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

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BACKGROUND: Inorganic fertilizers, particularly for use on maize, have been a cornerstone of Zambian government policy to improve smallholder incomes and food security. Investments in the fertilizer supply and credit systems have been costly for the national budget and yet fertilizer consumption among smallholders is low. With limited resources, the Zambian government is currently assessing its programs and seeking to determine the most productive investments to enhance agricultural incomes and production.

OBJECTIVES: Inorganic fertilizers will play a role in government programs, but whether or not a single policy is valuable for all farmers depends upon the net gain for the farmers. The research here seeks to demonstrate how to answer the question "Is fertilizer profitable in Zambia for maize and cotton in the smallholder sector?" This study[1] 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. Several cases are selected and the results are evaluated. This study will not present a complete picture of profitability, as that will vary for each farmer. Private profitability for the farmer at market prices will be discussed, leaving social profitability to other researchers. A simple method for farmers and extensionists to use to assess a fertilizer investment is given, to assist in more site specific analysis, given prices and environment.

METHODS: Partial budgeting is a standard technique for evaluating an agricultural technology (CIMMYT, 1998). In this case, additional analysis is conducted on the risks involved, assuming distributions for selected variables and then evaluating the effect on private profitability. To organize the work and control for some physical variability, the study was broken into three broad agro-ecological (AEC) regions: Region I[2] is in the south (low rainfall of less than 800 mms per annum short growing season); Region II in the central zone of the country (800-1000 mms of rainfall annually, with growing season of 100-140 days); and Region III (high rainfall greater than 1000 mms annually, growing season 120-150 days) in the north. Soils vary within the regions as well as across the regions (Damaseke 2000).

To assess smallholder profitability of fertilizers, a combination of on-farm and on-station research trials from the past 30 years were evaluated (Simumba 2000). The response rate of the crop to fertilizers is a key concept. It is the additional crop production resulting from application of an input compared to the amount of input applied. In this case, it is the total maize (or cotton) produced with fertilizers minus the maize (or cotton) that would be produced without fertilizer divided by the amount of fertilizer applied. For maize, FAO documents indicate that smallholders in Zambia tend to have maize response rates around 4-4.5 kg, whereas commercial farmers tend to get about 10 kg output maize per kg input (FAO, 1998). As can be seen in Table 1, smallholders in Zambia using fertilizer do tend to have higher yields, on average, than those without, but with wide variations in results.

Once the physical output is assessed, then prices come into play. Input prices are generally known by the farmer prior to planting, so the analysis simply estimates the results using two different price scenarios (40,000 Kwacha for 50 kg and 55,000 Kwacha per 50 kg bag). The higher price is close to the market price of fertilizer (urea or Compound D) without subsidies, whereas the lower price is close to the recent subsidized price.

[1] This Policy Brief is a summary of research presented in "Framework and initial analyses of fertilizer profitability in maize and cotton in Zambia", by Donovan, Damaseke, Govereh and Simumba, 2002.

[2] In the tables, "Mochipapa" is labeled as Region I. MACO researchers have explained that while the research station is physically in Region II, it is the administrative base for all of the Region I efforts, with sites off the station. Since research results do not always state the exact location, we have relied on identification by the lead researcher for the trial studied to indicate the appropriate AEC.

Table 1: Maize Yields for Smallholder Farmers, 1999-2000

Fertilizer Use	Broad Agro-ecological Regions Region 1	Region 2	Region 3	Overall Average
	(Kilograms-hectare)			
Not use fertilizers	1103	1371	1138	1293
Use fertilizers	1433	2101	1831	2028
Overall Average	1138	1581	1298	1488

Source: Post Harvest Survey 1999/2000, CSO/MACO/FSRP.
Note: Yields per ha >10,000kg were excluded.

We used market output prices for maize as found in the AMIC price system and for cotton as indicated by experts.[3] The input/output (I/O) price ratios are used as an indicator of the breakeven response rate. If farm-gate maize prices are 400 Kwacha per kg (36,000 Kwacha per 90 kg bag) and fertilizer prices are 1,100 Kwacha per kg (55,000 Kwacha per 50 kg bag), the I/O ratio is 1100/400 = 2.75. At a minimum, the farmer must obtain an additional 2.75 kg of maize to pay for each kg of fertilizer applied. This only pays off the cost of fertilizer, not any additional production costs incurred from applying the fertilizer or any transaction costs associated with obtaining the fertilizer.

Value cost ratios (VCRs) are then estimated, valuing the additional output (minus transport costs) and fertilizer costs (including some transport costs). A general guideline of a VCR=2.0 is used to indicate minimum desired VCR for profitability. The variability in VCRs is evaluated using simulation methods, presenting a view of the risks when response rates and output prices are not known beforehand.

RESULTS: The input output price ratios vary widely in Zambia. Table 2 indicates those ratios for maize and urea, based on wholesale prices in the provincial markets during 2000/2001 agricultural year. In Northern and Southern Provinces with I/O price ratios above 4, farmers would need to use fertilizer in an effective manner to make sure of profitability. Even in Central and Eastern Province, with prevailing prices, farmers needed to get at least 3-4 kg maize for each kg of fertilizer. For lower rates of application, this should be possible, but when higher rates (400 kgs of fertilizer or more), the response rates decline and likelihood of

Table 2: Input/output Price Ratios for Urea and Maize in Zambia, 2000/2001

Province	(urea/maize)
(A)	(B)
Eastern	3.6
Central	3.2
Lusaka	3.4
Southern	4.7
Western	2.5
Northwestern	4.4
Northern	4.3
Luapula	3.9
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: MACO and other documents.
Estimates by FSRP.

profitability drops. This can be seen with the results of the VCR analysis.

Maize

Table 3 presents some of the results for maize.[4] Higher dose rates of urea and Compound D tend to have lower average profitability. As an example, in Region I, higher doses of fertilizer have lower average response rates and, logically, lower VCRs than lower dose rates. Figures 1 and 2 demonstrate the difference in distribution in VCRs between the low dose and the high dose, at the lower price level. There is more than a 50% probability of VCRs less than 2.0 when higher dose rates were involved, yet for the lower dose rates, only about 4% probability of VCR less than 2 occurs. For farmers, this means there is risk involved with the higher dose rates, given the range of responses observed in trials. In both simulations, using the lower fertilizer prices, the I/O ratio was 2.4. As can be seen in the probability distributions in Fig. 1 and Fig. 2, relatively high VCRs still occur with high dose rates, with a lower probability, so farmers with good management practices and good weather may have highly profitable seasons.

[3] See the full report for more details.

[4] More complete reporting of results, probability distributions, etc. can be found in the full report.

Table 3: Results from 3 Locations for Fertilizer Profitability on Maize: Average Value Cost Ratios (Vcrs), Input/output Price Ratios (I/o Ratio) and Response Rates

AEC region	Location	Input dose level	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Average Response rates
			VCR	I/O price ratio	VCR	I/O price ratio	kg output per kg fertilizer
I	Mochipapa	1	3.4	2.4	2.6	3.3	12.5
I	Mochipapa	2	2.7		2.0		10.0
I	Mochipapa	3	1.7		1.3		6.3
II	Golden Valley	1	1.5	1.8	1.1	2.5	3.7
II	Golden Valley	2	1.2		0.9		2.9
II	Golden Valley	3	1.4		1.1		3.5
II	Msekera	2	2.5	2.8	1.9	3.8	11.3
II	Msekera	3	2.3		1.7		10.4
II	Msekera	4	1.8		1.4		8.3
III	Mansa	1	3.3	2.0	2.5	2.8	9.4
III	Mansa	2	1.1		0.8		3.2
III	Mansa	3	1.1		0.8		3.2
III	Mwinilunga	3	0.7	1.9	0.5	2.6	3.5
III	Mwinilunga	4	0.8		0.6		5.0
III	Misamfu	3	2.4	3.3	1.8	2.4	9.0
III	Misamfu	4	1.0		0.7		3.6

Source: Donovan, Damaseke, Simumba, Govereh, forthcoming, **Framework and initial analyses of fertilizer profitability in maize and cotton in Zambia**. 2002. FSRP/MACO.Note: Mochipapa research site was identified by MACO researchers as Region I, even though the research station is in Region II. VCR is the Value Cost Ratio. 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, the general recommended dose); Dose level 4: more than 400 kg of fertilizer applied (most common is 500 kg Compound D and 150 kg Urea).

For Region II, the Msekera results suggests that a dose level close to the recommended is on average profitable, with more than 55% of the simulations showing VCRs above 2, and all VCRs above 1.0, as long as the price of fertilizer is 40000 Kwacha per bag. However, at 55,000 Kwacha per bag, only 15% of the simulations show profitability with a VCR greater than 2. Looking at the lower dose levels, there is a 70% chance for VCR greater than 2 with the lower fertilizer price, and only a 35% probability when fertilizer prices are higher.

One of the difficulties in the work in Region II is the confounding issues of initial soil fertility and the use of on-station trials, where soil quality may be better than on most farmers fields. This is suggested in the Golden Valley profitability and response results which are poor and yet overall yields in the trials were high. Thus the results for Golden Valley may not be typical and may be conservative compared to farmers' fields.

Region III provides clear evidence of the lack of profitability for high dose levels near Mansa. This may be related to high acidity and high rainfall. The low dose

Figure 1. VCR Maize, Mochipapa, Low Input

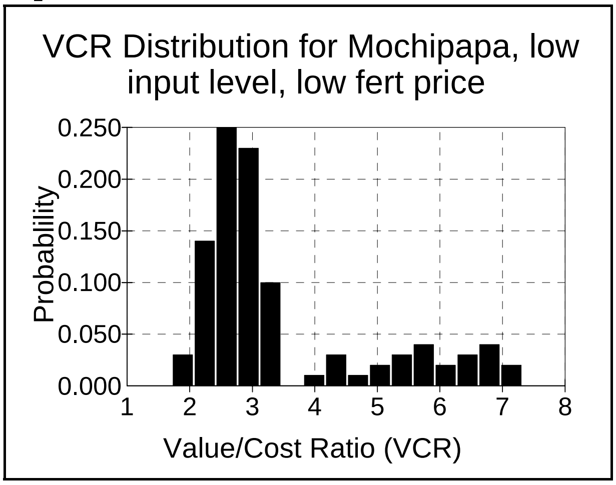
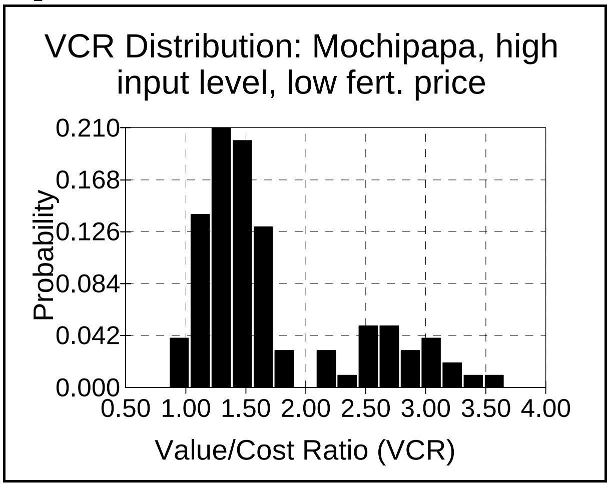


Figure 2. VCR Maize, Mochipapa, High Input



level is profitable in over 90% of the simulations, even at the high price for fertilizer. However, with the high dose levels, less than 5% of the simulations show profitable results, even with a low fertilizer price. This may be related to problems with soil acidity and the effect of increasing acidity problems with inorganic fertilizer in high doses. In other results in this region, trials at Misamfu and Mwinilunga involved only the high and highest dose levels. Simulations for Misamfu indicate that even with high I/O ratios, fertilizer may be profitable at relatively high dose levels, if not at the highest application rates of over 400 kg per hectare. Results from Mwinilunga were poor, with 50% of the simulations showing VCRs less than one with the very high dose level and low fertilizer prices.

Cotton

Cotton results are presented based on a combination of fertilizer and pesticide treatments, for it was found that there may be an interaction between fertilizer effectiveness and use of pesticides. The source of the poor profitability results is generally in the response rates, often less than 1 kg of cotton for each kg of fertilizer applied. Dose level 1 in this work was generally 150 kg/ha Compound D and 37.5 kg/ha urea, while dose level 2 was 300 kg/ha Compound D and 75 kg/ha urea. Researchers have been able to get relatively high responses using the high dose rates of 450 kg/ha of compound D and 112.5 kg/ha of urea. Fertilizer profitability appears to be 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 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 (see Table 4).

In Magoye, when a combination of high fertilizer dose and 15 pesticide sprays is used, there is a 65% probability of a VCR above 2 if the fertilizer price is low, and even when the fertilizer price is high, there is a 20% probability of a VCR of at least 2 and all cases had a VCR greater than 1. Similar results appear in Lusitu, where it is dryer and hotter: 75% with a VCR greater than 2 with the low fertilizer price and 30% when the fertilizer price is high. In Keembe, the results suggest greater riskiness, although lower input levels show promise. For the dose level one and only 5 pesticide sprays, there was a 15% probability of a VCR above 2 (with the low fertilizer price) and 55% probability of a results of at least 1.5. The average response rate of 2.6 kg of cotton for kg of fertilizer applied, a relatively good response rate.

SOURCES OF VARIABILITY AND RISK: The research trials, whether on-farm or on-station demonstrate the wide range of performance in all regions in Zambia. The factors that affect response rates include: weather, initial soil conditions (acidity, organic matter content, nutrient constraints, etc.), timing of activities, quality of inputs, weeding practices, density of seeding/planting, and crop and cultivar choices. Variability is thus not only due to physical location (agro-ecological region) but the farmers' own practices in a given year and over time.

Given all the variability, researchers and extensionists in Zambia know that a "one-size fits all" fertilizer recommendation does not meet the needs given the agro-ecological variability and the wide variation in cropping

Table 4: Results from 3 Locations for Fertilizer Profitability on Cotton: Average Value Cost Ratios (VCRs), Input/Output Price Ratios (I/O ratio) and Response Rates

AEC region	Location	Input dose level	Pesticide application rates (number of sprays in season)	Low fert price (40000 Kwacha)		High fert price (55000 Kwacha)		Response rates
				VCR (average)	I/O ratio	VCR (average)	I/O ratio	kg output per kg fertilizer
I	Lusitu	1	0	0.3	1.2	0.2	1.6	0.4
I	Lusitu	1	5	0.1		0.1		0.0
I	Lusitu	2	5	0.3		0.2		0.5
I	Lusitu	3	5	0.5		0.4		0.7
I	Lusitu	3	15	2.4		1.8		2.5
II	Keembe	1	0	1.1	1.2	0.8	1.7	1.6
II	Keembe	1	5	1.6		1.2		2.6
II	Keembe	2	5	1.0		0.7		1.6
II	Keembe	3	5	1.3		1.0		2.1
II	Keembe	3	15	1.5		1.2		2.4
II	Magoye	1	0	1.5	1.2	1.1	1.6	2.2
II	Magoye	1	3	0.4		0.3		0.6
II	Magoye	2	3	0.1		0.1		0.1
II	Magoye	3	3	0.4		0.3		0.6
II	Magoye	3	15	2.2		1.7		3.4

[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. Fertilizer doses: Dose 1 was most commonly 150 kg/ha Compound D and 37.5 kg/ha urea; Dose 2 was most commonly 300 kg/ha Compound D and 75 kg/ha urea; Dose 3: most commonly 450 kg/ha Compound D and 112.5 kg/ha urea. Pesticide treatments: No pesticide sprays, 5 sprays during the cropping season; and 15 sprays (weekly) during the season.
Source: Donovan, Damaseke, Simumba, Govereh, forthcoming, **Framework and initial analyses of fertilizer profitability in maize and cotton in Zambia**. 2002. FSRP/MACO.

practices in Zambia. Farmers working in the Chitemene system need a different set of nutrients compared to those intensively mono-cropping in Central Province. As smallholder fertilizer users know, there is a changing set of crop management practices that influence the usefulness of an inorganic fertilizer. Mt. Makulu maize breeders are currently seeking varieties that respond well to varying input levels, not just high recommended levels.

Farmers may be better off focusing their efforts on improving overall soil and crop management practices and eliminating management inefficiencies, rather than efforts on simply 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. Work with conservation farming technologies is designed to assist with this, and so should be evaluated for their potential. Crop suitability mapping at Mount Makulu may be useful for identifying alternative crops, as well.

IMPLICATIONS AND FUTURE CHALLENGES:
1) Inorganic fertilizer use can be profitable on maize and cotton, but often it is not in Zambia. This

research indicates that variability and risks can be high if weather and soil and crop management practices do not enable crop responses to the fertilizer. With a market price of 55,000 Kwacha, fertilizer is often unprofitable, except in the best of cases, where weather, soils, and crop management practices combine to give responses. Often on-station researcher trials are seen to be the "best possible results" and there are some high yields. Yet, overall, Zambian researchers experience many of the problems and the consequent effects on yields as smallholder farmers do: inputs not available or late, lack of resources for adequate weeding, weather risk, and initial soil fertility constraints. Thus these results may be a reasonable representation of outcome variability in maize and cotton production.

2) Profitability of fertilizer is improved by lowering fertilizer cost or raising crop prices. Two of the policy instruments available have been used in the past to improve the I/O price ratios: 1) to subsidize fertilizer and lower its price; and 2) to subsidize output prices, through marketing boards. Both of these policy instruments have proven costly in Zambia and are not sustainable without government revenues from other sources. In addition, untargeted subsidies may encourage input use where it is not economically viable. Lowering input prices and improving output prices through expansion of markets and greater efficiency of markets may provide greater long-term benefits, by improving the incentives for soil fertility enhancements by the farmers.

3) Improving fertilizer productivity means investments in research and extension, as well as on the farm, particularly in knowledge development. Another policy instrument available that may have longer term benefits is to invest in productivity. This would be through education, research and extension that enables more farmers to evaluate the most efficient use of his or her resources, getting the best efficiency in resource use. Whether that means 6 ton yields with a high dose rate or 3 ton yields with a moderate dose rate. It would also facilitate the farmer to know not only when fertilizers are not the best investment, but when a crop shift or management shift is needed. This is a challenge that researchers as well as farmers battle with because information is lacking. Extension programs that work with farmers to assess land and labor productivity constraints and how to minimize them would be a productive investment for the country. Extension must be combined with research on issues such as soil acidity and lime. Both extension and research could extend the current suitability mapping to include more economic analysis on crops and crop management practices, with site-specific results.

4) Farmers can and should be able to assess profitability of fertilizers and then make their own choices, given their prices, resources, and returns. Each farmer must be equipped with the information and knowledge to assess the most likely outcome and then decide whether or not to invest in fertilizer purchases. If they invest, they then make the decision on how much to invest, depending on credit availability, productivity, and returns to the investment. If farmers can replace maize purchases late in the season when prices are high with maize with their own maize production, the investment may have high returns. Input/output price ratios can be used as guidelines for comparison to expected response rates. If the I/O price ratio is 4.0, then a farmer who does not expect to get at least 4 kilograms of additional maize or cotton with fertilizer application might be better off investing less in fertilizer and more in other aspects of crop production.

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