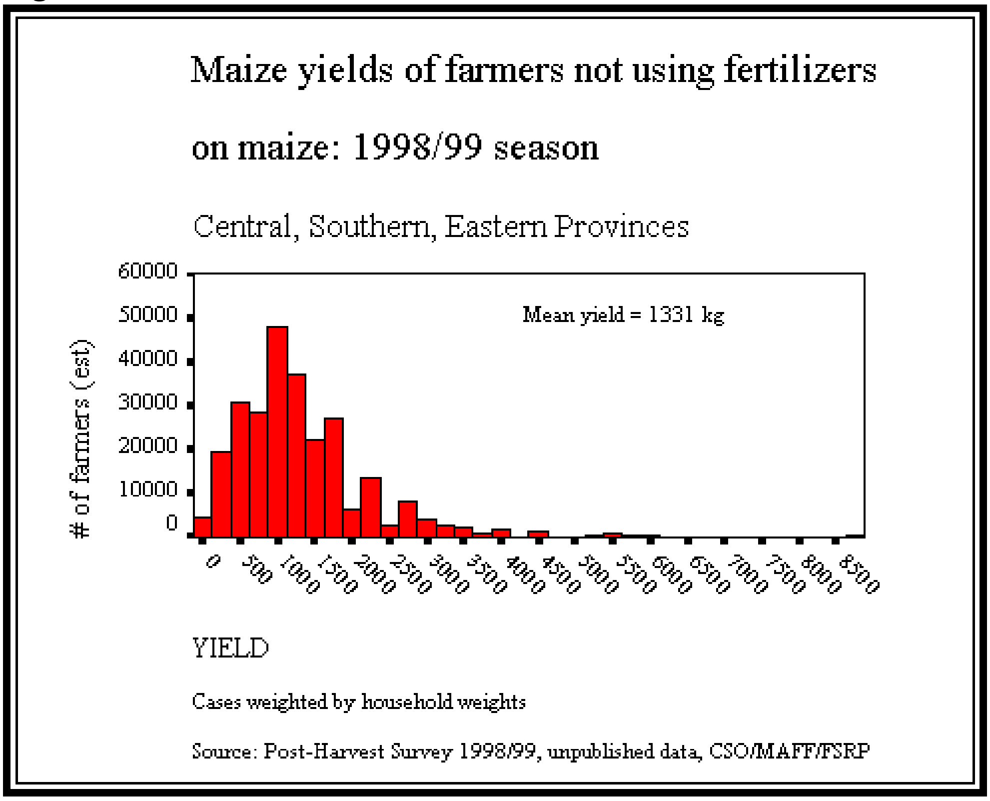

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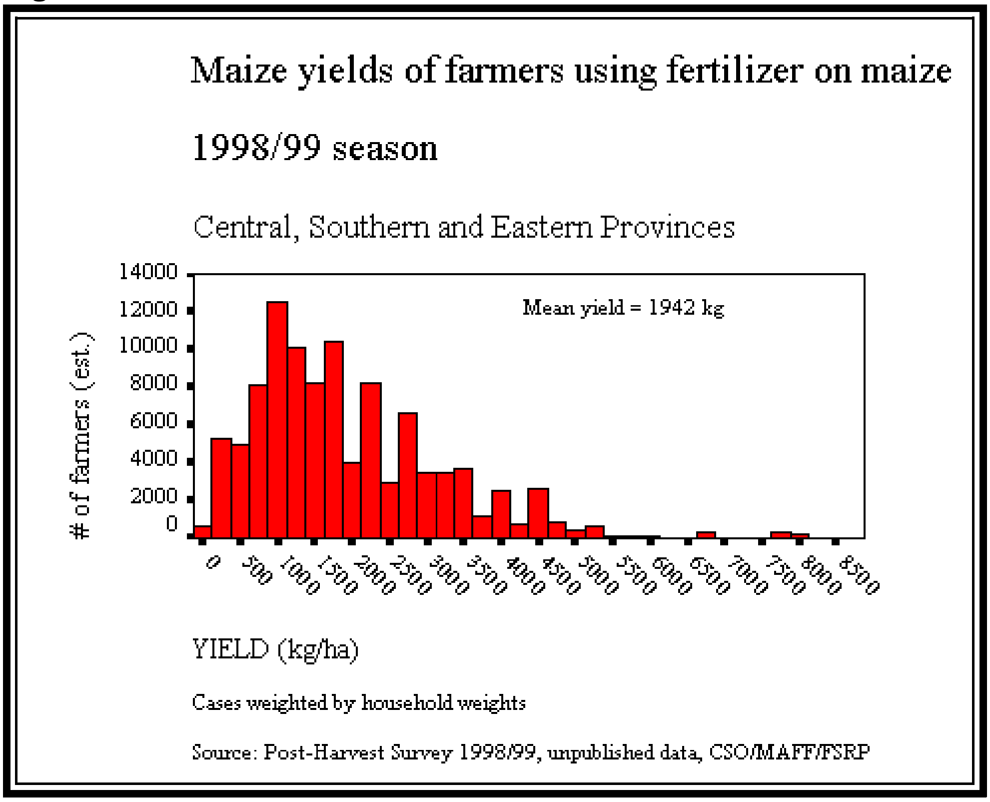
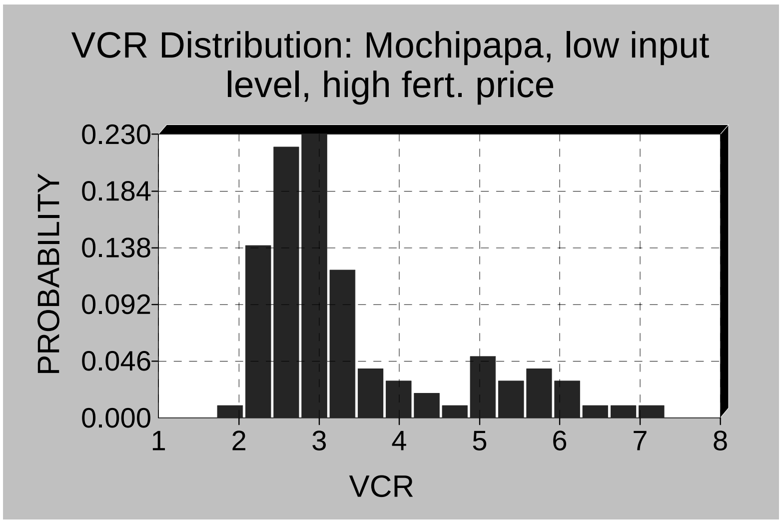


Maize Results

Figure 4



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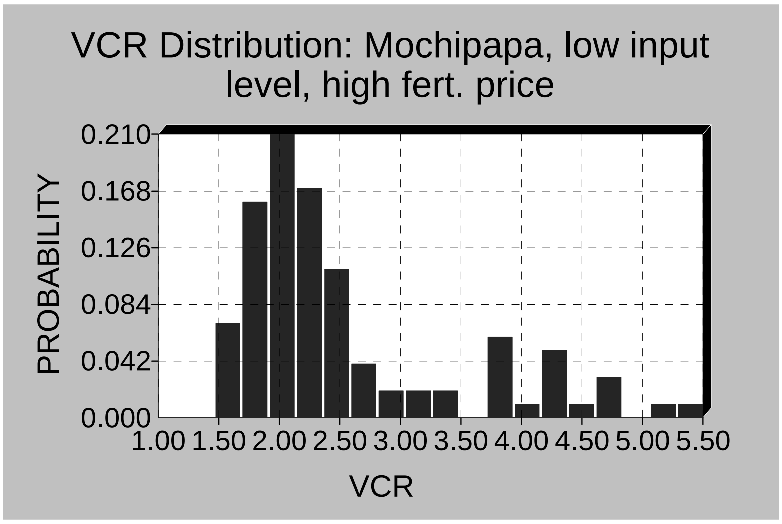
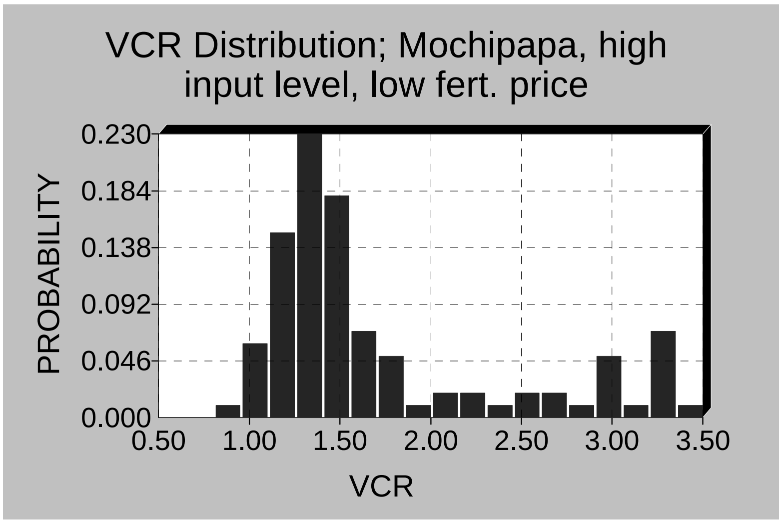


Maize Results

Figure 6



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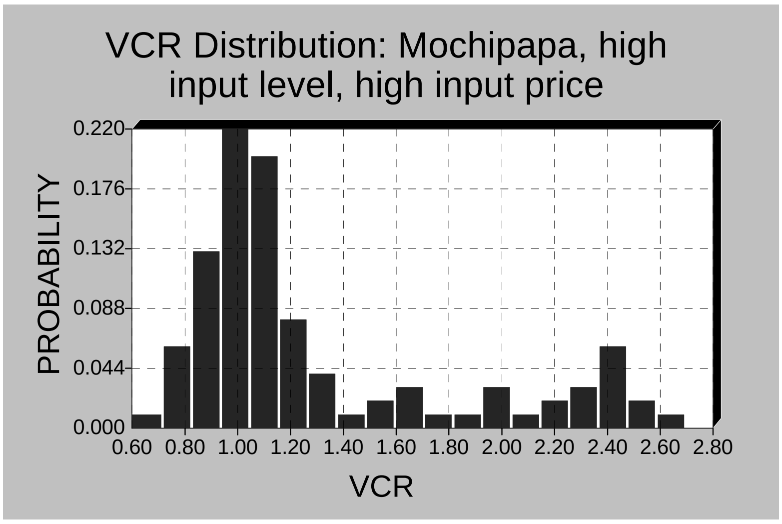
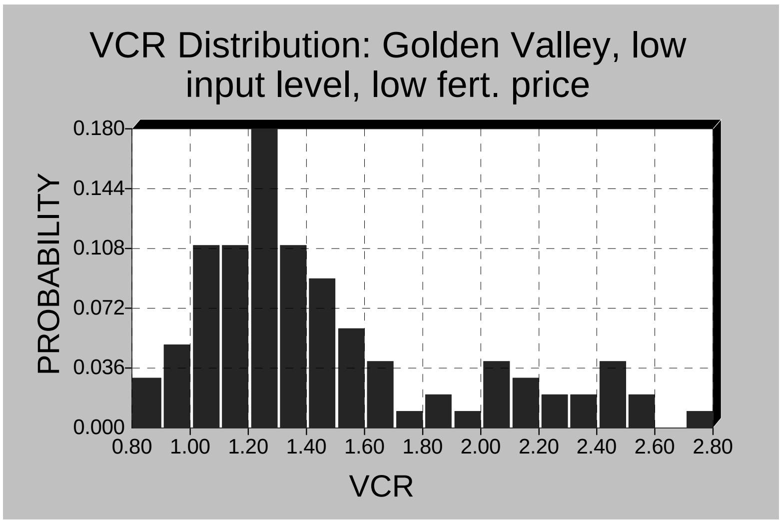


Maize Results

Figure 8



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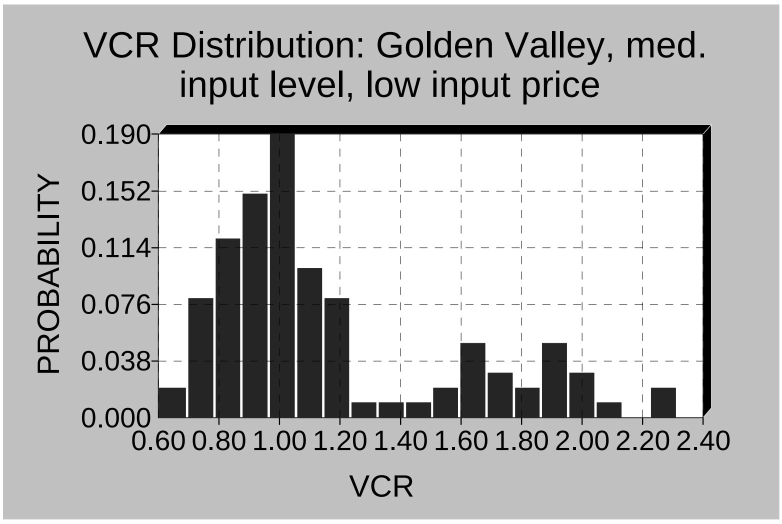
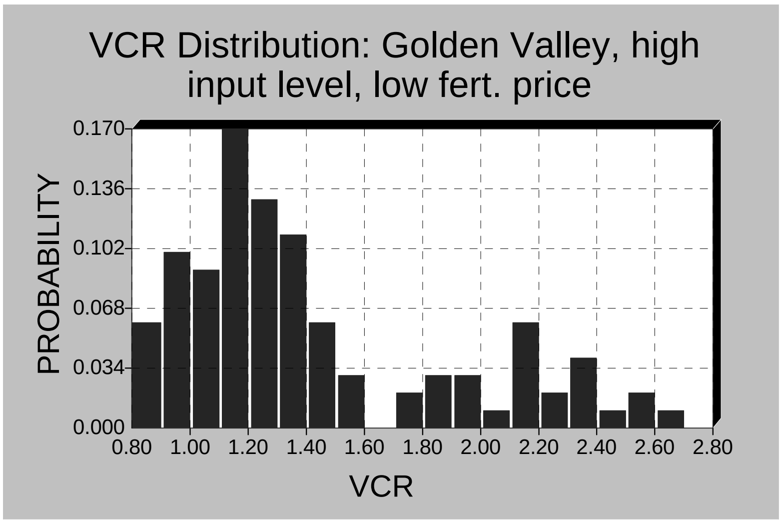


Maize Results

Figure 10



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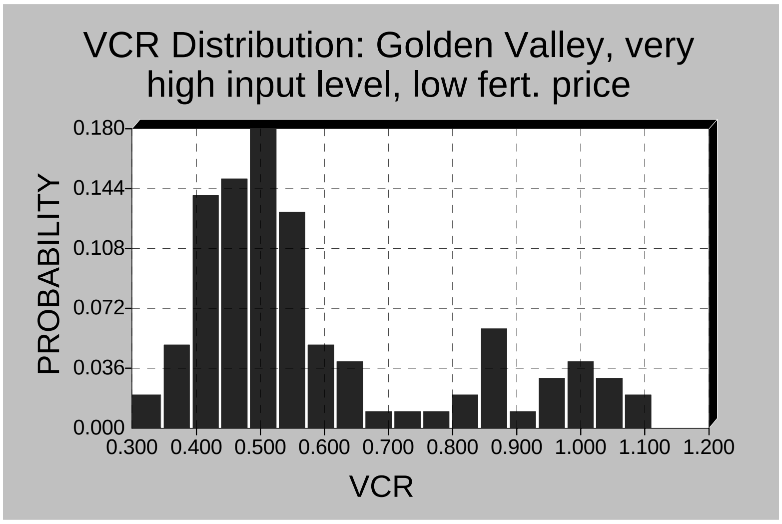

Maize Results

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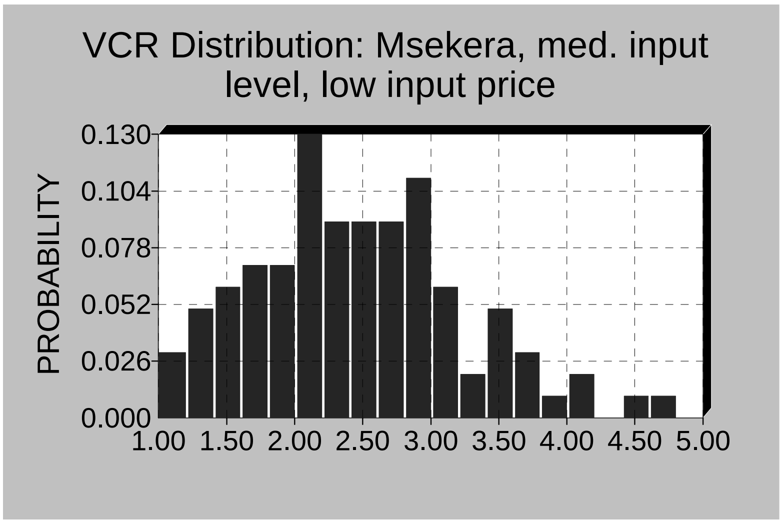

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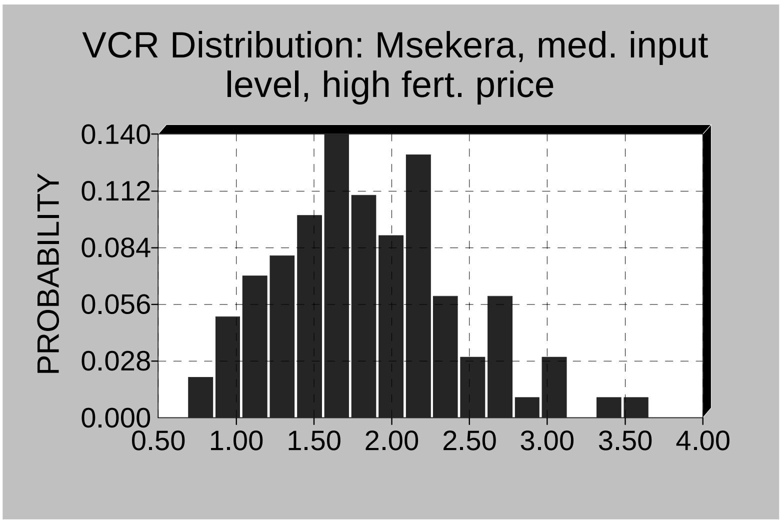

Maize Results

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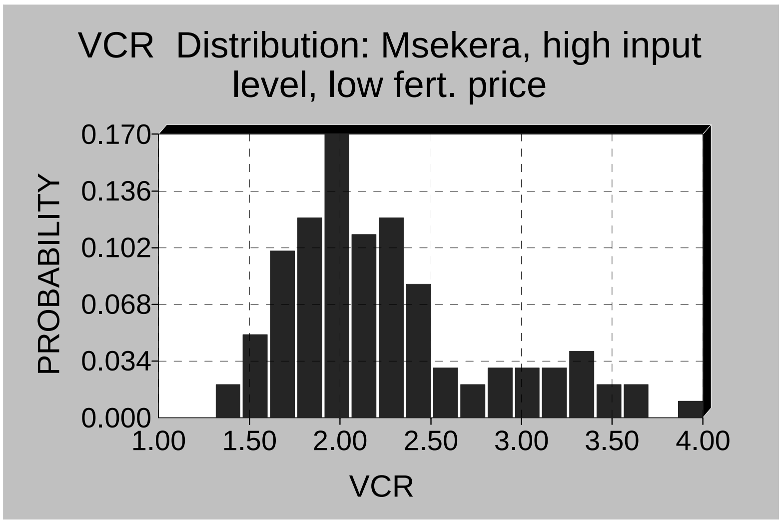

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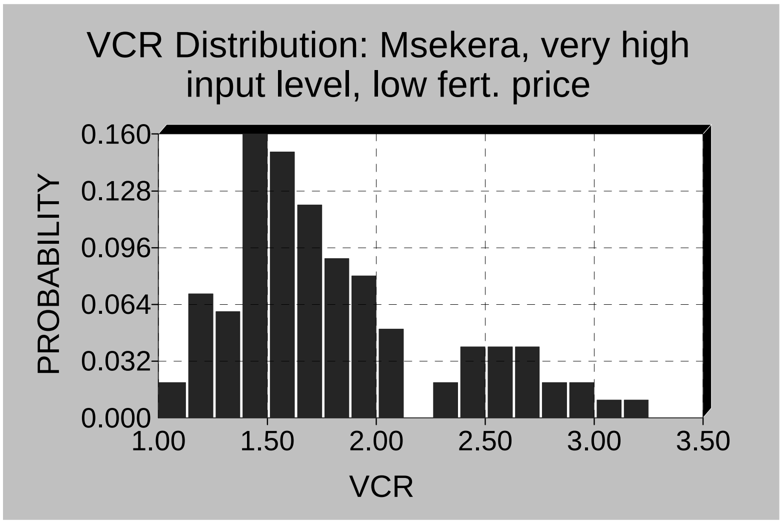

Maize Results

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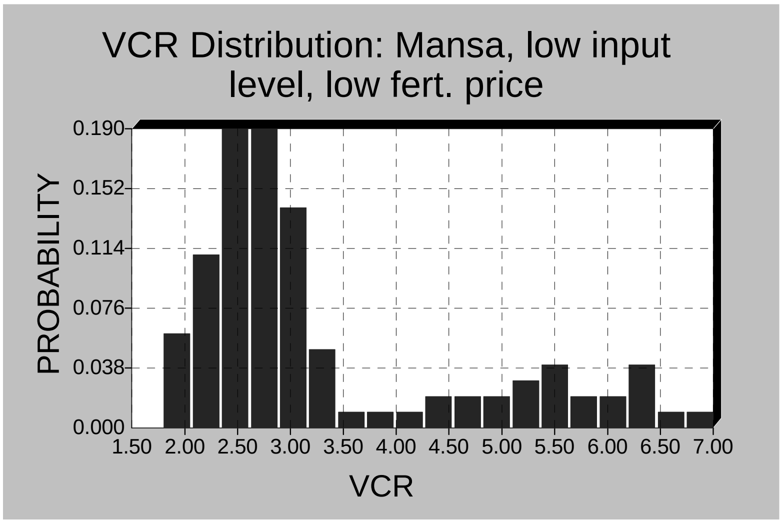

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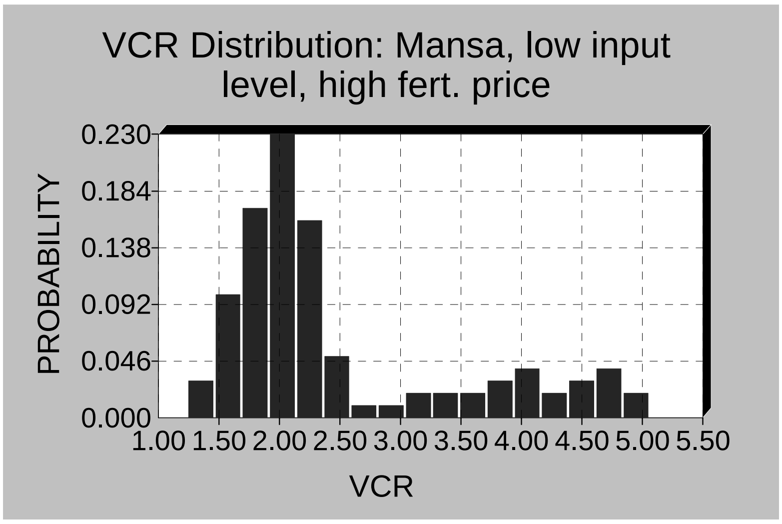

Maize Results

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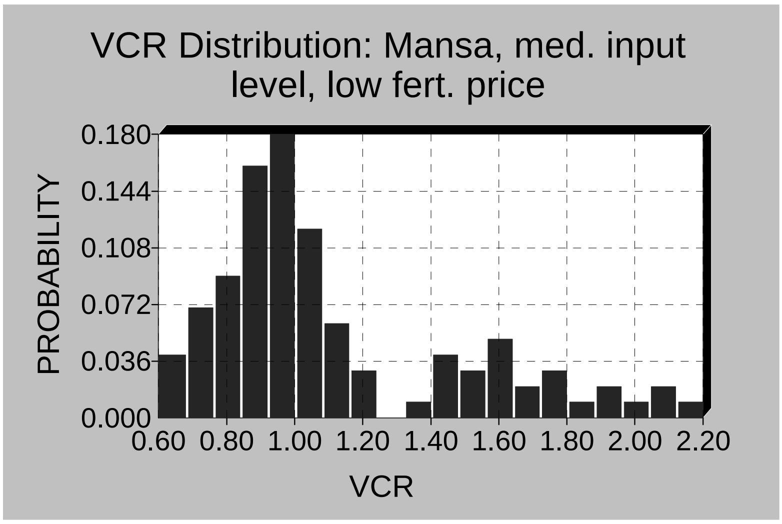

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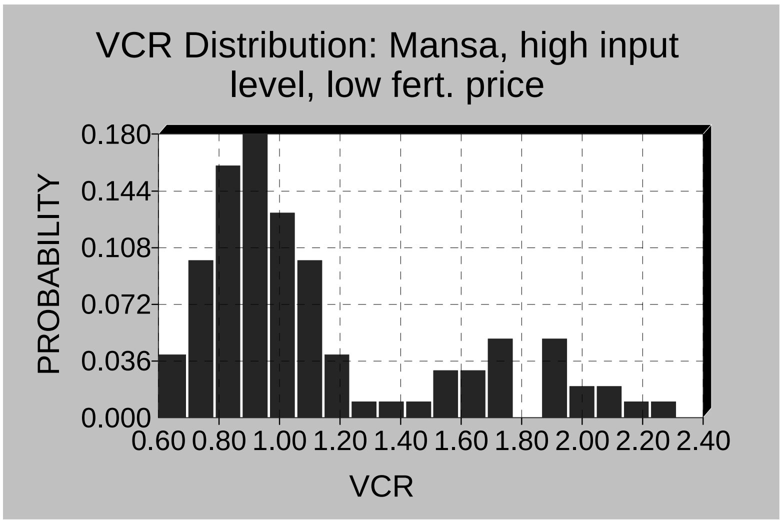

Maize Results

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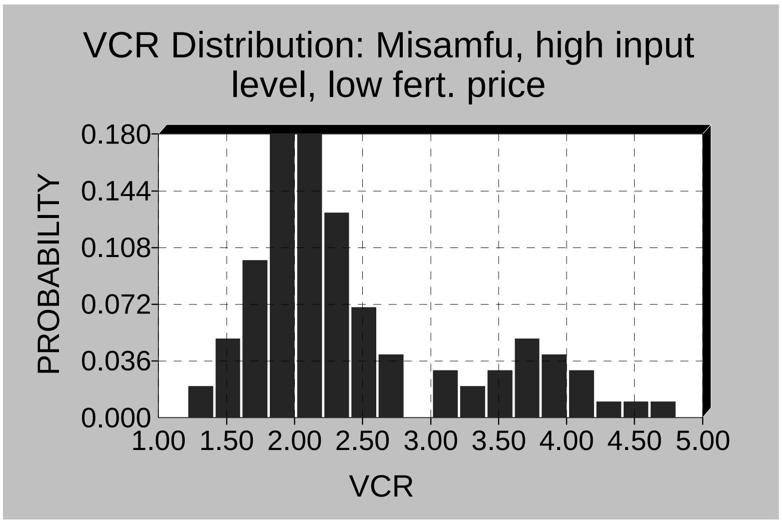

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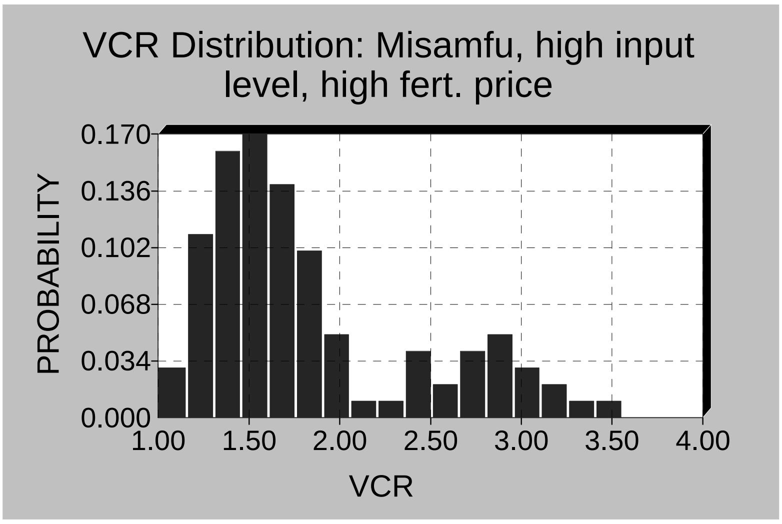

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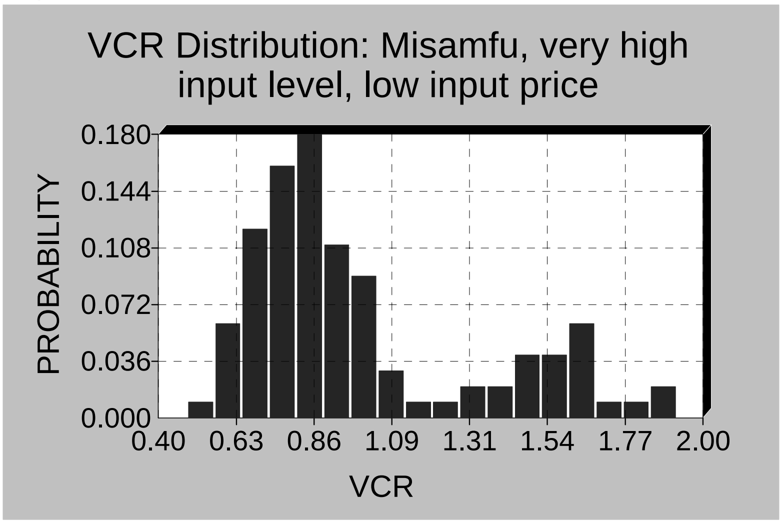

Maize Results

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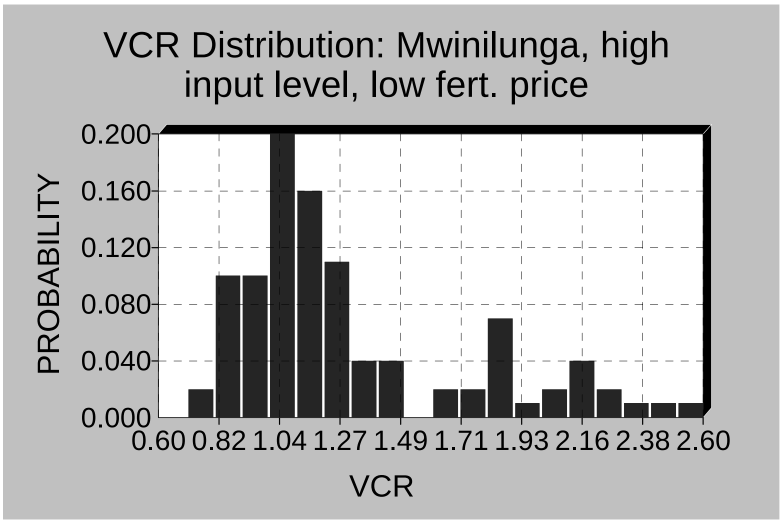

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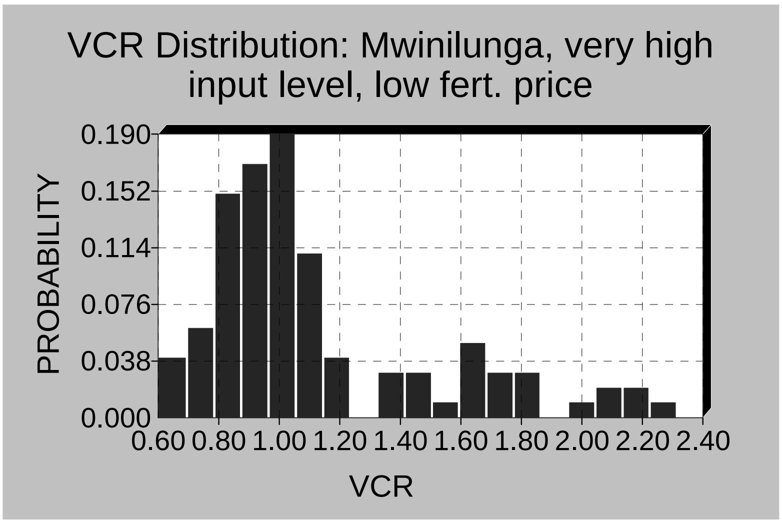

Cotton Results:

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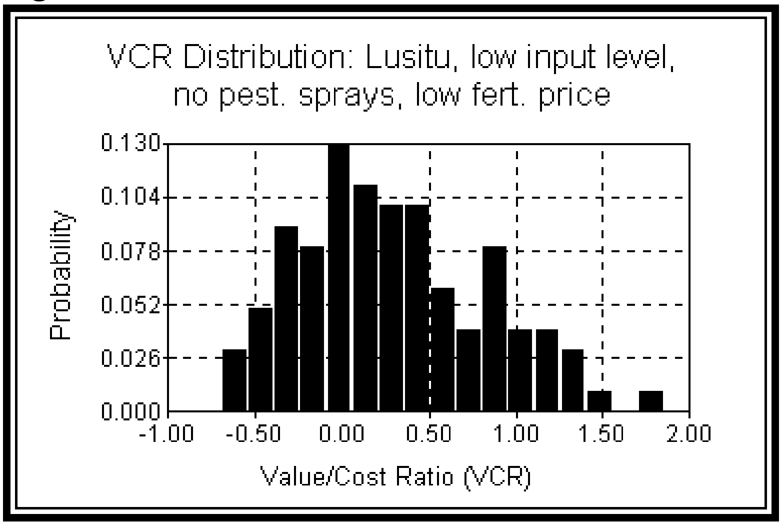

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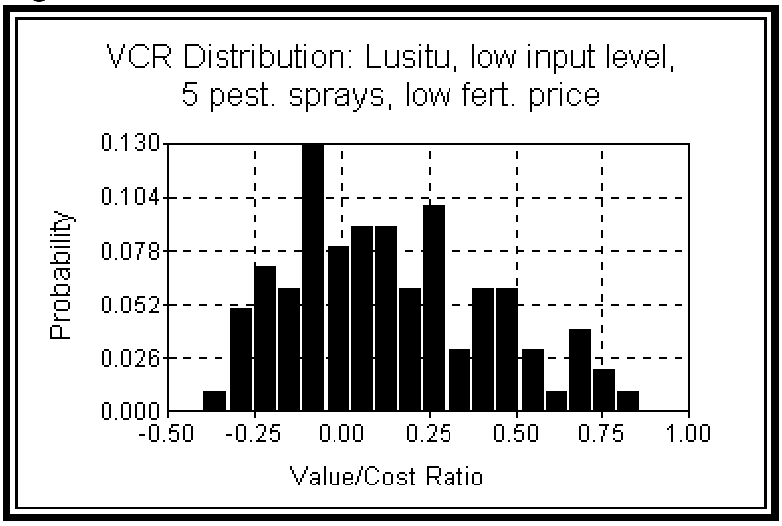

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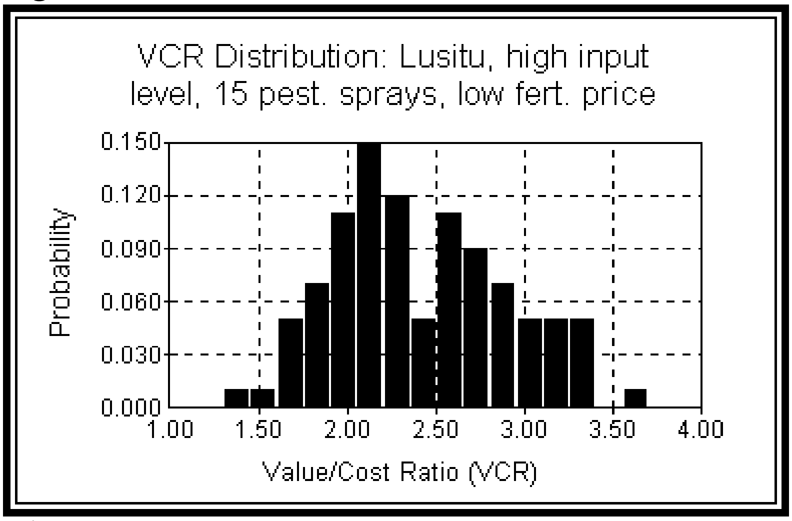

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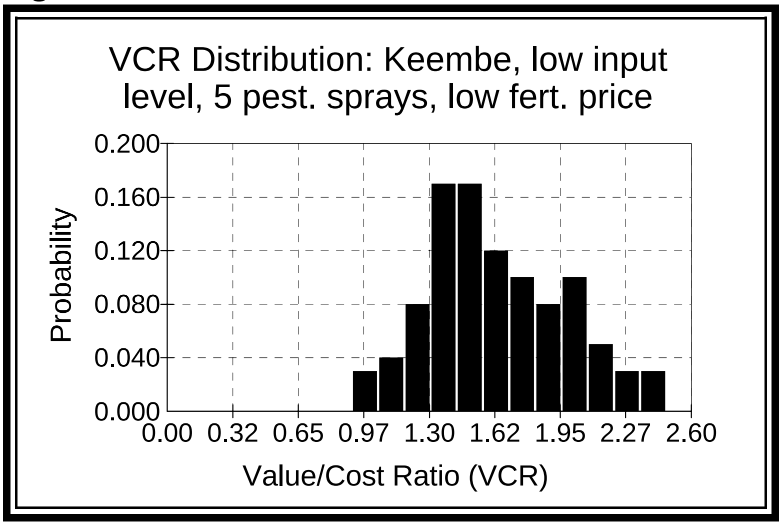

Cotton Results:

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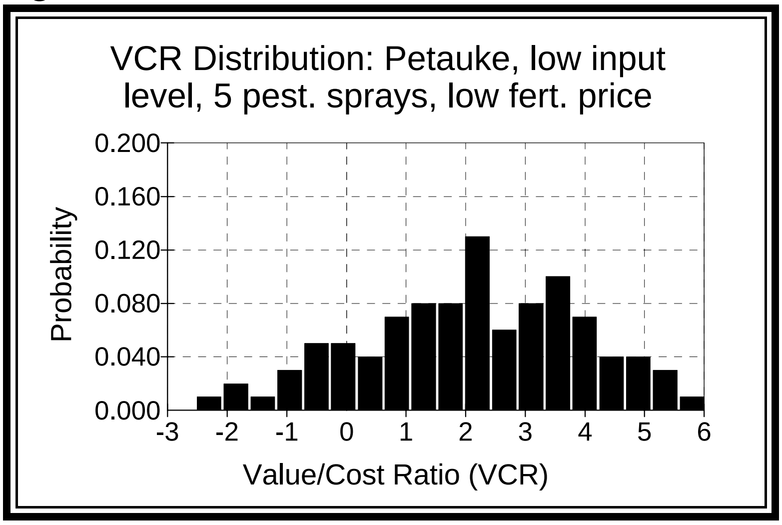

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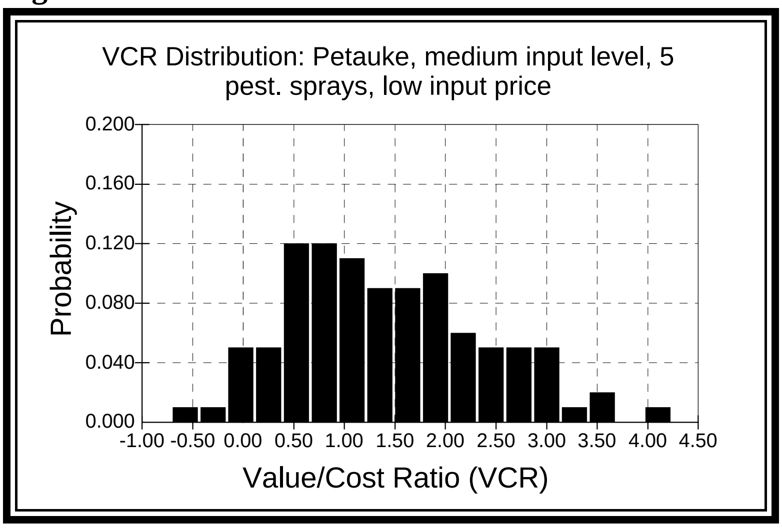
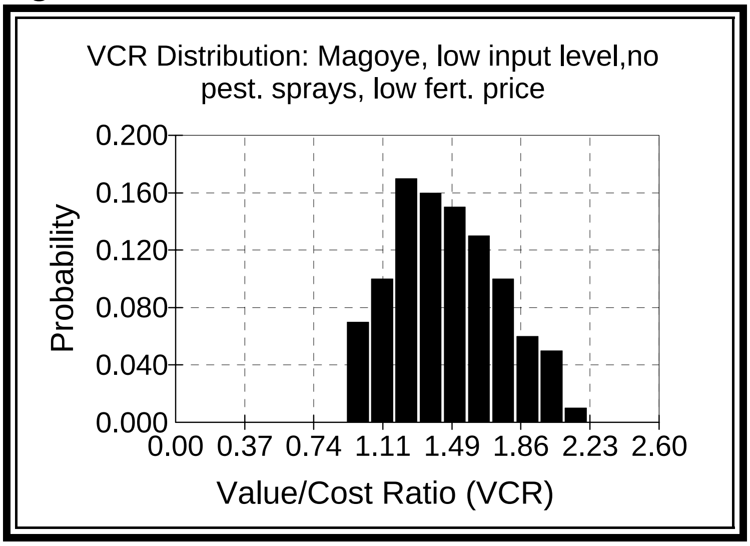


Cotton Results:

Figure 31



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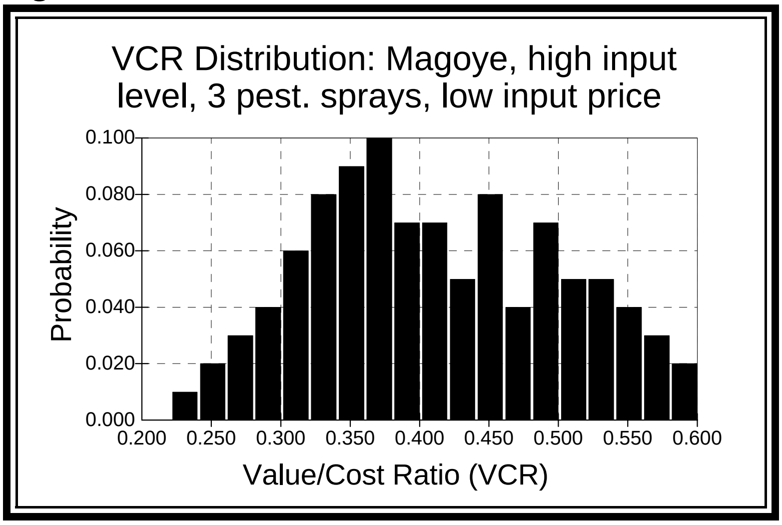

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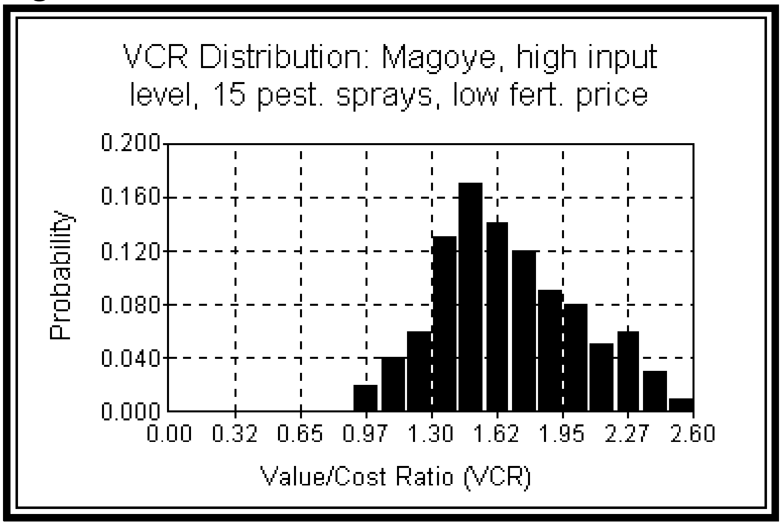

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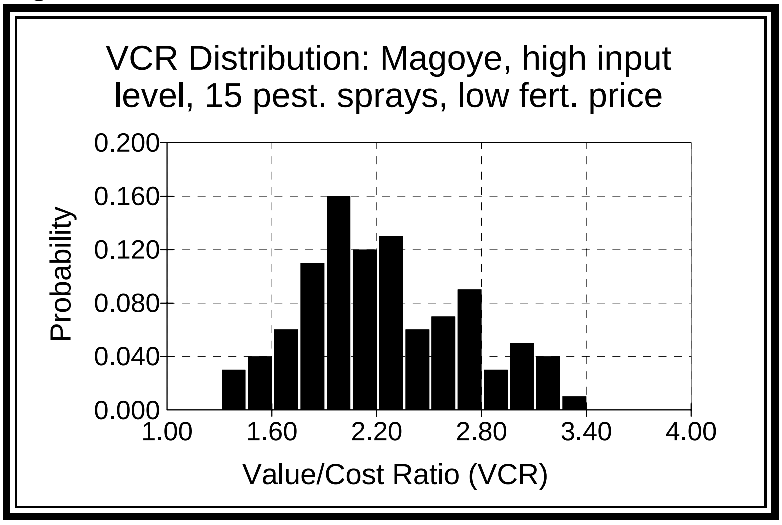

ANNEX OF TABLES

ANNEX Table 1: Maize Results from @RISK

				VCR			Input/ Output ratio			Response distribution			Maize price			Response rate		
AEC zone	Location	Input dose level	Fert price	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
I	Mochipapa	1	40000	1.77	3.42	7.16	1.64	2.43	2.69	839	1251	1656	297	345	489	8.2	12.5	16.8
I	Mochipapa	1	55000	1.32	2.57	5.37	2.25	3.34	3.70	839	1251	1656	297	345	489	8.2	12.5	16.8
I	Mochipapa	2	40000	1.40	2.72	5.79	1.64	2.43	2.69	1368	2003	2655	297	345	489	6.7	10.0	13.2
I	Mochipapa	2	55000	1.05	2.04	4.35	2.25	3.34	3.70	1368	2003	2655	297	345	489	6.7	10.0	13.2
I	Mochipapa	3	40000	0.89	1.71	3.60	1.64	2.43	2.69	1684	2515	3307	297	345	489	4.3	6.3	8.4
I	Mochipapa	3	55000	0.66	1.29	2.70	2.25	3.34	3.70	1684	2515	3307	297	345	489	4.3	6.3	8.4
I	Mochipapa	4	40000	0.55	1.06	2.24	1.64	2.43	2.69	1708	2532	3353	297	345	489	2.7	3.9	5.2
I	Mochipapa	4	55000	0.41	0.80	1.68	2.25	3.34	3.70	1708	2532	3353	297	345	489	2.7	3.9	5.2
II	Golden Valley	1	40000	0.81	1.47	2.91	1.26	1.81	1.99	246	367	482	402	460	635	2.4	3.7	4.9
II	Golden Valley	1	55000	0.61	1.10	2.18	1.73	2.49	2.74	246	367	482	402	460	635	2.4	3.7	4.9
II	Golden Valley	2	40000	0.63	1.16	2.29	1.26	1.81	1.99	391	578	765	402	460	635	1.9	2.9	3.8
II	Golden Valley	2	55000	0.47	0.87	1.72	1.73	2.49	2.74	391	578	765	402	460	635	1.9	2.9	3.8
II	Golden Valley	3	40000	0.77	1.42	2.81	1.26	1.81	1.99	934	1415	1857	402	460	635	2.3	3.5	4.7
II	Golden Valley	3	55000	0.58	1.07	2.10	1.73	2.49	2.74	934	1415	1857	402	460	635	2.3	3.5	4.7
II	Golden Valley	4	40000	0.32	0.58	1.14	1.26	1.81	1.99	625	949	1274	402	460	635	1.0	1.5	2.0
II	Golden Valley	4	55000	0.24	0.44	0.85	1.73	2.49	2.74	625	949	1274	402	460	635	1.0	1.5	2.0
II	Msekera	2	40000	0.92	2.46	5.34	2.19	2.75	2.93	807	1843	2956	273	296	365	4.9	11.3	18.1
II	Msekera	2	55000	0.69	1.85	4.00	3.01	3.78	4.03	807	1843	2956	273	296	365	4.9	11.3	18.1
II	Msekera	3	40000	1.31	2.25	4.06	2.19	2.75	2.93	2320	3376	4499	273	296	365	7.1	10.4	13.8
II	Msekera	3	55000	0.98	1.69	3.04	3.01	3.78	4.03	2320	3376	4499	273	296	365	7.1	10.4	13.8
II	Msekera	4	40000	1.02	1.80	3.26	2.19	2.75	2.93	2776	4031	5323	273	296	365	5.7	8.3	10.9
II	Msekera	4	55000	0.77	1.35	2.44	3.01	3.78	4.03	2776	4031	5323	273	296	365	5.7	8.3	10.9
III	Mansa	1	40000	1.74	3.29	6.86	1.36	2.02	2.24	629	940	1253	356	414	587	6.3	9.4	12.3
III	Mansa	1	55000	1.31	2.46	5.14	1.87	2.78	3.09	629	940	1253	356	414	587	6.3	9.4	12.3
III	Mansa	2	40000	0.60	1.12	2.31	1.36	2.02	2.24	425	639	841	356	414	587	2.1	3.2	4.2
III	Mansa	2	55000	0.45	0.84	1.74	1.87	2.78	3.09	425	639	841	356	414	587	2.1	3.2	4.2
III	Mansa	3	40000	0.60	1.12	2.36	1.36	2.02	2.24	846	1285	1685	356	414	587	2.1	3.2	4.2
III	Mansa	3	55000	0.45	0.84	1.77	1.87	2.78	3.09	846	1285	1685	356	414	587	2.1	3.2	4.2
III	Mansa	4	40000	0.47	0.88	1.81	1.36	2.02	2.24	1117	1634	2177	356	414	587	1.7	2.5	3.3
III	Mansa	4	55000	0.35	0.66	1.36	1.87	2.78	3.09	1117	1634	2177	356	414	587	1.7	2.5	3.3
III	Mwinilunga	3	40000	0.69	1.30	2.68	1.31	1.93	2.13	471	700	922	375	434	612	2.4	3.5	4.6
III	Mwinilunga	3	55000	0.52	0.97	2.01	1.80	2.65	2.93	471	700	922	375	434	612	2.4	3.5	4.6
III	Mwinilunga	4	40000	0.60	1.12	2.25	1.31	1.93	2.13	989	1500	1999	375	434	612	2.0	3.0	4.0
III	Mwinilunga	4	55000	0.45	0.84	1.68	1.80	2.65	2.93	989	1500	1999	375	434	612	2.0	3.0	4.0

AEC zone	Location	Input dose level	Fert price	VCR Minimum	VCR Mean	VCR Maximum	Input/ Output ratio Minimum	Input/ Output ratio Mean	Input/ Output ratio Maximum	Response distribution Minimum	Response distribution Mean	Response distribution Maximum	Maize price Minimum	Maize price Mean	Maize price Maximum	Response rate Minimum	Response rate Mean	Response rate Maximum
III	Misamfu	3	40000	1.30	2.44	4.93	1.70	2.41	2.65	1218	1801	2413	302	344	471	6.1	9.0	12.1
III	Misamfu	3	55000	0.98	1.83	3.70	2.34	3.32	3.64	1218	1801	2413	302	344	471	6.1	9.0	12.1
III	Misamfu	4	40000	0.54	0.99	2.02	1.70	2.41	2.65	1229	1800	2370	302	344	471	2.5	3.6	4.7
III	Misamfu	4	55000	0.40	0.74	1.51	2.34	3.32	3.64	1229	1800	2370	302	344	471	2.5	3.6	4.7

Dose levels

Dose level 1: less than 200 kgs of fertilizer applied (most common: 100 kg of urea)

Dose level 2: 200 - 250 kg fertilizer applied (combined urea, compound D and others) (most common: 100 kg each of Compound D and urea)

Dose level 3: 300-400 kg of fertilizer applied. (Most common is 200 kg Compound D and 200 kg Urea).

Dose level 4: more than 400 kg of fertilizer applied. (Most common is 500 kg Compound D and 150 kg Urea).

Response:

For response rates: TRIGEN: Triangular general model used with rough data when lowest and highest can actually occur.

For each case, bottom and top values are indicated with their likely percent of occurrences; the most likely value is also indicated.

Assumption that the highest and lowest values may occur 10% of the time each, the rest of the time, the mean occurs.

Output Price:

Price distributions are based on seasonality and the tendency of farmers to sell at harvest time when prices are likely to be on the low end, although not the lowest. For maize, using the April 2000 observed wholesale price and seasonal price indices, we estimate a low harvest season price (valid 75% of time) and a higher non-harvest season price (valid 25% of time). An exception is made for Mansa with an extremely low observed April 200 price. For Mansa, the Choma price with a 20% increase was selected as the distributions are similar, with a 20% difference, on average.

Maximum, minimum, mean from seasonality work with real prices and then April 2000 price for that market as the base price to work from.

Input prices:

To account for the farmers' transport costs to/from market, transport costs are a per kg cost at a given rate, no variability at this point.

Urea and DAP are assumed to be sold at the same price, although there is variability in different markets, depending upon the source of the input. The low price of 40000/bag would reflect a subsidized rate; whereas the high price of 55000 Kw/bag is closer to market prices for 2000.

Sensitivity analysis is used to demonstrate the effect of a higher or lower cost for fertilizer

Assumptions:

No correlation between input and output prices in any given market

No correlations between response rates and output prices. This assumption may need to be changed, since in a bad cropping year, responses would be expected to be low and output prices would be expected to be high. The high variability in response rates, even in good cropping years, means that a forced negative correlation between output prices and response rates would tend to make bad results appear more positive than they would be.

Notes:

Msekera trials were all starting from a base level of 163 kg urea, rather than from no fertilizer.

Msekera in these cases is assumed to be Zone II as site was on the plateau.

ANNEX Table 2: Cotton Results from @RISK

AEC Zone	Location	Pesticide level	Fert. dose level	Fert price	VCR			Input/output price ratio			Response distribution			Cotton price		
					Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
I	Lusitu	0	1	40000	-0.65	0.29	1.84	1.04	1.17	1.30	-188	82	463	617	694	771
I	Lusitu	0	1	55000	-0.49	0.22	1.38	1.43	1.60	1.78	-188	82	463	617	694	771
I	Lusitu	0	2	40000	0.05	0.08	0.12	1.04	1.17	1.30	31	45	59	617	694	771
I	Lusitu	0	2	55000	0.04	0.06	0.09	1.43	1.60	1.78	31	45	59	617	694	771
I	Lusitu	0	3	40000	0.05	0.10	0.14	1.04	1.17	1.30	53	81	107	617	694	771
I	Lusitu	0	3	55000	0.04	0.07	0.11	1.43	1.60	1.78	53	81	107	617	694	771
I	Lusitu	5	1	40000	-0.34	0.14	0.82	1.04	1.17	1.30	-99	39	252	617	694	771
I	Lusitu	5	1	55000	-0.25	0.10	0.62	1.43	1.60	1.78	-99	39	252	617	694	771
I	Lusitu	5	2	40000	-0.23	0.30	0.74	1.04	1.17	1.30	-116	173	385	617	694	771
I	Lusitu	5	2	55000	-0.17	0.23	0.55	1.43	1.60	1.78	-116	173	385	617	694	771
I	Lusitu	5	3	40000	0.28	0.47	0.72	1.04	1.17	1.30	271	401	540	617	694	771
I	Lusitu	5	3	55000	0.21	0.35	0.54	1.43	1.60	1.78	271	401	540	617	694	771
I	Lusitu	15	3	40000	1.45	2.42	3.57	1.04	1.17	1.30	1415	2063	2717	617	694	771
I	Lusitu	15	3	55000	1.08	1.82	2.68	1.43	1.60	1.78	1415	2063	2717	617	694	771
I	Masumba	0	1	40000	1.25	1.92	2.85	0.90	1.01	1.12	314	462	608	713	802.5	892
I	Masumba	0	1	55000	0.94	1.44	2.14	1.23	1.39	1.54	314	462	608	713	802.5	892
I	Masumba	0	1	40000	1.17	1.92	2.80	0.90	1.01	1.12	307	462	622	713	802.5	892
I	Masumba	0	1	55000	0.88	1.44	2.10	1.23	1.39	1.54	307	462	622	713	802.5	892
I	Masumba	0	2	40000	0.22	0.36	0.54	0.90	1.01	1.12	119	173	229	713	802.5	892
I	Masumba	0	2	55000	0.16	0.27	0.40	1.23	1.39	1.54	119	173	229	713	802.5	892
I	Masumba	0	3	40000	0.12	0.20	0.30	0.90	1.01	1.12	97	143	191	713	802.5	892
I	Masumba	0	3	55000	0.09	0.15	0.22	1.23	1.39	1.54	97	143	191	713	802.5	892
I	Masumba	5	1	40000	-0.76	-0.53	-0.32	0.90	1.01	1.12	-169	-127	-87	713	802.5	892
I	Masumba	5	1	55000	-0.57	-0.40	-0.24	1.23	1.39	1.54	-169	-127	-87	713	802.5	892
I	Masumba	5	2	40000	0.21	0.35	0.50	0.90	1.01	1.12	115	169	223	713	802.5	892
I	Masumba	5	2	55000	0.16	0.26	0.38	1.23	1.39	1.54	115	169	223	713	802.5	892
I	Masumba	5	3	40000	0.05	0.09	0.14	0.90	1.01	1.12	42	65	87	713	802.5	892
I	Masumba	5	3	55000	0.04	0.07	0.10	1.23	1.39	1.54	42	65	87	713	802.5	892
I	Masumba	15	1	40000	2.02	3.34	5.02	0.90	1.01	1.12	541	805	1069	713	802.5	892
I	Masumba	15	1	55000	1.52	2.51	3.76	1.23	1.39	1.54	541	805	1069	713	802.5	892
I	Masumba	15	2	40000	0.57	1.00	1.46	0.90	1.01	1.12	312	479	630	713	802.5	892
I	Masumba	15	2	55000	0.43	0.75	1.10	1.23	1.39	1.54	312	479	630	713	802.5	892
I	Masumba	15	3	40000	0.35	0.57	0.84	0.90	1.01	1.12	270	407	538	713	802.5	892
I	Masumba	15	3	55000	0.26	0.42	0.63	1.23	1.39	1.54	270	407	538	713	802.5	892
I	Muyumbwe	5	1	40000	-0.91	0.14	1.03	1.04	1.17	1.30	-169	27	204	617	694	771
I	Muyumbwe	5	1	55000	-0.69	0.11	0.77	1.43	1.60	1.78	-169	27	204	617	694	771

AEC Zone	Location	Pesticide level	Fert. dose level	Fert price	**VCR** Minimum	Mean	Maximum	**Input/output price ratio** Minimum	Mean	Maximum	**Response distribution** Minimum	Mean	Maximum	**Cotton price** Minimum	Mean	Maximum
I	Muyumbwe	5	2	40000	-0.71	0.37	1.57	1.04	1.17	1.30	-239	138	528	617	694	771
I	Muyumbwe	5	2	55000	-0.53	0.28	1.18	1.43	1.60	1.78	-239	138	528	617	694	771
II	Keembe	0	1	40000	0.65	1.05	1.53	1.07	1.20	1.33	211	308	405	600	675	750
II	Keembe	0	1	55000	0.48	0.79	1.15	1.47	1.65	1.83	211	308	405	600	675	750
II	Keembe	0	2	40000	0.31	0.54	0.81	1.07	1.20	1.33	211	321	429	600	675	750
II	Keembe	0	2	55000	0.23	0.41	0.61	1.47	1.65	1.83	211	321	429	600	675	750
II	Keembe	0	3	40000	0.41	0.68	1.03	1.07	1.20	1.33	411	599	802	600	675	750
II	Keembe	0	3	55000	0.30	0.51	0.77	1.47	1.65	1.83	411	599	802	600	675	750
II	Keembe	5	1	40000	0.96	1.63	2.47	1.07	1.20	1.33	324	478	641	600	675	750
II	Keembe	5	1	55000	0.72	1.22	1.85	1.47	1.65	1.83	324	478	641	600	675	750
II	Keembe	5	2	40000	0.58	0.99	1.45	1.07	1.20	1.33	391	581	764	600	675	750
II	Keembe	5	2	55000	0.43	0.74	1.09	1.47	1.65	1.83	391	581	764	600	675	750
II	Keembe	5	3	40000	0.76	1.31	1.96	1.07	1.20	1.33	774	1157	1530	600	675	750
II	Keembe	5	3	55000	0.57	0.99	1.47	1.47	1.65	1.83	774	1157	1530	600	675	750
II	Keembe	15	3	40000	0.90	1.54	2.34	1.07	1.20	1.33	912	1355	1820	600	675	750
II	Keembe	15	3	55000	0.68	1.15	1.75	1.47	1.65	1.83	912	1355	1820	600	675	750
II	Magoye	0	1	40000	0.92	1.45	2.10	1.04	1.17	1.30	282	413	545	617	694	771
II	Magoye	0	1	55000	0.69	1.09	1.58	1.43	1.60	1.78	282	413	545	617	694	771
II	Magoye	0	2	40000	0.14	0.23	0.35	1.04	1.17	1.30	91	133	175	617	694	771
II	Magoye	0	2	55000	0.10	0.18	0.26	1.43	1.60	1.78	91	133	175	617	694	771
II	Magoye	0	3	40000	0.00	0.00	0.00	1.04	1.17	1.30	1	1	1	617	694	771
II	Magoye	0	3	55000	0.00	0.00	0.00	1.43	1.60	1.78	1	1	1	617	694	771
II	Magoye	3	1	40000	0.26	0.41	0.59	1.04	1.17	1.30	78	118	155	617	694	771
II	Magoye	3	1	55000	0.20	0.31	0.44	1.43	1.60	1.78	78	118	155	617	694	771
II	Magoye	3	2	40000	0.05	0.09	0.13	1.04	1.17	1.30	33	50	66	617	694	771
II	Magoye	3	2	55000	0.04	0.07	0.10	1.43	1.60	1.78	33	50	66	617	694	771
II	Magoye	3	3	40000	0.24	0.41	0.60	1.04	1.17	1.30	230	348	466	617	694	771
II	Magoye	3	3	55000	0.18	0.31	0.45	1.43	1.60	1.78	230	348	466	617	694	771
II	Magoye	15	1	40000	0.50	0.81	1.20	1.04	1.17	1.30	160	232	306	617	694	771
II	Magoye	15	1	55000	0.37	0.61	0.90	1.43	1.60	1.78	160	232	306	617	694	771
II	Magoye	15	2	40000	0.41	0.70	1.04	1.04	1.17	1.30	269	398	524	617	694	771
II	Magoye	15	2	55000	0.31	0.53	0.78	1.43	1.60	1.78	269	398	524	617	694	771
II	Magoye	15	3	40000	0.33	0.55	0.83	1.04	1.17	1.30	324	471	626	617	694	771
II	Magoye	15	3	55000	0.25	0.42	0.62	1.43	1.60	1.78	324	471	626	617	694	771
II	Magoye	15	3	40000	1.31	2.24	3.31	1.04	1.17	1.30	1283	1909	2555	617	694	771
II	Magoye	15	3	55000	0.98	1.68	2.49	1.43	1.60	1.78	1283	1909	2555	617	694	771
II	Mpangwe	5	2	40000	1.28	4.33	7.73	0.90	1.01	1.12	291	1125	1891	713	802.5	892

AEC Zone	Location	Pesticide level	Fert. dose level	Fert price	**VCR** Minimum	Mean	Maximum	**Input/output price ratio** Minimum	Mean	Maximum	**Response distribution** Minimum	Mean	Maximum	**Cotton price** Minimum	Mean	Maximum
II	Mpangwe	5	2	55000	0.96	3.25	5.80	1.23	1.39	1.54	291	1125	1891	713	802.5	892
II	Nangoma	5	1	40000	-0.80	1.08	3.40	1.07	1.20	1.33	-138	212	608	600	675	750
II	Nangoma	5	1	55000	-0.60	0.81	2.55	1.47	1.65	1.83	-138	212	608	600	675	750
II	Nangoma	5	2	40000	-0.28	0.97	2.59	1.07	1.20	1.33	-126	386	931	600	675	750
II	Nangoma	5	2	55000	-0.21	0.73	1.94	1.47	1.65	1.83	-126	386	931	600	675	750
II	Petauke	5	1	40000	-2.13	2.08	5.66	0.90	1.01	1.12	-391	330	804	713	802.5	892
II	Petauke	5	1	55000	-1.60	1.56	4.24	1.23	1.39	1.54	-391	330	804	713	802.5	892
II	Petauke	5	2	40000	-0.59	1.40	4.07	0.90	1.01	1.12	-166	452	1156	713	802.5	892
II	Petauke	5	2	55000	-0.44	1.05	3.05	1.23	1.39	1.54	-166	452	1156	713	802.5	892
II	Shibuyunji	5	1	40000	0.41	2.12	4.37	1.07	1.20	1.33	71	414	756	600	675	750
II	Shibuyunji	5	1	55000	0.31	1.59	3.27	1.47	1.65	1.83	71	414	756	600	675	750
II	Shibuyunji	5	2	40000	1.07	2.13	3.41	1.07	1.20	1.33	421	834	1219	600	675	750
II	Shibuyunji	5	2	55000	0.80	1.60	2.55	1.47	1.65	1.83	421	834	1219	600	675	750

Notes: 1 This observation was made by Pons (1989) and is an average over several years, but the original documents were not found to support this. Pons also reported high values for this combination of treatments over the 1984/85-1987/88 seasons for Magoye, Golden Valley, Masumba and Monze.

Dose rates:

Dose level 1: less than 200 kgs of fertilizer applied (most common: 150 kg of Compound D and 37.5 kg of urea; Petauke, 100 Compound D and 25 urea);

Dose level 2: 250 - 375 kg fertilizer applied (combined urea, compound D and others) (most common: 300 kg of Compound D and 75 urea; Petauke, 200 Compound D and 50 urea);

Dose level 3: 400-550 kg of fertilizer applied. (Most common is 450 kg of Compound D and 112.5 kg of Urea)

Response:

For response rates: TRIGEN: Triangular general model used with rough data when lowest and highest can actually occur.

For each case, bottom and top values are indicated with their likely percent of occurrences; the most likely value is also indicated.

Assumption that the highest and lowest values may occur 10% of the time each, the rest of the time, the mean occurs.

Input prices:

To account for the farmers' transport costs to/from market, transport costs are a per kg cost at a given rate, no variability at this point.

Urea and DAP are assumed to be sold at the same price, although there is variability in different markets, depending upon the source of the input. The low price of 40000/bag would reflect a subsidized rate; whereas the high price of 55000 Kw/bag is closer to market prices for 2000.

Sensitivity analysis is used to demonstrate the effect of a higher or lower cost for fertilizer

Assumptions:

No correlation between input and output prices in any given market

No correlations between response rates and output prices. This assumption may need to be changed, since in a bad cropping year, responses would be expected to be low and output prices would be expected to be high. The high variability in response rates, even in good cropping years, means that a forced negative correlation between output prices and response rates would tend to make bad results appear more positive than they would be.