The Profitability of Manure Use on Maize in the Small-holder Sector of Zimbabwe

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Abstract

Several manure use options were analysed for profitability using results from farmer participatory trials conducted in the small holder farming sector of Zimbabwe. The options analysed were

a) not using any manure
b) using aerobically composted (heap stored) manure,
c) using manure improved through anaerobic storage (pit stored),
d) different manure application methods such as banding, broadcasting and station placement, and
e) supplementing manure with mineral fertilizer.

The use of manure provided a marginal rate of return (MRR) of at least 215% compared to not using manure. The MRR on manure use was increased significantly by composting manure in pits. Financial benefits obtained from pit stored manure were much higher in the first year of manure application compared to those of heap stored manure. Higher returns from heap stored manure were obtained in the second and third seasons after manure application. Overall undiscounted financial benefits for the three years were marginally higher for pit stored manure. Higher financial benefits were obtained from supplementing manure with mineral fertilizer compared to using manure alone. Banding and placing manure on-station increased returns from using both pit and heap stored manure. The conventional practice of broadcasting manure was found not to be profitable.

Key words: Economic Returns, Profitability, Manure, Mineral Fertilizer, Smallholder, Zimbabwe

Introduction

Soil fertility depletion in the smallholder farms is the fundamental cause for declining per capita food production in sub-Saharan Africa (Sanchez *et al.*, 1997). Increased food insecurity, reduced farm incomes, limited returns from agricultural investment and rural poverty are some of the consequences of declining soil fertility. Input purchases by smallholder farmers have not been enough to cover for the nutrient outflows (Smaling *et al.*, 1997). Mineral fertilizers have become unaffordable for most smallholder farmers since the removal of subsidies in 1991 when the Zimbabwe government embarked on the Economic Structural Adjustment Program (ESAP). Most smallholder farmers in Zimbabwe have turned to the use of manure as a low cost option. However the effective utilisation of manure is constrained by severely limited quantities available, poor quality of the manure with most manures having less than 1 % nitrogen and a high sand content (Mugwira, 1985; Tanner and Mugwira, 1984). Improving manure management and storage is an important option for improving yields and returns to investment in crop production.

This paper is an economic appraisal of the promising manure related soil fertility management options that were tested in the smallholder farming environment.

Materials and Methods

Three sets of different farmer participatory trials were conducted in the smallholder farming area of Murewa. The trials were on (1) the effect of supplementing 5 tonnes of manure with varying levels of fertilizer N (0, 20, 40, 80, 100 kg N ha^{-1}) on maize yield, (2) the effect of differently cured manure (aerobic and anaerobic) on maize yield and residual effects in subsequent seasons and (3) the effect of different manure placement methods on maize yield. All the trials were implemented in Murewa, north east of Harare. The trials were conducted on sandy soils, typical of most smallholder farming areas of Zimbabwe.

In the trial on supplementing manure with mineral fertilizer, the nitrogen was applied twice, at 6 and 10 weeks after planting and this conforms to the normal farmer practice. Manure was broadcasted at planting. The trial was conducted for two seasons, 1997/98 and 1998/99.

Most smallholder farmers store their manure for at least three months before application in the field. The conventional way involves digging manure out of the kraal and heaping it beside the kraal for 3 months. This was compared to the new innovation of digging a pit beside the kraal and then putting manure in the pit that is then covered to ensure anaerobic decomposition. The manure is kept in the pit for three months. The manure was banded and applied at a rate of 10kg N ha^{-1}.

The other option was to test different manure placement methods; broadcasting, banding and spot application. Broadcasting is the conventional method of applying manure used by most smallholder farmers in Zimbabwe. For the comparison of different application methods an application rate of 100kg N ha^{-1} equivalent was used basing upon the total N concentrations of the manures.

A financial analysis was conducted to appraise the different options for private profitability. A cost benefit analysis was conducted for the trial on different manure storage systems and their residual effects. A full budget for the maize enterprise under the different treatments or trials was prepared based on marketable output. The trial yields were adjusted by 10% to cater for field losses. Factory gate maize price was used in the analysis. The cost of transporting the maize to nearest depot was included in the analysis. Farm gate prices were used for all the inputs namely mineral fertilizer, seed and insecticides. The prices of inputs were collected from the nearest rural service centre offering such inputs.

One of the major costs in the utilization of manure is the labour used in the digging, curing, transportation and application of the manure. A survey was undertaken in two communal areas, Murewa and Tsholotsho, to collect information on labour. Farmers were asked to state the time they take and the cost of the labour used in the management and utilization of manure. Information was collected for each manure related operation, digging manure from the kraal, heaping or placing manure into the pit, transporting manure to the field and application of manure in the field. Discussions were also held with farmers to confirm survey findings.

The survey results and discussions with farmers revealed that pitting of manure require an additional 5 person days compared with curing manure on the heap. Farmers also indicated that heap stored manure has a lot of weed seed compared to pit stored manure and farmers allocate more labour days on weeding fields where heap stored manure is applied compared to where pit stored manure is applied.

Financial returns from the technologies are a function of the maize yield obtained from the technology, cost of implementing the technology and improvement in the fertility status of the soil (residual effects) over time.

The financial returns are given by the function:

$$\frac{\Delta R}{\Delta T} = f\left[\frac{\Delta Q_o}{\Delta T}, \frac{\Delta C_o}{\Delta T}, \frac{\Delta SF}{\Delta T}\right]$$

where

$\frac{\Delta R}{\Delta T}$ = returns from the technology

$\frac{\Delta Q_o}{\Delta T}$ = yield

$\frac{\Delta C_o}{\Delta T}$ = total cost

$\frac{\Delta SF}{\Delta T}$ = residual benefits

Residual benefits are a function of the change in the fertility status of the soil over time and are given by the function:

$$\frac{\Delta Q_{t+i}}{\Delta T} = f\left[\frac{\Delta SF_{t+i}}{\Delta T_o}\right]$$

where

$\frac{\Delta Q_{t+i}}{\Delta T\Delta}$ = yield obtained the following year

$\frac{\Delta SF_{t+i}}{\Delta T_o}$ = residual soil fertility

Residual soil fertility is a result of the improvement of the soil due to additions of manure. Economic quantification of other benefits related to residual soil fertility other than the yield obtained is beyond the scope of this paper.

Net Present Values (NPV), present value of expected future earnings or benefits (Gittinger, 1982), were calculated for the future stream of benefits from residual soil fertility. Normally the going interest rate is used as the discount rate. Most smallholder farmers obtain farming loans from the Government owned commercial bank, Agribank at 20% interest rate. A 20% discount rate was therefore used to discount future benefits into today's values.

The Benefit Cost Ratio (BCR) was also calculated with the provision that if the BCR ≥1 then it is profitable to adopt the technology when the cost and benefit streams are discounted at the opportunity cost of capital (Gittinger, 1995).

Results

Supplementing manure with mineral fertilizer

Greater benefits were obtained when manure was supplemented with some mineral fertilizers. Using 5 t ha^{-1} of manure produced a yield advantage of 84% compared to not using any fertility inputs. The addition of 20 kg N provided a further 45% yield gain compared to using manure only (Table 40.1). The maize yield increased at a decreasing rate with successive additions of mineral fertilizer.

Table 40.1: Marginal rates of return for manure and mineral fertilizer combinations

Variables	0 Manure+	5 t/ha manure +				
	0 fertilizer	0 fertilizer	20kgN ha^{-1}	40kg N ha^{-1}	80kg N ha^{-1}	100kg N ha^{-1}
Yield (t ha^{-1})	1.18	2.17	3.14	3.96	4.59	5.03
Adjusted yield (10%)	1.06	1.95	2.83	3.564	4.13	4.53
Selling Price(Z$ ton^{-1})	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00
Gross Benefit(Z$)	9027.00	16600.50	24021.00	30294.00	35113.50	38479.50
Total Variable Costs (Z$ ha^{-1})	7877.40	8745.90	10555.80	12365.70	17795.40	19605.20
Net Benefit (Z$ ha^{-1})	1149.60	7854.60	13465.20	17928.30	17318.20	18874.30
Rate of Return (%)	15	90	122	134	105	100
Marginal Net Benefit(Z$)	NA	6705.00	5322.10	4174.60	622.70	1267.60
Marginal Variable Cost (Z$)	NA	868.60	2098.40	2098.40	4196.80	2098.40
Marginal Rate of Return (MRR) %	NA	772%	254%	199%	15%	60%

Note: 1US$ = Z$55

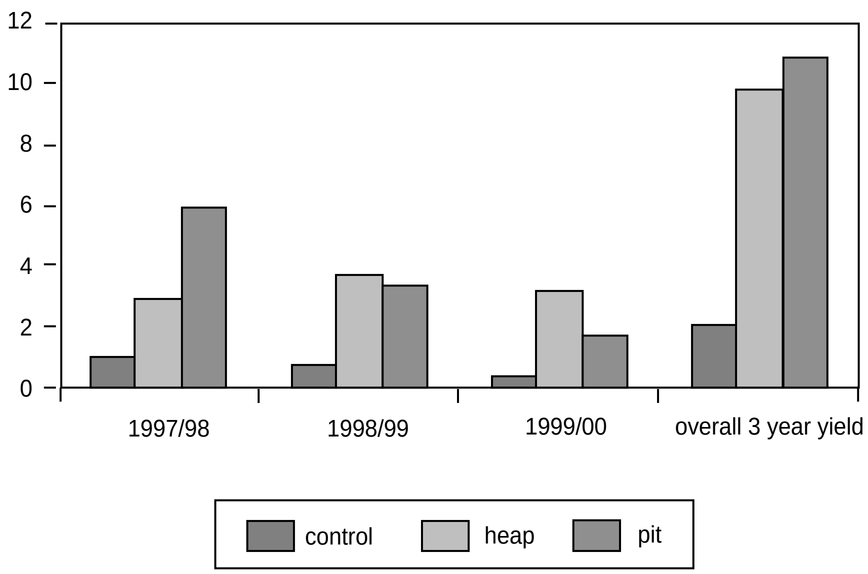
All treatments produced positive net financial benefits including the no fertility inputs option (Table 40.1). Supplementing 5 t ha^{-1} of manure with 40 kg N ha^{-1} produced the highest rate of return (134% $\$^{-1}$) invested (Table 40.1). Higher levels of N offered lower returns per dollar invested compared to 20 and 40 kg N ha^{-1}. The practice of not using any manure and mineral fertilizer only offered a 15% return on investment. The use of 5 t ha^{-1} of manure without any mineral fertilizer increased the rate of return 6 fold to 90% (Table 40.1), compared to not using any manure and mineral fertilizer. Use of manure alone offered a marginal rate of return of more than 300% compared to not using manure. The marginal rate of return increased to more than 400% by supplementing the 5 t ha^{-1}of manure with 20kg N ha^{-1}. The marginal rate of return declined with higher levels of mineral fertilizer (Table 40.1).

Marginal net benefit first increased with the first 20 kg of N but declined with successive additions of N. On the other hand the marginal variable cost, which is the extra cost incurred by using an additional bag of mineral fertilizer, remained constant, since it is the price of each additional bag of fertilizer. On the basis of the Marginal Approach in evaluating profitable level of input use, the most profitable level of fertilizer is given where the marginal benefit will be equal to the marginal cost (Hill, 1990). The most optimum level of N to apply per hectare was found to be 43 kg N ha^{-1} .

Comparisons of the effectiveness of pit and heap stored manure

In the first year of manure application, manure stored anaerobically in pits produced a 104% yield gain compared to that aerobically stored on a heap (Figure 40.1). Heap stored manure offered 11 and 88 % yield gain in the second and third seasons respectively and offered higher residual fertility compared to storing manure in pits.

Figure 40.1. Residual effects of pit and heap stored manure on maize yield on a sandy soil in Murewa, 1997/98 to 1999/00 season



The two manure storage methods all produced positive net financial benefits in all the three seasons. (Table 40.2). Negative financial returns were obtained in all the three seasons for the control. In the first season of application, a rate of return of 219% was obtained from pit stored manure compared to 70% from heap stored manure. The trend was reversed in the second season in which manure stored on a heap offered a 244% return compared to 210% from pit stored manure (Table 40.2). Investment in the use of heap stored manure provided a more than 200% MRR compared to the control in the first year of application. A MRR of more than 1900% was obtained from pit stored manure in the first year of application compared to heap stored manure (Table 40.2).

Table 40.2: Analysis of the profitability of using pit and heap stored manure and residual effects over 3 years at prices deflated for inflation

Variables	1997/98 Season			1998/99 Season			1999/2000 Season		
	Control	Heap	Pit	Control	Heap	Pit	Control	Heap	Pit
Yield (t ha^{-1})	0.94	2.89	5.88	0.69	3.71	3.34	0.41	3.17	1.69
Adjusted yield (10%)	0.84	2.60	5.29	0.62	3.34	3.01	0.37	2.85	1.52
Selling Price (Z$ ton^{-1})	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00
Gross Benefit (Z$)	7191.00	22108.50	44982.00	5278.50	28381.50	25551.00	3136.50	24250.50	12928.50
Total Variable Costs (Z$ ha^{-1})	8247.40	12982.70	14096.60	8247.40	8247.40	8247.40	8247.40	8247.40	8247.40
Net Benefit (Z$ ha^{-1})	-1056.40	9125.80	30885.50	-2968.90	20134.10	17303.60	-5110.90	16003.10	4681.10
Rate of Return (%)	-13	70	219	-36	244	210	-62	194	57
Marginal Net Benefit	NA	10182.20	585.30						
Marginal Variable Cost	NA	4735.40	5.60						
Marginal Rate of Return (MRR)	NA	215%	1954%						
Net Present Values (NPV)	-1056.40	9125.80	30885.50	-2474.00	16778.50	14419.70	-4259.00	13336.00	3901.00

Note: 1US$ = Z$55

Undiscounted overall three year net financial benefits were 17% higher for pit than for heap stored manure and the benefits increased to 25% when discounted using a 20% discount rate (Table 40.3). Sensitivity analysis revealed that the higher the discount rate, the higher the benefits from pitting manure compared to heap stored manure. Pit stored manure had a higher BCR, 1.72 compared to 1.49 from heap stored manure. This further confirms the profitability of pit stored manure compared to heaping. A 47% increase in all costs will render heap storage unprofitable with a BCR of less than 1 whereas it will take more than a 77% increase in overall costs to make pit storage unprofitable. Another sensitivity analysis on labour revealed that a 200% increase in the price of labour would make storing manure on heaps unprofitable. It would take a 600% increase on the current labour prices to make pit storing manure unprofitable. The break even grain price for heap and pit stored manure is $3400 and $ 3100 respectively all being equal.

Table 40.3: Overall benefits over 3 years of using pit and heap stored manure on sandy soils in Murewa

Factor	Control	Pit	Heap
Total harvest (tonnes)	1.83	9.82	8.79
Total Net Financial Benefit (Z$)	-9136.10	52870.20	45263.10
Net Present Values (NPV)	-7789.50	49206.10	39240.20

Note: 1US$ = Z$55

Effect of Manure Placement Methods on Maize Yield

Banding and placing manure on-station produced higher yields for both pit and heap stored manure compared to the farmer practice of broadcasting manure (Table 40.4). Pit stored manure yielded more than heap stored manure in all the different placement methods, banding, broadcasting and station placement. Banding heap stored manure yielded more compared to placing it on-station or broadcasting it. On-station application of pit stored manure marginally out-yielded banding though it was not statistically significant. Broadcasting manure gave the least yield compared to the other two methods, (banding and station placement).

The rate of return for heap stored manure was negative for broadcasting and station placement. A 6% rate of return was obtained for banded heap stored manure (Table 40.4). Net financial benefits for pit stored manure were positive for all the three different placement methods. Banding and station placement produced more than a 70 % rate of return while broadcasting offered a 50% return to investment (Table 40.4). A sensitivity analysis on labour rates revealed that a 50% increase in labour costs made heap stored manure unprofitable. Increases in labour rates of more than 100% reduced rates of return for pit stored manure to less than 20%.

Table 40.4: Marginal rates of return for pit and heap stored manure using different application methods (banding, on-station and broadcasting)

Variables	Heap, Broadcasted	Heap, Banded	Heap, On-station	Pit Broadcasted	Pit, Banded	Pit On-station
Yield(t ha^{-1})	1.01	1.79	1.39	2.76	3.22	3.30
Adjusted yield (10%)	0.91	1.61	1.25	2.48	2.90	2.97
Selling Price(Z$ ton^{-1})	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00
Gross Benefit(Z$)	7726.50	13693.50	10633.50	21114.00	24633.00	25245.00
Total Variable Costs (Z$ ha^{-1})	12804.30	12891.20	13291.80	13964.00	14050.80	14451.40
Net Benefit (Z$ ha^{-1})	-5077.80	802.30	-2658.30	7150.00	10582.20	10793.60
Rate of Return (%)	-40	6	-20	51	75	75
Marginal Net Benefit (Z$)	NA	-1574.10	-1564.70	1861.70	1516.10	2031.50
Marginal Variable Cost (Z$)	NA	-56.70	85.10	28.40	28.40	28.40
Marginal Rate of Return (Z$)	NA	2776%	-1840%	6567%	5348%	7176%

Note: 1US$ = Z$55

Discussion

The use of manure with smaller quantities of mineral fertilizers offers much larger productivity gains compared to using mineral fertilizer alone or manure alone. Combinations of mineral fertilizers and manure generally yield better though responses are very variable across sites because of the variability of the manure quality and site characteristics (Murwira *et al.*, 1998). From this study the most optimum level of supplementing 5 tonnes of manure was 43 kg N ha^{-1}. Sensitivity analysis revealed that an increase of more than 50% in the price of mineral fertilizer would make higher rates of supplementation less favourable with MRR. The variation in responses across different sites makes blanket recommendations impractical. Recommendations on supplementing organic materials with mineral fertilizers should be area specific. Application of inorganic fertilizer with manure can reduce the risks of economic losses and increase the probability of higher financial returns. Results from the study indicate that supplementing manure with mineral fertilizers can significantly increase net financial returns.

The improvement of manure quality through pit storage on the farm provides a realistic option for improving productivity in the smallholder sector. For resource constrained households that cannot raise enough cash to buy mineral fertilizers, pit storage is a technology which makes it possible for farmers to substitute cash requirements for soil fertility management with their labour. Despite the evident benefits of storing manure in pits, more than 65% of smallholder farmers who use manure in Murewa store their manure on a heap. Extension is silent on how farmers can improve their manure for effective utilization despite the research evidence that manure from the smallholder farming sector is of very poor quality. Most farmers are likely to adopt this technology given that technologies that offer larger benefits in the first season of adoption are likely to be adopted than those which yield benefits later in the project cycle like heaping manure (Gittinger, 1995).

The yield benefits from manure application can be increased for both heap and pit stored manure if the appropriate method of application is used. Pit stored manure produced higher rates of returns on all the different application methods compared with heap stored manure. Studies done in Zimbabwe have identified banding and station placement as the most rewarding placement methods (Mubonderi *et al.*, 1999).

Though most farmers in Zimbabwe broadcast their manure, results from this analysis show that this is not a profitable option especially for heap stored manure. Farmers can realise greater returns by either banding or station placement of the manure. However labour requirements for banding and station placement make these options unattainable for labour constrained households. Manure application methods are becoming more targeted in reaction to reduced livestock numbers and increase in the prices of mineral fertilizers (Snapp *et al.*, 1997; Ahmed *et al.*, 1997).

Smallholder farmers in Zimbabwe supplement manure with varying levels of mineral fertilizers but yields are still below potential due to inadequate amounts, poor quality of organic materials and inefficient combinations (Murwira and Palm, 1998). To these farmers what is more critical is how much of mineral fertilizer should supplement the manure for maximum benefit. A range of combinations that are profitable should be recommended to farmers given their different resource endowments and variability of the quality of manure from 0.1 to 1.9% N content depending on the management and handling of the manure (Nzuma and Murwira, 2000). Specific decision guides could be developed to provide farmers with guidelines for supplementing different quality manures with mineral fertilizers (Figure 40.1). These decision guides need to be farmer-friendly and take account of available quantities of manure and fertilizer N, farmer perceptions of quality and other management factors like soil type and methods of application.

Conclusion

Economic returns are an important determinant of technology use (CIMMYT, 1988). The options that offer higher economic returns have been identified in this study and merit further testing with farmers.

Extension can play a major role in expanding further testing and adoption of these options by farmers. Information on how farmers can realise maximum returns by supplementing organic materials with mineral fertilizer seems not available or if available it is scanty yet this option provides substantial opportunities for increasing productivity in the smallholder farming sector.

Most farmers find it difficult to raise the capital required for investments in mineral fertilizer and find it cheaper to invest their labour than capital. Despite the additional labour requirements of pit storing, manure farmers can invest their labour and be able to realise returns of more than 100% from utilizing pit stored manure. Concerns have been raised about labour availability in the smallholder farming sector especially considering the high incidences of HIV. Labour shortages are likely to discourage adoption of pit storing but an in-depth study is required to ascertain labour availability and its impact on adoption of labour intensive technologies.

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