Risk Diversification Opportunities Through Legumes in Smallholder Farming Systems in the Semi – Arid Areas of Zimbabwe

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Introduction

During the past decade, there has been growing interest in the use of legume-based technologies as nutrient sources in smallholder farming systems in Sub- Saharan Africa due to constraints on expanded fertilizer use and because of the negative externalities that synthetic fertilizers might have on the environment. In Zimbabwe, legumes have been grown as intercrops and in rotation with cereals for many decades. However, in the past 50 years, extension has discouraged intercropping and has promoted the growing of pure crops targeted for commercial purposes. Despite this advice, farmers have continued to grow legume based intercrops albeit in small areas (Meerman, 1996). To re-introduce legumes into the system at large enough scale to enable farmers to capture potential benefits of biological nitrogen fixation, the legume technologies need to give a competitive rate of return on investment compared to alternative investment options available to households while meeting farmer's risk requirements. Generally highly rewarding production systems are associated with higher risks. A compromise has therefore to be established between the level of production desired and the level of risk to be borne.

This paper uses simulation modelling and portfolio analysis to evaluate the long-term benefits of diversification and compare different legume based farming systems as candidates for diversification. The technologies to be evaluated include maize-groundnut and maize-cowpea intercrops and rotations sorghum-cowpea and sorghum-groundnut intercrops and rotations, and the use of small doses of nitrogen (9Kg per Ha).

Research Methodology

Conceptual Framework

For farmers to invest resources in new technologies, the rates of return of these investments need to be competitive with available investment opportunities. With a single crop enterprise such as maize production, the rate of return on investment in new fertilizer technologies is compared with return on capital using the portfolio theory of capital markets. Between different crop enterprises, return on investment in new management technologies are compared against other investments including livestock, off-farm activities, and temporary and permanent labour migration. Because of the uncertainty of payoffs to alternative investments, new investments must fit farmers' objectives of risk in addition to profitability. Since high profitability is associated with high risks, farmers face trade-offs between allocating resources to activities with high profits and more desirable and riskier and therefore less attractive outcomes compared to activities with low profits and yet less risky, which makes them more appealing.

Mean-variance or E, V efficiency analysis can be used to find which investments are more appealing than others from the return –risk perspective. The mean-variance efficiency rule is based on the proposition that, if the expected value of choice A is greater than or equal to the expected value of choice B, and the variance of A is less than or equal to the variance of B, with at least one strict inequality, then A is preferred to B. (Hardaker et al, 1997). Only those options that are not dominated in the E, V sense are regarded as members of the E, V efficient set. This implies that options with the greatest ratio of return (mean) to risk (variance) are considered to dominate those with lower coefficients and are likely to be chosen.

To evaluate the suitability of different farm enterprises as candidates for diversification, that is, whether the addition of the new enterprise will complement the existing farm plan and result in desirable outcomes, Moss et al (1991) developed an approach for evaluating diversification opportunities of alternative farm investments that is based on portfolio theory of financial markets and the capital asset pricing model (CAPM). These analysts argue that for a new or candidate enterprise to improve the risk-return trade-off provided by any existing group or portfolio of enterprises, the following condition must hold:

$R_i / STD_i > R_p / STD_p * Corr_{ip}$--(1)

Where:

R_i = The mean return of the potential new i^{th} investment alternative,

STD_i = The standard deviation of the new i^{th} alternative investment,

R_p = The mean return of the current/existing farm plan,

STD_p = The standard deviation of the current/existing farm plan, and

$Corr_{ip}$ = The correlation coefficient for the current farm plan returns and the new i^{th} alternative investment returns.

If the mean return divided by the standard deviation of new investment alternative is greater than the mean of the whole farm plan's return divided by the standard deviation times the correlation between investments, the new investment will compliment the current operation from a risk-return perspective. Based on this risk return condition necessary for a new enterprise to improve the risk-return trade-off provided by the current farm portfolio, one can calculate a risk diversification index (RDI) as follows:

$$RDI = R_i / STD_i - R_p / STD_p * Corr_{ip} \text{------------------------------------} (2)$$

If the RDI is greater than zero, the candidate technology is a good investment opportunity for diversification. But if RDI is less than zero the candidate technology offers no gains through diversification to the farm household. The greater the value of the RDI the better the investment as a candidate for diversification.

Applying the E, V analysis and the risk diversification index framework generates the following two hypotheses about relationships between the risk-return characteristics of new technologies, farmers' risk management strategies, and potential for adoption that are tested in the study:

1. Legume-based soil fertility management technologies are attractive if they lie on the E, V efficient frontier and offer farmers expected returns that are high enough to compensate them for additional risks; and
2. Diversification into legume-based soil fertility management technologies will benefit farmers if the new technologies complement the current farm portfolio and better offset the total risk of the whole farm compared to allocating resources to alternative farm and non-farm investment opportunities available to farmers.

Methods

The study uses enterprise and whole farm budgeting and simulation modelling with the Agricultural Production Simulation Modelling (APSIM) and @Risk to generate data used to evaluate the hypotheses. Enterprise budgets are constructed for alternative investment technologies. Different enterprises are defined by different outputs such as maize, sorghum; sole stands and crop mixtures and; and different crop production technologies, including high rates of application of kraal manure, inorganic nitrogen fertilizer and organic and inorganic fertilizer combinations. Enterprise budgets are used to compare profitability of maize and sorghum crop production using traditional methods and improved soil fertility management technologies with different activities available to farmers and the profitability of different enterprises for households with different endowments. The budgets are constructed using yield and input output coefficients data from farm surveys, Farmer Participatory Research experiments, and yields predicted by APSIM.

The input-output coefficients are combined with prices from the Ministry of Agriculture, Zimbabwe Farmers' Union, and Commercial Farmers' Union to calculate gross margins per hectare. Input prices are reported at the supply point. Input prices paid by farmers are estimated by adding input prices reported by suppliers and the cost of transport. Output prices are reported at the marketing points. The opportunity cost of family labour is estimated by multiplying the minimum wage rate of engaging in urban employment by the probability of finding a job.

Because APSIM crop yield predictions are only available for 10 years from 1990 to 2000, and for a few improved technology options, this analysis focuses on the following:

- Sole maize and sorghum grown with fertilizer and with small quantities (9kg) of nitrogen; kraal and pit manure; manure and fertilizer combinations.
- Sole cowpeas and groundnuts
- Maize and sorghum-cowpea intercrops and rotations
- Maize-cowpea and maize-groundnut rotations.

The budgets include only the physical grain output of crop enterprises for primary and secondary crops valued at farm gate prices. Farmers frequently grow crops in mixtures of more than two crops and the budget needs to include the whole mixture. The values of by-products such as stalks, which have value as livestock feed, in construction and composts are not included. The enterprise budgets are used to construct whole farm budgets for current farm plans for different household categories by aggregating the returns per unit over the number of units produced by the households. Because there are expenses and revenues that cannot be allocated to particular enterprises, and cases where we do not have a linear budget, this may underestimate returns from some activities. The budgets are used to estimate the expected annual returns, the degree of risk, and the correlation coefficients for different crop and livestock combinations.

Results and Discussion

Return - Risk Coefficients

Tables I represents the annual return – risk ratios per hectare above fixed costs for 11 years from 1990/91 to 2000/01 on alternative maize and sorghum soil fertility production technologies by area. The table also shows the annual return- risk ratios of investing funds in a relatively less risky asset, the POSB savings account whose annual rates of interest do not fluctuate much.

Gwanda is the driest of the three areas. It receives mean annual rainfall of below 200mm. Tsholotsho receives rainfall amounts of between 200 and 250mm while Zimuto the wettest of the three receives annual rainfall amounts of around 300mm per year. The soil type for Tsholotsho is mainly heavy clay while Gwanda has a mixture of loam soils and clay soils. Zimuto is dominated by lighter soils ranging from loamy to sandy loams.

From the E,V analysis, the following farming systems have favourable return risk coefficients and therefore would be attractive to farmers. For Gwanda, which is the driest and has relatively fertile soils we have, in decreasing order of desirability: sorghum-cowpea rotations, sole sorghum without any treatment, maize-cowpea rotation, sorghum with small doses of nitrogen (9kg per hectare), and sorghum-groundnut rotation. Labour intensive investments such as pit and kraal manure applications did not yield favourable return-risk ratios because labour is in short supply in Gwanda and therefore it is very expensive. This is because most able-bodied men and women migrate to the neighbouring South Africa to seek employment. Legume based technologies are attractive in Gwanda and due to low rainfall, combinations of sorghum and legumes (especially cowpea) have high return-risk ratios (both sorghum and cowpea are drought resistant). Low doses of nitrogen are also attractive though to a small extend. High doses of nitrogen have unfavourable return risk rations because they are riskier due to low levels of rainfall.

The investments that yield attractive return risk ratios for Tsholotsho include: Maize-groundnut rotation, Sole sorghum without treatment, Maize-cowpea rotations, sorghum-groundnut rotation, sorghum-cowpea rotation and sole maize. The use of fertilizer does not yield very favourable results probably because the soils are inherently fertile and also due to low rainfall. Tsholotsho is also affected by labour migration in the same way as Gwanda and therefore labour demanding investments are not very attractive.

For Zimuto with lighter soils and relatively higher rainfall, maize dominated farming systems are attractive especially when coupled with small doses of fertilizer or other soil fertility enhancing technologies. The best investments are therefore: Maize-groundnut intercrop, Maize with small fertilizer doses, Maize with kraal manure and small fertilizer doses, Maize-cowpea intercrop, and Maize-groundnut rotation. Labour intensive manuring becomes favourable in Zimuto due to the lower costs of labour.

Table I: Return risk coefficients for Gwanda, Tsholotsho, and Zimuto
(for the period1990/91 to 2000/2001)

Activity	Return/Risk Coefficient		
	Gwanda	Tsholotsho	Zimuto
POSB fixed deposit account	0.881	0.881	0.881
Sorghum + Kraal manure	-3.550	-1.773	
Sorghum no treatment	1.209	1.149	
Maize no treatment	0.887	0.897	0.739
Sorghum + 9kg N per Ha	0.330	0.977	
Maize + Groundnut intercrop	0.310	0.574	1.018
Sorghum + Groundnut intercrop	0.019	0.750	
Sorghum + pit manure	-0.277	0.474	
Sorghum groundnut rotation	0.886	1.030	0.088
Sorghum cowpea rotation	1.241	0.999	
Maize + 9kg N per Ha	0.315	0.900	1.012
Maize groundnut rotation	0.739	1.335	0.596
Maize cowpea rotation	0.897	1.064	-0.229
Sorghum + 18kg N per Ha.	0.624	0.883	-0.093
Sorghum + Kraal + 18kg N/Ha	0.061	0.618	
Maize + Kraal + 9kg N/Ha	0.337	0.851	
Maize + pit Manure	0.518	0.843	0.532
Maize cowpea intercrop	0.088	0.743	0.718
Maize + Kraal manure	-0.059	0.756	
Sorghum cowpea intercrop	0.306	0.651	0.309
Sorghum + Kraal manure + 9N	0.467	0.618	0.903
Maize + 18N	0.636	0.991	-0.254
Maize + Kraal manure + 18N	0.237	0.731	

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Risk Diversification Index

Because different technology investments are differently correlated with the current farm plan and farm households can choose to invest resources among several investments in order to reduce risks without reducing expected returns, we need to consider the effect of including a production technology on the whole farm portfolio when deciding whether or not to include it in the current farm plan. Table II reports the risk diversification indices for the whole farm for the three study areas. The analysis is extended to include the benefits of diversifying to medium and long duration pigeon peas and temporary migration to urban labour markets. The risk indices for maize-cowpea and maize-groundnut rotations and maize-pigeon pea intercrops and rotations are positive for different kinds of households across all sites indicating that these legume-based soil fertility production technologies offer significant gains through diversification. They are therefore likely to be adopted by farmers. The breakdown of this analysis by study area gives the following results:

In Gwanda, maize-long duration pigeon pea rotation, sorghum-cowpea intercrop, and maize-medium duration pigeon pea offer good diversification opportunities. The dominance of pigeon pea in the results is due mainly to its drought resistance, high market value and the fact that it is relatively easier and cheaper to produce. Tsholotsho is also dominated by pigeon pea technologies so that we have: Maize-long duration pigeon pea rotation, Maize-medium duration pigeon pea intercrop, and maize cowpea rotation. However, for Zimuto the results are slightly different so that we have: Maize kraal manure, maize with small nitrogen dosages, and maize long pigeon pea intercrop are good diversification candidates.

Table II: Risk diversification indices for alternative maize and sorghum soil fertility management technologies for Gwanda, Tsholotsho, and Zimuto 1990/91 to 2000/01.

Activity	Gwanda	Tsholotsho	Zimuto
Sorghum + Kraal manure	-4.00	-2.30	
Sorghum groundnut intercrop	-0.92	-1.10	
Sorghum cowpea intercrop	0.91	0.40	
Sorghum + 18N	-0.69	-0.55	
Sorghum + pit manure	-0.67	-0.52	
Sorghum + 9N	-0.53	-0.31	
Sorghum + Kraal manure + 18N	-0.41	-0.30	
Sorghum cowpea rotation	0.37	0.19	
Sorghum + Kraal manure + 9N	-0.36	-0.26	
Sorghum groundnut rotation	-0.25	-0.21	
Maize cowpea intercrop	-0.14	-0.23	0.14
Maize + 18N	-0.13	-0.32	0.13
Maize groundnut intercrop	-0.09	-0.33	0.09
Maize + pit manure	0.02	0.28	-0.02
Maize + Kraal Manure + 9N	0.04	0.29	-0.04
Maize + Kraal manure + 18N	-0.13	-0.38	-0.09
Maize cowpea rotation	0.07	0.55	0.07
Maize + Kraal Manure	0.16	0.27	0.41
Maize + groundnut rotation	0.24	0.26	-0.24
Maize + 9N	0.31	0.53	0.31
Maize + long pigeon pea Intercrop	0.56	0.19	0.14
Maize + medium pigeon pea intercrop	0.61	0.53	0.13
POSB Fixed deposit account	0.65	0.74	0.80
Maize + medium pigeon pea rotation	0.89	0.74	-0.02
Maize + long pigeon pea rotation	1.03	0.95	-0.04
Urban labour market	7.96	7.80	6.57

Conclusions and Recommendations

The risk analysis presented in this paper is a first cut to evaluate technologies that merit further study. In addition to meeting requirements for risk and return, new technologies must fit with the resource boundaries of farmers and management capabilities. Mathematical optimisation provides tools for a more detailed analysis of the benefits and adoption potential of technologies under the severe resource and institutional constraints faced by households in semi-arid areas.

The paper evaluates the attractiveness of alternative soil fertility management technologies for adoption by farmers with varying resource endowments and risk preferences. Results indicate that maize-legume based technologies such as: maize-cowpea and maize-groundnut rotations and maize-pigeon pea intercrops and rotations, yield attractive results in wetter areas of the country (Zimuto), and are therefore good diversification candidates while sorghum-legume intercrops and rotations yield better results in drier areas of the country (Tsholotsho). Significant gains can also result from diversification into non-farm assets such as money markets and urban employment. However more detailed analysis using mathematical programming is needed to evaluate the feasibility and sensitivity of options to changes in environmental factors.

The paper also does not evaluate livestock such as cattle, sheep, goats and poultry as possible diversification candidates. These are likely to have more favourable return risk ratios than crop farming especially considering the fact that the study areas are either arid or semi-arid. A more encompassing study is therefore recommended.

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