Economic Implications of Using Manure Decision Guides as Decision Support Tools for Smallholder Soil Fertility Management in Zimbabwe

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Abstract

The flow of information between researchers, extension and farmers is critical to the adoption and success of soil fertility improving technologies. In bridging the information gap that exist between research, extension and farmers, a Farmer Manure Decision Guide (FMDG) has been developed to provide a means of selecting appropriate interventions for effective dissemination. The study uses descriptive analysis to assess the compatibility of the use of FMDG to farmers living under different environments in Mangwende communal area. Gross margin and linear programming analysis are used to assess the potential implications in terms of resource utilization and crop choice from the use of FMDG. Data were collected through interviews with individual farmers.

Results indicate that the FMDG should be accompanied by a set of detailed notes that provide different soil fertility management information of importance to smallholder farmers. Though the use of FMDG results in improved utilization of resources, farmers will be affected differently depending on the quality of manure they use, amount of labour available to them and whether they can achieve higher maize yield responses to the use of FMDG. In this regard because of this heterogeneity in farmers' socio-economic and biophysical environments the main emphasis should focused on the use of FMDG as an extension learning framework that could be used to inform farmers on different soil fertility management options available to them.

Key words: information, decision guides, soil fertility, linear programming

Introduction

Decision-making in rural, natural and environmental resource management is a complex process concerned with achieving the integrated, productive and sustainable use of biological, physical, social and financial capital at diverse geographic and temporal scales (Brooksbank, 2001). As the complexity of the decision-making task increases, resource managers including farmers are increasingly unlikely to have the necessary expertise, and, therefore, capacity to make resource management decisions that integrate the range of issues that demand consideration (Walker, 2000). This increasingly complex environment for resource use and management has necessitated the development of new skills, methods and tools to consider new information and apply new ways of thinking to consideration of that information. Decision tools can be at different scales, for example making provision of information and assessments and fostering of knowledge management for food and agriculture at global and national levels, or tools aimed at enabling farmers to use fertilizers in a correct way and thus improve the environmental performance of fertilizers (Rafn, 2002). Another approach, which is the main focus of this study, that is believed to have the potential of bridging the information gap between researchers, extension agents and farmers is the use of a decision guides as an aid to soil fertility management. Extension guides, are designed for use by Agricultural Extension Agents to train farmers and by farmers to improve their agricultural practices (Mawere, 2001). A manure decision guide (FMDG) recently developed by TSBF (2001) in central Zimbabwe focuses research activity on what is relevant to rural livelihoods and is sufficiently flexible to adapt technology options to specific farmer circumstances. The FMDG focuses on four important aspects of soil fertility management i.e. soil fertility improving strategies, manure quantity increasing strategies, manure quality improving strategies and agronomic practices that can be employed by farmers. The use of FMDG helps farmers make choices on what soil fertility management practices to employ on their fields given their bio-physical environment.

Decision guides seek to improve the way farmers make decisions pertaining to their soil fertility management hence their utility needs to be established and verified. The main aim of the study was to validate the manure guide in a smallholder farming area where it had not been tested before. The study evaluated the potential use of manure decision guides in other smallholder farming areas in Zimbabwe and made a comparative economic assessment of whether the soil fertility management options suggested by the FMDG would be superior in terms of returns to resources employed in production compared with current conventional farmer management practices. The study also determines average households' optimum resource allocation and crop choice in the presence of FMDG.

Research Methodology

Data Requirements and Sources

Two sources of data, i.e., primary and secondary data sources were used in the study. Secondary data on type of fertilizer to use, rate of inorganic fertilizer application and maize yield responses to different management practices, from manure technical research mainly done under TSBF soil fertility programs were also used. To understand soil fertility management practices of different households in terms of soil fertility improving options, manure quantity increasing strategies, quality improving strategies and management practices, primary data was collected using a baseline survey questionnaire administered to selected households in Murehwa district in north-eastern Zimbabwe. This farmer soil fertility management information was then compared to practices represented in the guide as a way of validating the FMDG. A total of 150 farmers were interviewed in the study. The farmers were selected on the basis that they live around Chigogodza area where TSBF is already carrying some soil fertility research.

Analytical Approaches

Descriptive Analysis

Descriptive analysis was used to compare the soil fertility management practices of sampled households and those recommended by the FMDG.

Gross margin analysis

The study used gross margin analysis to come up with returns to resources employed in maize production. The averages of the whole sample were used in this analysis. Gross margins for six maize enterprises were computed. HFp and LFp are real enterprises for the maize that was grown by Mangwende communal farmers using high and low quality manure. The other remaining four maize enterprises are hypothetical enterprises. With the availability of FMDG household decide on what type of manure to use and how to use it. Households could decide to follow FMDG recommendations through out their soil fertility management or to partially follow it i.e. blending it with some conventional farmer agronomic practices. Table 1 defines each of the maize enterprises considered in this study.

Table 1. Defining different Maize Enterprises

Maize Enterprise	Characteristics
HFp	Grown with high quality manure, purely conventional farmer manure application rates and other agronomic practices.
HDg	Grown with high quality manure but farmers purely following FMDG soil fertility management recommendations
HFpDg	Grown with high quality manure with farmers partially following the FMDG soil fertility management recommendations
LFp	Grown with low quality manure, purely conventional manure application rates and other agronomic practices.
LDg	Grown with low quality manure but farmers purely following FMDG soil fertility management recommendations
LFpDg	Grown with low quality manure with farmers partially following the FMDG soil fertility management recommendations

Below are listed some of the assumptions used to calculate the gross margins for the hypothetical maize enterprises.

- Minimum manure application rates used are 5 t/ha manure application for high quality cattle manure and 10t/ha for low quality cattle manure.
- Apply no inorganic basal fertilizer but apply a minimum of 40kg AN in two phases for both qualities of manure.
- Yields of maize increase by approximately 80% with low quality manure also recorded by Nhamo (2002) at Chisunga treatment site and by as high as 120% with high quality manure (Murwira and Mugwira, 1997).

Linear Programming Analysis

The study model explores how households optimize their resource allocation in the presence of FMDG as sources of soil fertility information. Resources available to the farm act as constraints in the model. The study also assumes that information, which can be in the form of decision guides, is a key constraint to farm operations. Farmers who have access to new soil fertility management information especially from extension are likely to improve the soil fertility status of their soils by using knowledge gained from this information compared to farmers who do not have access to extension information. Information on soil fertility affects soil fertility management practices influencing farm production and hence welfare of rural households. Information in the current period is subject to knowledge or experience acquired in the previous period and new information in the form of extension messages in current period. Effects of the presence of new soil fertility information from FMDG are incorporated through the effects of the soil fertility management recommendations on the gross margins of the different maize enterprises.

The objective function of the model is to maximize net farm income (W).

Maximize W = $\sum_{i=1} giYi$

Subject to

$\sum \alpha_i Cr_i \leq L$	Land constraint
$\sum \beta_i Cr_i \leq F_j$	Labour constraint
$\sum \lambda_i Cr_i \leq K$	Working capital
$\sum \mu_i Cr_i \leq D$	Draft power
$\sum \left[\rho_i^{Hqm} Hqm.mz_i\right] \leq QHqm$	Quantity of High quality manure
$\sum \left[\sigma_i^{Lqm} Lqm.mz_i\right] \leq QLqm$	Quantity of Low quality manure
$Y_{mz_i} \geq Mz_i$	Maize subsistence requirements
$I_t = I_{t-1} + extI_t$	Information constraint
$Y_n \geq 0$	non negativity condition for all the inputs

Where

t	time
g_i	net income per unit of output from the $_i$th enterprise
$Y_{m1}, Y_{m2},\ldots,Y_{m3}$	quantities of maize yields from different enterprises
Cr_I	crop from the ith enterprise
L	total land available
F_j	total available labour in a given labour season where $1 \leq j \leq 3$
K	total available working capital
D	total available draft labour
I	soil fertility information
extI	extension messages in the form of decision guides

α, β, λ, μ, ρ and σ are coefficients for land, labour, working capital, draft power, high quality and low quality manure.

Sensitivity Analysis

Sensitivity analysis was used to consolidate the above gross margin and linear programming analysis. Farmers would not always get the observed maize yields in other years. Yields of maize could be smaller or greater depending on the state of the biological and physical environment. Sensitivity analysis was done on the gross margins for pure FMDG and conventional maize enterprises i.e. HFp, HDg, LFp and LDg. The analysis tried to find out how the maize gross margins would change if the farmers got 25%, 50%, 75%, 125%, 150% and 175% of their present yield. Fig 3 shows the changes in gross margin with different maize yields.

Sensitivity Analysis was also done on the household linear programming model under the following conditions;

a) Households face different labour constraints. Analysis explored how household resource allocation and crop choice could change given different household adult labour equivalence.
b) The sensitivity and stability of the model to the unavailability of a labour market.
c) Households can not always achieve the 120% and 80% increase in maize yield with high and low quality manure respectively when using recommended soil fertility management practices due to a number of constraints. Thus household resource allocation was investigated under different maize responses to the use of recommended manure quantity strategies and agronomic practices.
d) What effects would arise by introducing a manure market to the model.

Findings

Assessing farmers' soil fertility management practices

a) Sources, quantification and treatment of Manure

Cattle manure is the most common source of manure used by farmers. Other sources of manure include leaf litter, anthill, legume residue and chicken droppings, which are mainly used in the garden. These sources of manure are also identified in the manure decision guide. There is a potential existence of a manure market in smallholder farming as another source of manure. A small percentage (8%) of farmers bought cattle manure from other farmers.

Households quantify their manure in different ways. About 82.9% and 75% of households in the study add residue to low and high quality cattle manure respectively.[1] Treatment of low quality manure is done especially during the production of the manure in the cattle pens whilst with high quality cattle manure much attention is given to the manure during pit storing period. Approximately 15% of households add water to high cattle manure, which shows that some farmers are knowledgeable about how to treat low quality manure to obtain better quality manure.

b) Manure storage and quality indicators

The majority of farmers i.e. 46.7% and 42% of farmers employ mainly the heap and pit methods respectively in storing their cattle manure. Results also indicate that farmers mainly store chicken droppings, leaf litter and anthill in heaps. The FMDG identifies the same methods of increasing manure quantity and manure storage as being employed by smallholder farmers.

Moulds, color, weight, compactness and temperature were found to be important cattle manure quality indicators. Most households (59.4%) use moulds as an indicator of the quality of cattle manure. Moulds reveal the extent to which added crop residues or the manure itself is decomposed. The appearance of white moulds is a good indicator of quality of manure. Approximately 5% of farmers consider the type of tree from which leaf litter comes from as an important quality indicator. Though the FMDG identifies most of the indicators of quality of cattle manure used by smallholder farmers it misses this indicator by focusing on generic characteristics.

c) Farmer Agronomic Practices

(i) Manure application

Generally average rate of manure application in the Mangwende community is low to the recommended rates of 5t and 10t respectively with high and low quality manure. On average 5.1

tonnes (8.5 carts) and 3.8 tonnes (6.3 carts)[2] of manure per hectare were applied to maize with high and low quality manure respectively.

Manure application was targeted to fields under the maize crop. No manure was applied under grain legumes, as farmers knew that these crops were nitrogen-fixing crops. This selective application was mainly due to the non-availability of adequate amounts of manure such that manure was only targeted to the maize crop for food security reasons.

An important observation captured from the results of the survey is the inverse relationship that existed between the rate of manure application and the distance of each field from the source of manure (Fig 1). Generally the rate of manure application declined as the distance of the field from the source of manure increased. This meant that less manure was applied the further away a field was from home, which was the source where the common type of manure used, i.e., cattle manure, came from. This kind of relationship is not represented in the FMDG and needs research attention if the guide it to be useful to smallholder farming.

Two methods of manure application were common i.e. banding and broadcasting, with both qualities of manure as indicated in the FMDG. No farmer employed the station placement method as it was deemed labour intensive. Shortage of labour and lack of knowledge could be some possible factors to explain why some households still used the banding and the broadcasting methods with low quality and high quality cattle manure respectively. Mostly cattle manure was applied every year regardless of the quality of manure. This soil fertility management practice conforms to the recommendations of the FMDG that states that high and low quality cattle manure that would have been pit stored and heaped respectively should be applied after every year. The unavailability of manure was the reason why some households are not able to apply manure every year.

(ii) Use of inorganic fertilizers

On average, amount of ammonium nitrate (AN) fertilizer used was highest when used in combination with high quality cattle manure i.e. 139.5kg and lowest when used in combination with leaf litter manure which had an average of only 1.1kgs per household. This could be explained by the fact that cattle manure was mainly targeted to fields that had maize crop planted to them and this was the same crop that households preferred to use their little inorganic fertilizer for, so as to ensure satisfaction of their food security goal. On the other hand quite a number

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[1] Cattle manure quality was determined by the way farmers store and process their manure. High quality manure is that which is pit stored with other residues and water as additives. On the other hand low quality manure is heap stored and deep stalled.

[2] 1 m3 scotch cart approximately =600kg cattle manure

households i.e. 48% of the sample did not use any compound D (8%N, 16%P_2O_5, 7%K_2O) in the 2003/04-production season.

Another important observation that was also mentioned in FMDG though no concrete recommendations were given was the fact that low quality cattle manure households should use compound X (a mixture of AN and compound D often in unspecified proportions) whenever they had few quantities of compound D and AN available. Results showed that 21% of the sampled households indicated that they used a mixture of AN and Compound D with low quality cattle manure because they had few quantities of both AN and compound D fertilizers (Fig 2).

Maize Enterprises Gross Margins

Households that had access to high quality manure are better off growing maize using HDg than HFp (Fig 3). This was because the former yield relatively higher returns (Z$1500000)[3] per hectare of land ploughed compared to the latter (Z$487000). On the other hand households that only have access to low quality manure are better off growing LDg and LFpDg as these yield higher returns per hectare of maize land planted. In both cases households are better off integrating their conventional soil fertility management practices with the recommendations from the FMDG as these have shown to have a greater potential in terms of returns per hectare of land planted than their normal conventional practices of managing soil fertility. Use of high quality manure results in higher yield responses as compared to when you use low quality manure. Fig 4 consolidates the above findings when considering returns to other resources employed in production such as labour and working capital.

With respect to hired labour, households are better off integrating the use of FMDG with their agronomic practices because this has the potential of increasing the efficiency use of hired labour compared to a situation when they use purely FMDG and conventional soil fertility management practices (Fig 4). This is because the use of integrated soil fertility management practices saves on the labour that is used in production whilst enhancing the potential of increasing maize yields for the farmer. When considering returns to working capital invested into maize production, FMDG soil fertility management practices are more superior to conventional soil fertility management practices. This is because HDg and LFp yield higher returns per dollar of capital invested in maize production with both qualities of manure.

Effects of Yield changes on Maize Gross Margins

Generally FMDG are superior to the conventional farmer soil fertility management practices even at lower maize yields. The only exception is when using low quality manure. Households that use

[3] US$=ZW$5600

low quality manure are better off using their conventional ways of managing their soils than employing recommendations from the FMDG at 50% and less of the expected maize yield. This is because at this level of production the returns per hectare of land planted for the FMDG are lower than those of the conventional practices i.e. gross margin for LFp is greater than that of LDg (Fig 5). The implication of this is that if yields of maize turn out to be lower than expected for low quality manure users then the use of FMDG in smallholder soil fertility management practices would leave the households worse off.

Household Optimization Model Results

Table 2 highlights some of the important results from the linear programming solution. The household would get a net farm income of Z$517006. The optimum mix includes only two cropping enterprises, which are HDg and groundnuts. The other enterprises are not profitable enough to appear in the optimum solution. The implication of this result is that though households are encouraged to grow maize as a staple food crop they should also allocate enough resources of labour, capital and management to the growing of grain legumes such as groundnuts that also help in improving their soil fertility, food security and cash inflow.

The household is implicitly taxing itself by engaging in HFp and LFp production. This is because these enterprises are not profitable enough to the household. If the household would only increase the profitability of LDg by only Z$25987 then it will be able to use low quality manure to produce maize with FMDG recommendations.

Generally land is not a limiting factor to farm production because a surplus of 2.6 acres of land not used in this model is observed (Table 2). Labour is limiting production especially in the November period. This may be due to high labour demands for manure production i.e. digging, transporting, etc. This then results in a very high opportunity cost of labour in the November period of Z$24138. This value also represents the marginal productivity of an extra unit of labour in November, which is very high. The household would hire 11.8 units of labour and not hire out any labour because its net farm income would decrease by $9138 if it hires out a unit of labour. Family labour severely constraints production having an opportunity cost of $496887. Labour is not limiting in the other labour seasons as a surplus of 48 and 19 labour days appear for Dec-Jan and Feb-April labour seasons respectively.

Capital is another limiting factor to farm production. The opportunity cost of capital in the model is $1.6. This means the household would get $1.6 for a dollar extra capital invested in production. In the model, the household would use only 1.38 tonnes of high quality manure to produce HDg. This quantity of manure is too low such that the household has to supplement its organic nutrients with inorganic fertilizers. High quality manure is also constraining maize production such that the opportunity cost of a tonne of high quality manure to the family would be $120 690. No low quality manure is used in the model since no maize enterprise that uses low quality manure appears in the optimum solution.

The household is not able to meet all its minimum maize requirements. The household should be prepared to pay approximately $171 for an extra kg of maize bought. The negative sign indicates the fact that the household's net farm income would decrease by $171 if an extra kilogram of maize is bought.

Effects of Changes in Availability of Family Labour

Changing the adult labour equivalence of the households assesses how changes in the availability of family labour affect resource allocation and production. The initial model has an adult labour equivalence of 4. Availability of family labour affects the optimum crop mix of the household. With an adult equivalence of 3 the household's optimum crop mix changes from that in the initial model to only one crop i.e. LDg. This means that LDg is less labour intensive and hence would be preferred. Increasing adult equivalence to 6 and 8 does not change the optimum crop mix in the solution but changes the land allocated to the two enterprises i.e. HDg and groundnut. Fig 6 shows changes in land allocated to HDg and groundnut enterprises.

Land allocated to HDg and groundnut increases with increasing adult labour equivalence. This shows that these two are labour intensive enterprises especially in the November period and as such their production will increase with increasing amounts of labour. Changes in adult equivalence also affect the amount of hired in and hired out labour of the household. Fig 7 shows effect of changing adult labour equivalence on hired in and hired out labour.

Labour hired in by the household decreases with increasing family labour until it reaches zero at 6 adult labour equivalence. Hired out labour increases with increasing number of family labour. This shows how differently a household will be affected by the use of the FMDG depending on its family labour.

On the other hand reducing the adult labour equivalence to 3 greatly affected the food security status of the household. Not only does the household not meet its minimum maize requirements but the opportunity cost of an extra unit of maize is increased to unsustainable levels i.e. $937500. Increasing adult labour equivalence to 6 and 8 reduces the shadow price of a kilogram of maize to $99.80 for the household. This shows that it will be difficult for households with smaller adult equivalencies to satisfy their subsistence needs with the use of FMDG.

Unavailability of a Labour market

The removal of a labour market meant that the only source of labour was that from the family. Household's net farm income is reduced by 23% to $398300. The optimum crop mix changes to less labour intensive enterprises i.e. LDg and groundnuts. LDg is allocated 0.47ha whilst groundnuts land allocation is reduced from 0.12ha to 0.023ha.

November labour becomes more limiting to farm production with its marginal productivity increasing from Z$24138 to Z$83000. Family labour becomes more limiting because the household can no longer hire in additional labour. With no labour market the budget constraint is no longer limiting crop production. This shows that most of the budget is going to the hiring in of additional labour. Thus the removal of a labour market has got serious implications on the use of FMDG especially when low maize yield responses are being anticipated or when the household has a small adult labour equivalence.

Effects of Changes in Maize yield responses

Changes in maize yield responses affects optimum crop mix, net farm income and attainment of food security. With low maize yield responses to soil fertility management practices recommended by the FMDG i.e. 30% expected yield, the optimum crop mix of the household consists of two enterprises i.e. LFpDg and groundnut. The household would be better using its conventional ways of managing its soil fertility because the FMDG maize enterprises would not be profitable enough to worth the investment in land, labour, capital and manure needed to produce them. At 50%-80% maize yield responses the optimum crop mix changes to LFp and groundnuts and at 120% maize yield responses, the optimum mix would now consist of HDg and groundnuts as in the initial model. This shows that potential yield responses that each household has with the use of FMDG, affects the extent to which these tools become relevant to smallholder farming.

Net farm income of the household is improved with increasing yield responses of maize to FMDG soil fertility management recommendations. Net income is gradually increased from Z$341946 at 30% yield response to Z$517006 at 120% yield responses. Household's food security is greatly enhanced with increasing maize yield responses. Figs 8 shows changes in the shadow price of maize with changes in maize yield responses. At low levels of maize yield responses food security status of the household is greatly compromised. This has some negative implications on the use of FMDG when the farmers in question do not have the potential to achieve higher maize yield responses.

Availability of a Manure market

The availability of a manure market increases a household's net farm income by approximately 47%. The optimum crop mix does not change but land allocated to groundnut enterprise increases from 0.12ha to 0.41ha. Results also indicate that all high quality manure is used whilst there is a surplus of 6.12 tonnes of low quality manure that is left. The opportunity cost of high quality manure is $48116 a tonne i.e. the household will be willing to pay $48116 to acquire an extra tonne of high quality manure.

Conclusion

There still remains a lot of work that needs to be done on the FMDG to make it represent to a greater extent different soil fertility management practices of smallholder farmers. A set of notes providing advise on recommended fertilizer application, combinations of AN and Compound D and fertilizer application rotations between different fields should accompany the FMDG so as to inform farmers on how to manage soil fertility of different enterprises. Using FMDG as a prescriptive tool is complicated by the heterogeneity in the smallholder farmers themselves. In this case more emphasis should be given to the use of FMDG as a learning framework that could be used by extension officers to train and teach farmers on how best they could manage their soils given their bio-physical environment.

The use of FMDG has got a potential to increase maize yields in smallholder farming, but more labour is needed to carry out sufficiently most of the recommendations of the FMDG. As such ways of reducing the labour demand of some of the recommendations need to be explored. At low levels of maize yields, farmers that use low quality manure are better off using their conventional way of managing their soil fertility. Imposing the use of FMDG in such a case actually reduces smallholder farmers' welfare. Research needs to concentrate on the potential of integrating the use of FMDG recommendations and the conventional farmer agronomic practices to enhance smallholder maize yields. This has the potential of capturing smallholder farmers' interest because it's a less risky option than abandoning all their conventional practices in favour of the FMDG recommendations.

It is really difficult to conclude the suitability of FMDG to high quality manure using households as this greatly depends on the other factors such as availability of family labour and maize yield responses. Households differing in household characteristics (sizes and family labour) are affected differently by the use of FMDG. Given the complexity and the heterogeneity of smallholder farmers the FMDG is best used a learning framework to teach farmers on managing their soil fertility. On the other hand if FMDG is to be used as a decision aiding tool then they should be targeted to households with adequate labour and those with potential of getting high maize yields given their previous performance and their resource endowments.

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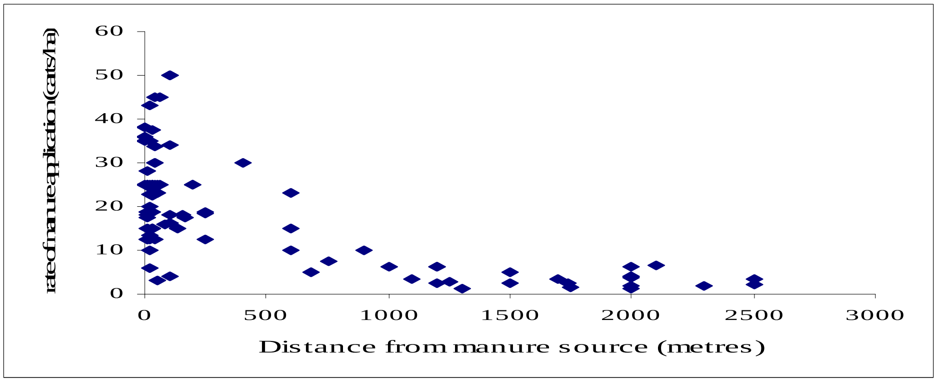

Fig 1 Relationship between rate of manure application and distance from source

Source: Survey Data

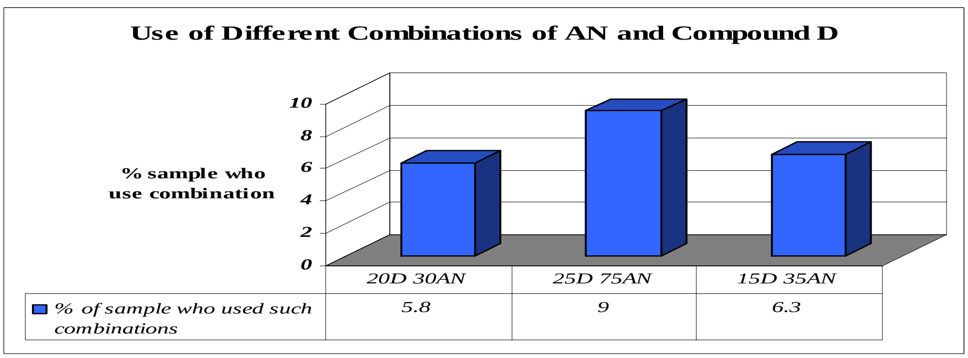

Fig 2. Combinations of AN and Compound D

Source: Survey Data

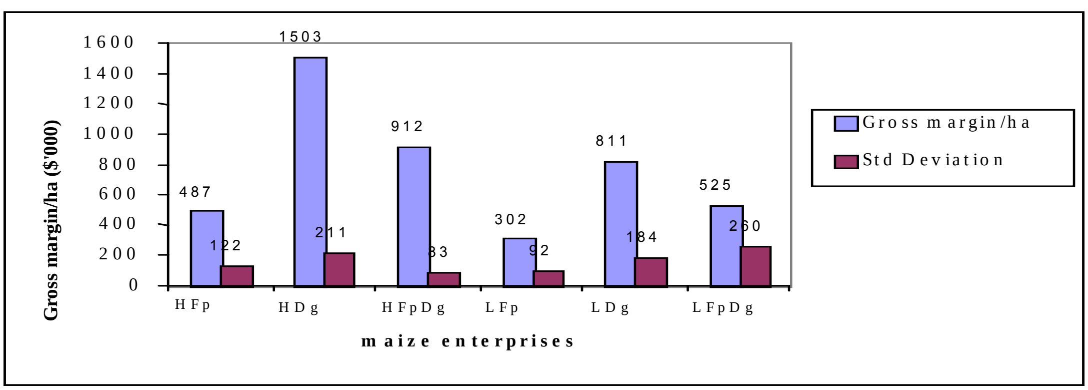

Fig 3 Comparison of Maize Gross Margins

Source: Survey Data

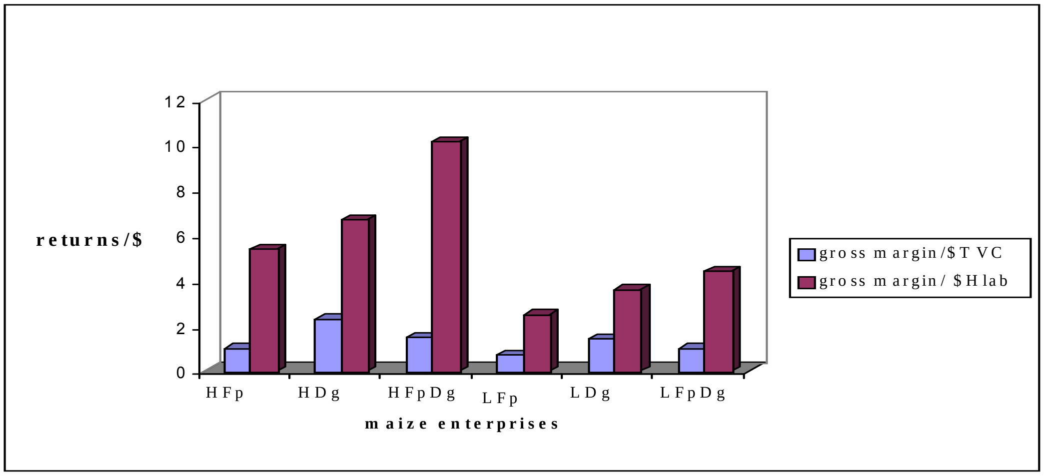

Fig 4 Returns to resources of capital and hired labour employed in Production

Source: Survey Data

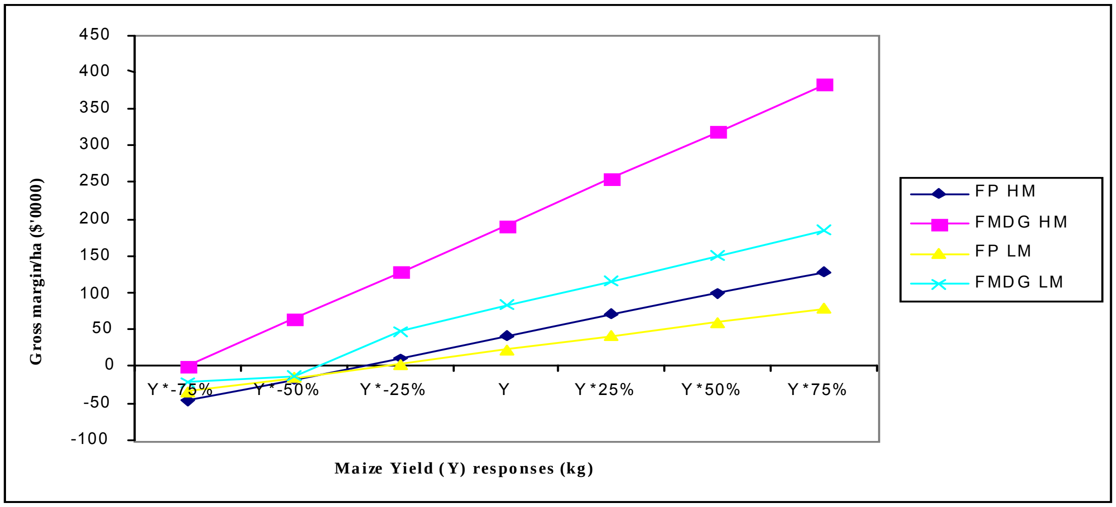

Fig 5 Changes in Maize Gross Margins with changing yield

Source: Survey Data

Table 3 Optimum solutions for conventional and recommended practices

Enterprise	**Conventional (optimal)**	
	Land Allocation	**Reduced Cost**
HqmDg	0.27	0
Groundnuts	0.12	0
Hireout labour	0	9138.2
Hire in Labour	11.8	0
Hqmanure	1.38	0
Lqmanure	16.2	0
Resource Utilisation	**Slack/Surplus**	**Dual Price**
Land	2.6	0
November Labour	0	24138
Dec-Jan Labour	48	0
Feb-April Labour	19	0
Capital	0	1.6
Hqmanure balance	0	120690
Lqmanure balance	16.2	0
Family labour	0	496887
Subsistence Requirements		
Maize requirements	0	-170.8
Total Net Income	**517006**	

Source: Survey Data

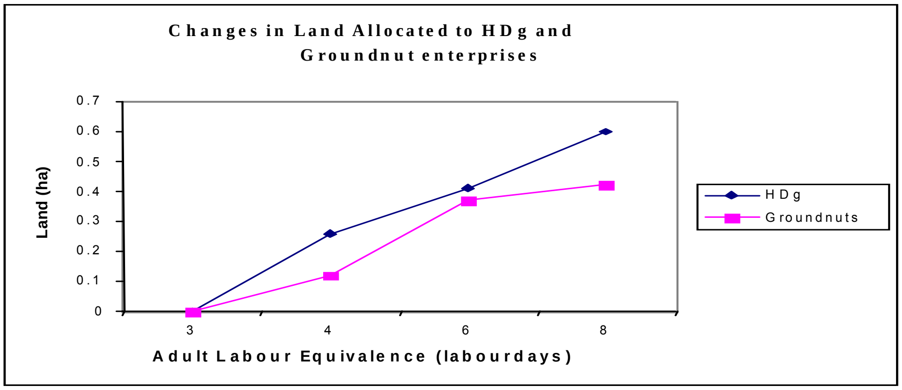

Fig 6 Changes in Land Allocated to enterprises

Source: Survey Data

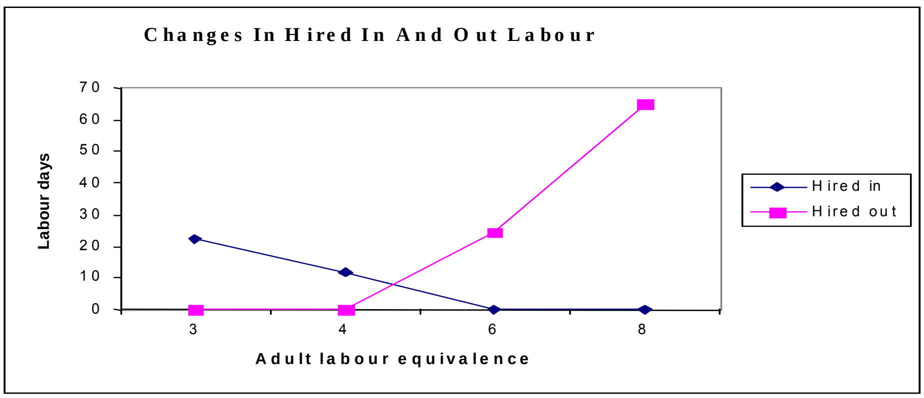

Fig 7 Effects of Changing adult labour equivalence on hired in and hired out labour.

Source: Survey Data

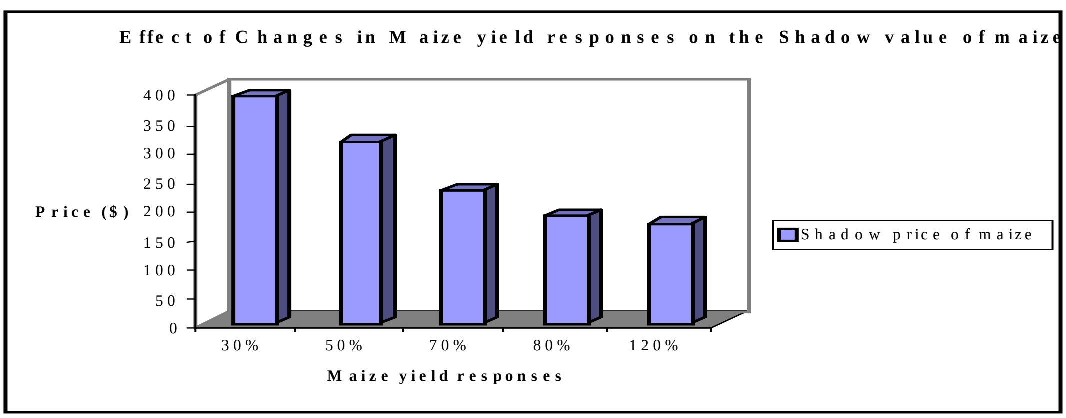

Fig 8 Shadow price of Maize with changing yield responses

Source: Survey Data