The financial benefits of integrated soil fertility management

Using inorganic fertilizer in combination with other ISFM practices

By

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Abstract.

Soil fertility depletion has been singled out as the fundamental cause of low per capital food production in sub Saharan Africa (SSA). Soil fertility depletion is mainly caused by physical soil loss from erosion nutrient leaching and nutrient mining from continuous cropping. The use of organic manure, inorganic fertilizer and leguminous crops has been advocated to restore lost fertility. However, farmers' resource limitations and endowments on one hand and different soil requirement on the other demand integrated management of soil fertility. Field trials and experiments done on these different soil fertility restoring technologies have successfully shown huge increase in output. However, due to their different cost implications, their profitability may differ hence affecting their adoption by famers.Using data from Kenya and Tanzania, this paper evaluates the financial benefits of using inorganic fertilizer combined with organic manure and legume intercrop in maize based systems. The combined application of organic manure plus inorganic fertilizers gives highest net cash returns and returns to labor. Intercropping maize with pigeon peas also provides high net returns when combined with inorganic fertilizers. The implication of this is that by applying organic manure and intercropping with legumes, the amount of inorganic fertilizers can be reduce without reducing total output and net revenue. This can translate into reduced subsidy costs with less pressure on government budgets.

1.0 INTRODUCTION

Soil fertility depletion has been singled out as the fundamental cause of low per capital food production in sub Saharan Africa (SSA). Fertility depletion is mainly caused by physical soil loss from erosion, leaching of nutrients from agricultural fields and nutrient mining from crop harvest. Over decades, small-scale farmers in SSA have removed large quantities of nutrients from the soils without using sufficient organic manure or inorganic fertilizer to replenish them. Sanchez, (2002) estimated an annual loss equivalent to US$4 billion in fertilizer from nitrogen, phosphorous and potassium in the last 30 years in 37 Sub-Saharan African countries. This has negatively affected production of both food and cash crops.

In an effort to address this problem, researchers in different disciplines have conducted studies aimed at finding better solutions that can replenish the lost soil fertility. Soil scientists have established that soil fertility is better improved by additions ofboth organic manure and inorganic fertilizers (Woomer and Swift 1994; Palm, Gachengo et al. 2001; Vanlauwe, Diels et al. 2002; Vanlauwe and Giller 2006; Tittonell et al, 2008; Chivenge et al, 2011), and intercropping with legumes (Kimaro et al, 2009; Chamshama et al, 2006) in what is termed integrated soil fertility management (ISFM)[1].The ISFM paradigm acknowledges the need for both organic and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them (Buresh et al., 1997; Vanlauwe et al., 2002a). However, these approaches to soil fertility management rely on different household resources, for example fertilizers require financial capital and organics mainly require labor, land (Place et al 2003) and livestock (Kassie et al 2009).Access to animal manure is often constrained in African farming systems (Kumwenda et al. 1996) as is access to land.

[1]Integrated soil fertility management is defined as the application of soil fertility management practices and the knowledge to adapt these to local conditions, which maximize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm (Vanlauweet at, 2010).

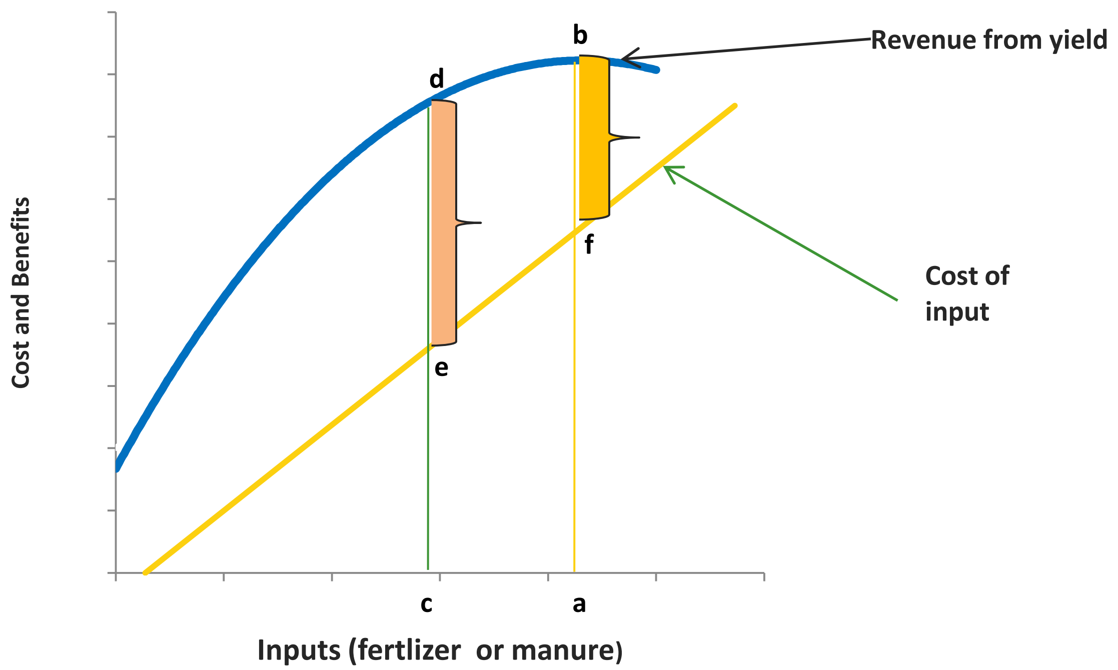
With imperfect markets for inorganic fertilizer and output, and missing markets for organic manure, use of these will much depend on the farmers' characteristics and resource endowments. Most of the evidence of the benefits of ISFM has been shown using physical crop output. Fewer economic studies have been done on the different inputs costs and benefits. This paper uses a number of studies that quantified the physical benefits and extends by assessing the costs and benefits of combining organic manure and inorganic fertilizer and the use of legumes (specifically pigeon peas) in maize based cropping systems in Kenya and Tanzania.

The combined application of organic resources and mineral fertilizers is increasingly gaining recognition as a viable approach to address soil fertility decline in sub-Saharan Africa (SSA) (Chivenge et al. 2011). A number of benefits for combined use have been identified. Several attempts to quantify the size of added benefits and the mechanisms creating them have been made. Vanlauwe et al. (2002b) reported positive interactions between urea and use of stover and other organic applications while Nhamo (2001) observed added benefits from manure and ammonium nitrate combinations. Chivenge et al (2011) conducted a meta analysis of studies from 12 countries in SSA to provide a comprehensive and quantitative synthesis of conditions under which organic fertilizers (ORs), N fertilizers, and combined ORs with N fertilizers positively or negatively influence *Zea mays* (maize) yields, agronomic N use efficiency and soil organic carbon (SOC) in SSA. They found that yield responses were greater following the combined application of ORs with N fertilizers compared to the addition of either input alone.

Intercropping of maize and legumes has also proven to increase maize yields over time. Kimaro et al (2009) found that intercropping maize and pigeon peas, enhanced maize yields over sole maize only when fertilized which indicated nutrient competition. Improved fallow (i.e. intercropping maize and pigeon peas in different fallows) with and without inorganic fertilizer both increased maize yield by 1.6

tons/ha and 1.2 ton/ha respectively over sole maize with inorganic fertilizer. They also found that combined fertilizer and manure application improved maize and pigeon peas yield.

All the above studies indicate positive physical impact on maize yield. However, all inputs used (inorganic fertilizer, organic manure and the pigeon pea seeds) are not cost-less and available to households in different quantities and quality. The maximum agronomic yield may not be the profitable yield when input costs are positive. The graph below presents this point. Given a normal relationship between input and output, and multiplying by the prices we get the revenue curve and the cost line. The highest revenue (line ***a-b***) is not the highest profit point given positive cost of inputs. Line ***a-b*** gives profit ***b-f*** but highest profit is obtained at ***d-e*** where the total revenue ***d-c*** is less than highest revenue ***a-b.*** With this in mind, this paper extends on two studies done by Tittonel et al. (2008) in Kenya and Chamshama et al. (2006); Kimaro et al. (2009) in Tanzania and evaluates the profitability of two ISFM technologies, combination or organic manure and inorganic fertilizer and intercropping of pigeon peas and maize. . This is done by creating full crop budgets mainly for maize cropping systems given different input prices for Kenya and Tanzania.



An illustration of the effect of positive cost of inputs on profit

2.0 MATERIALS AND METHODS

This paper uses published research output from Kenya and Tanzania (Chamshama et al 2006; Kimaro et al 2009; Tittonel et al 2008). This is mainly from research trials where different methods of ISFM were experimented and yields of maize obtained. This paper extends on the yield output by assuming cost of inputs per ha and calculating a number of economic indicators e.g. profit, breakeven prices at full cost and on cash basis returns to family labor, gross margin (see table 1). Family labor is one of the main resources rural households own. However, it is not frequently traded on the markets hence does not have direct price. This paper uses rural wage rate for family labor cost in the different areas to estimates total labor cost. The final financial analysis presents results taking into account cash expenditures alone and then the combination of cash expenditures and full costs associated with the use of family labor. Organic manure is also not commonly traded and involves a lot of work. The preparation, transportation, and application of organic manure are labor demanding which may reduce their net benefit and use. This is included with an assumption of how much labor it would cost per person /day to apply manure on one hectare of land. Basic hired labor costs are assumed to apply in manure use and used in this analysis. Table 1 below presents details of the analysis done in the crop budgets. Prices for the analysis are obtained from different reports in the past 2 years. The farm gate price for maize price was pegged at US$0.30 per kg and US$0.20in Tanzania and Kenya respectively (Yamano and Arai, 2010). Fertilizer and seed prices were obtained from AMISTA (http://www.amitsa.org/). Maize is assumed to demand a total of 180 man days (i.e. 3 people working on 1 hectare of land of hybrid maize for 60 days).

Wage rates were obtained from Wikipedia (http://en.wikipedia.org/wiki/List_of_minimum_wages_by_country). The minimum wage rates used for estimating labor costs are US$1.2/day for Tanzania and US$1.4/day for Kenya. Cost estimates are approximate, but using the budget spreadsheets they can easily be adjusted to take into account different assumptions about key components such as the wage rate where there might be some controversy about the "correct" value.

Table 1: Crop Budget Estimate for maize: financial, per hectare/season

OUTPUT:	Unit	Yield	Unit Price, US$	Value, US$
Main product: Grain	kg			Yield*Unit price
Total Farm gate Value	**US$/ha**			
VARIABLE COSTS:	**Unit**	**Rate/Quantity**	**Unit Price, US$**	**Costs**
Seeds/planting material	g			Quantity *Unit price
Fertilizer - basal/compound	kg			Quantity *Unit price
Fertilizer - top dress/other	kg			Quantity *Unit price
Manure cost (labor)	kg			
Total Variable Costs (Cash Basis)	**US$/ha**			
GROSS MARGIN (Cash Basis)	**US$/ha**			**Total revenue- Total V cost**
LABOR COSTS	**Unit**	**Rate/Quantity**	**Unit Price, US$**	**Costs**
Family Labor	person day			Quantity *Unit price
Total Labor Costs	**US$/ha**			
TOTAL COSTS				**Total V cost + Total L cost**
NET MARGIN				**Gross Margin-Total cost**
RETURNS				
Returns over Variable costs				Total Revenue- Total cost
Benefit cost ratio (full cost basis)				Total revenue/Total cost
Benefit cost ratio (cash cost basis)				Total Revenue/Total V cost
Return to Family Labor day	US$/day			Total Revenue/Total L cost
Breakeven price on cash basis	US$/kg			Total V cost/ Yield
Breakeven price on Full cost	US$/kg			Total cost/Yield
Break even Yield cash basis	Kg			Total V cost/Yield unit price
Break even Yield full cost	Kg			Total cost/Yield unit price

Table 2: Maize yield from Tanzania under pigeon peas intercrop and combination of manure and fertilizers

	no fertilizer *(tons/ha)*	**fertilizer (40kh/ha N 20kg/ha P)** *(tons/ha)*	**fertilizer (80kh/ha N 40kg/ha P)** *(tons/ha)*
Sore maize	1.1	1.5	2.1
Intercrop (maize/pigeon peas)	1.3	1.8	2.3
No manure	0.9	1.55	2.4
Manure (5tons/ha)	1.1	1.8	2.35
Manure (10tons/ha)	1.5	2.1	2.5

Data source: Chamshama et al 2006; Kimaro et al 2009

3.0 RESULTS AND DISCUSSION

Financial analysis of the farm budgets confirms thatthe addition of the organic and inorganic fertilizer and intercropping with legumes increase net profit per hectare. Intercropping maize with pigeon peas also provides high net returns when combined with inorganic fertilizers. Tables 3, 4 and 5 in annex present all financial analysis results. In the Tanzania trials, (Figure 1), fertilizer maize under intercrop had the highest profit of US$305/ha which was about US$100 more than sole maize crop. Interestingly intercropping maize with half the recommended fertilizer rate gave almost similar profit margins to sole full rate fertilized maize US$431.80/ha and US$430.9/ha respectively. It should be noted that profits from pigeon peas have not been included in this analysis. Therefore the total profit from the intercrop is much higher under the intercrop that sole maize crop.

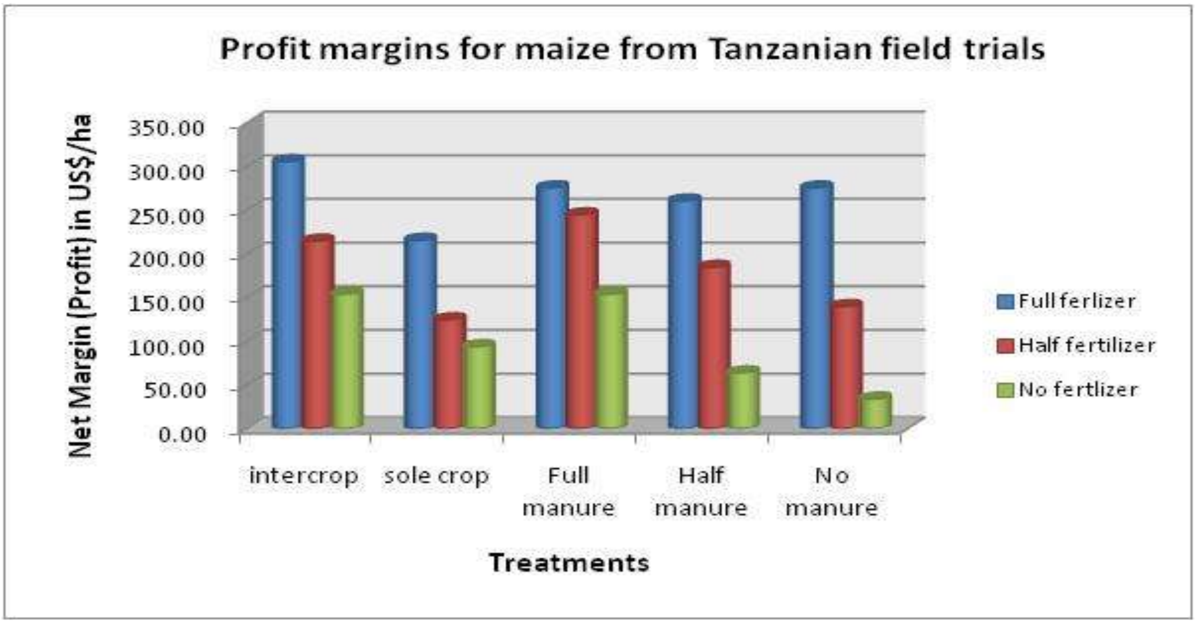


Figure 1: Profit margins for maize from Tanzania.
Data source for analysis: Kimaro et al (2009)

Organic manure also generally increased the profit margins when combined with inorganic fertilizers. However the addition of extra cost from manure (primarily the labor) reduced the profit even though the physical output was significantly higher that when fertilizer was used alone. There was no significant difference in profit from maize when fertilizer was used at full rate in all three manure treatments. As this was a one year experiment, long term effect of manure was not observed.On the other hand it could be as a result of soil having already high organic matter and hence not affected by the additional organic matter. Tittonel at al (2008) reported that in field trials in Kenya, crop productivity was larger during the first three to four seasons of application of mineral fertilizers than with application of manure of best quality. They further said that replacement of fertilizer i.e. application of the same amounts of N and P as in manure and basal fertilizer led to similar productivity levels in responsive and fertile fields. This could indicate that the Tanzanian trial could have been done on already fertile soil. In addition manure application was also high (10tons/ha) and this increased the total labor cost. However, there is anincrease in profit of US$30.9 from half to full fertilizer rate with full manure treatment but this comes with an additional cost of US$89 from fertilizer. Therefore, fertilizer costs can be reduced without having a significant reduction in profit when fertilizer is combined with manure.

Kenyan data provided a different picture as the trials were done for 12 years (figure 2). Combination of manure and inorganic fertilizer gave a higher profit margin than fertilizer alone. There was an additional profit of US$180 from maize when fertilizer was combined with manure than when fertilizer was used alone. Manure use alone also gave higher profit of US$403/ha than fertilizer alone of US$343/ha. This confirms with what a number of organic farming advocates proclaim. However, a lot more profit (US$120/ha) can be achieved by adding inorganic fertilizer which is very significant for poor African farmers.

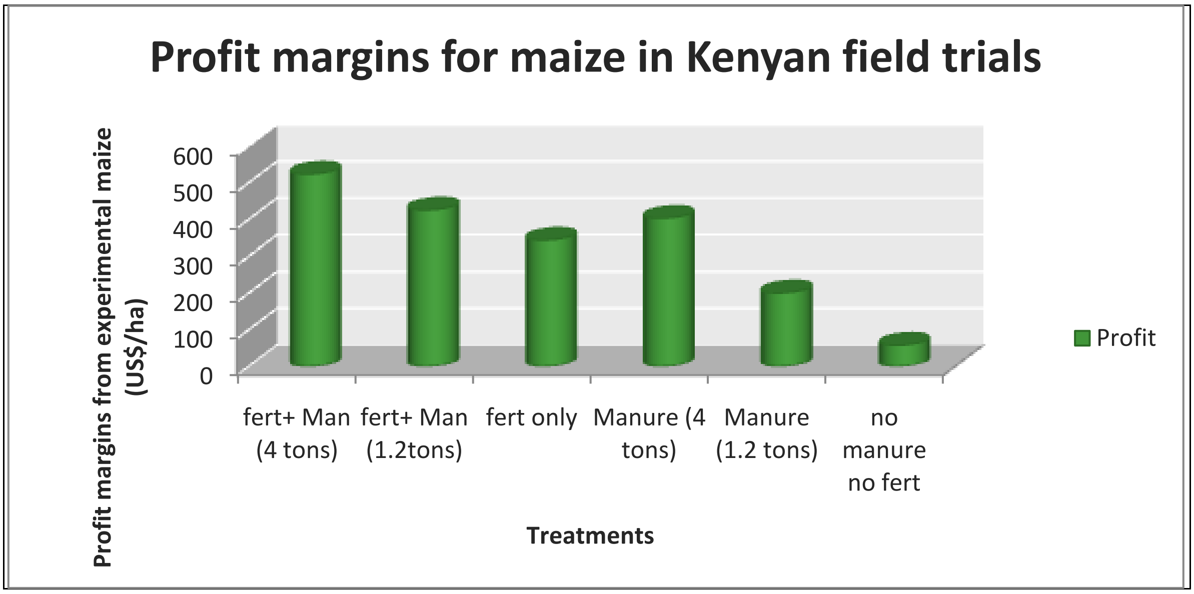
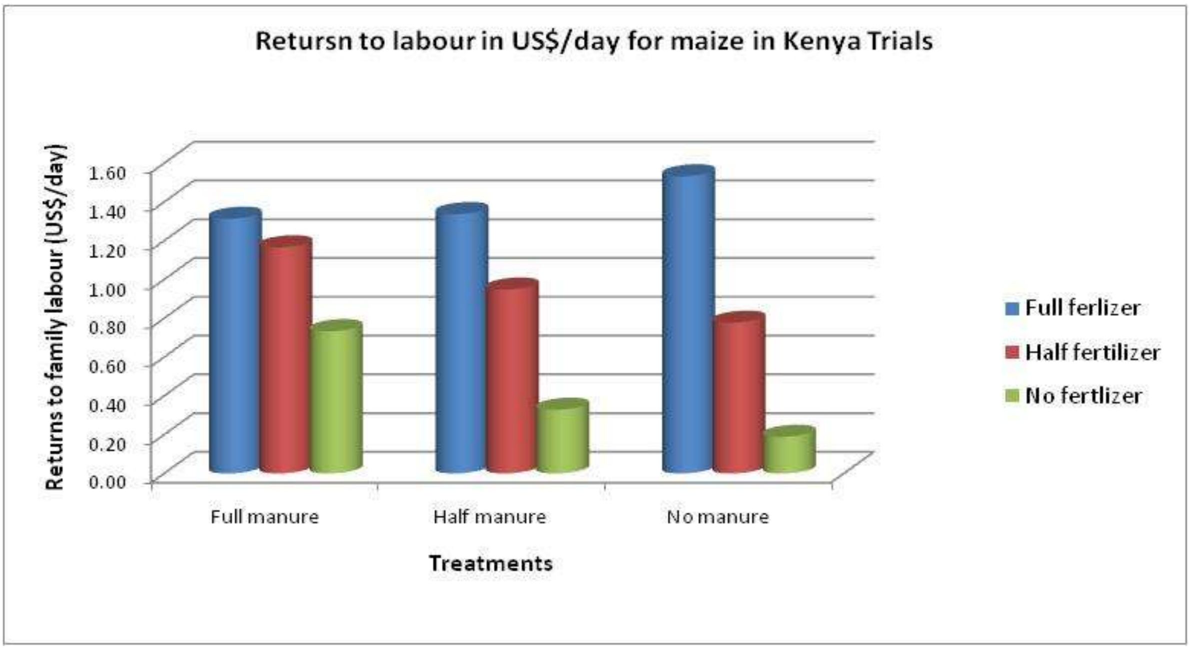


Figure 2: Profit margins for maize in Kenyan field trials
Data source for analysis: Tittonel et al 2008

Another interesting statistic is the return to family labor. The main constraint of using organic manure in areas where they are available is the labor demanded to transport and apply them in the field. Using the Kenyan field trial data, returns to labor under combined fertilizer and manure maize was US$1.31/day. Mekuria and Waddington, (2002) found similar returns of about $1.35 per day to labor in the integration of manure and fertilizer on maize in Zimbabwe. Place et al., (2002)found that returns to integrated biomass transfer and rock phosphate systems on kales and tomatoes in Kenya showed returns to labor of between $2.14 to $2.68 as compared to a best return of $1.68 when only one of the options were used. However kale and tomatoes are high value crops hence higher returns compared to maize. Increasing maize output price therefore could have a positive impact on profit and returns to labor.



The graph above also shows that returns to labor is highest when only fertilizer is used. These results from the reduction in labor demands associated with the manure application. However, half fertilizer and full manure, does not reduce the returns to labor. Therefore the farmer is still paid back well again when using both inputs that not using them at all (no manure no fertilizer) or using manure alone.

4.0 CONCLUSION

The evidence presented above indicates that indeed organic and inorganic nutrient systems can increase profits and returns to famers. There is enormous potential in East Africa to boost yield by integrating the smaller amounts of fertilizer with organic inputs and improved germplasm. Given limited and different resources endowments of farmers, different combinations of manure and fertilizer or intercropping maize and legumes are superior to single approaches. This raises questions about what governments that are promoting fertilizer subsidies can do encourage adoption of practices that have the capacity to improve the use-efficiency of the subsidized fertilizers. The implication of this is that by applying organic manure and intercropping with legumes, the amount of inorganic fertilizers can be reduce without reducing total output and net revenue. This can translate into a reduced cost for fertilizer subsidies and reduce pressure on government budgets. Recently, many governments have instituted fertilizer subsidy programs. Making fertilizers less expensive for farmers through subsidies is a commendable goal, but unless these subsidy programs are accompanied by a concerted effort to promote other fertility management option e.g. organic manure or legume intercrops, governments will fail to realize the full benefits of their expenditures on fertilizer subsidies, and most farmers will fail to improve productivity enough to be able to finance fertilizer and other complementary inputs on their own in the future. One can even imagine some situations where the yield and income effects of ISFM are so positive that direct government support to educating farmers about ISFM might be a viable alternative to subsidies rather than a complement.

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ANNEX: FINANCIAL ANALYSIS RESULTS

Table 2: Financial analysis of organic manure and inorganic fertilizer on maize in Tanzania

Financial indicators		Full fertilizer rate 200 kg Urea and 100kgs TSP			Half fertilizer rate 100kg Urea and 50kgs TSP			No fertilizer		
	units	Full manure *(10 tons)*	Half manure *(5 tons)*	No manure	Full manure *(10 tons)*	Half manure *(5 tons)*	No manure	Full manure *(10 tons)*	Half manure *(5 tons)*	No manure
GROSS MARGIN (Cash Basis)	*US$/ha*	551.80	506.80	491.80	520.90	430.90	355.90	430.00	310.00	250.00
NET MARGIN (Profit)	*US$/ha*	275.80	260.80	275.80	244.90	184.90	139.90	154.00	64.00	34.00
Returns over Variable costs	*US$/ha*	275.80	260.80	275.80	244.90	184.90	139.90	154.00	64.00	34.00
Benefit cost ratio (full cost basis)		1.58	1.59	1.67	1.64	1.52	1.43	1.52	1.24	1.14
Benefit cost ratio (cash cost basis)		3.78	3.56	3.48	5.77	4.95	4.26	22.50	16.50	13.50
Return to Family Labor day	*US/day*	1.31	1.34	1.53	1.17	0.95	0.78	0.73	0.33	0.19
Breakeven price on cash basis	*US$/kg*	0.08	0.08	0.09	0.05	0.06	0.07	0.01	0.02	0.02
Breakeven price on Full cost	*US$/kg*	0.19	0.19	0.18	0.18	0.20	0.21	0.20	0.24	0.26
Break even Yield cash basis	*Kg*	660.67	660.67	660.67	363.67	363.67	363.67	66.67	66.67	66.67
Break even Yield full cost	*Kg*	1580.67	1480.67	1380.67	1283.67	1183.67	1083.67	986.67	886.67	786.67

Table 3:Financial analysis of intercropping maize and pigeon peas in Tanzania

		Full fertilizer rate 200 kg Urea and 100kgs TSP		Half fertilizer rate 100kg Urea and 50kgs TSP		No fertilizer	
		Intercrop with PP	Sole crop	Intercrop with PP	Sole crop	Intercrop with PP	Sole crop
GROSS MARGIN (Cash Basis)	*US$/ha*	521.80	431.80	430.90	340.90	370.00	310.00
NET MARGIN (Profit)	*US$/ha*	305.80	215.80	214.90	124.90	154.00	94.00
Returns over Variable costs	*US$/ha*	305.80	215.80	214.90	124.90	154.00	94.00
Benefit cost ratio (full cost basis)		1.74	1.52	1.66	1.38	1.65	1.40
Benefit cost ratio (cash cost basis)		3.63	3.18	4.95	4.12	19.50	16.50
Return to Family Labor day	*US$/day*	1.70	1.20	1.19	0.69	0.86	0.52
Breakeven price on cash basis	*US$/kg*	0.08	0.09	0.06	0.07	0.02	0.02
Breakeven price on Full cost	*US$/kg*	0.17	0.20	0.18	0.22	0.18	0.21
Break even Yield cash basis	*Kg*	660.67	660.67	363.67	363.67	66.67	66.67
Break even Yield full cost	*Kg*	1380.67	1380.67	1083.67	1083.67	786.67	786.67

Table 4: Financial analysis from farm budget from field experiments in Kenya.

		Manure		
WITH FERTILIZER		4 tons	1.2 tons	0
Gross margin (Cash Basis)	*US$/ha*	805.60	685.60	595.60
Net margin (Profit)	*US$/ha*	523.60	425.60	343.60
Returns over Variable costs	*US$/ha*	523.60	425.60	343.60
Benefit cost ratio (full cost basis)		2.20	2.03	1.85
Benefit cost ratio (cash cost basis)		6.22	5.44	4.86
Return to Family Labor day	*US$/day*	2.73	2.31	1.91
Breakeven price on cash basis	*US$/kg*	0.03	0.04	0.04
Breakeven price on Full cost	*US$/kg*	0.09	0.10	0.11
Break even Yield cash basis	*Kg*	772.00	772.00	772.00
Break even Yield full cost	*Kg*	2182.00	2072.00	2032.00
NO FERTILIZER				
Gross margin (Cash Basis)	*US$/ha*	730.00	490.00	310.00
Net margin (Profit)	*US$/ha*	403.00	200.50	58.00
Returns over Variable costs	*US$/ha*	403.00	200.50	58.00
Benefit cost ratio (full cost basis)		2.16	1.65	1.21
Benefit cost ratio (cash cost basis)		37.50	25.50	16.50
Return to Family Labor day	*US$/day*	1.92	1.03	0.32
Breakeven price on cash basis	*US$/kg*	0.01	0.01	0.01
Breakeven price on Full cost	*US$/kg*	0.09	0.12	0.16
Break even Yield cash basis	*Kg*	100.00	100.00	100.00
Break even Yield full cost	*Kg*	1735.00	1547.50	1360.00