Can manure lift crop production in communal lands of semi-arid Zimbabwe?

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Abstract

We report on farmer-participatory testing of strategies to increase manure use on crops to improve food sufficiency in communal farming lands of semi-arid southern Zimbabwe. In seeking to overcome farmers' reluctance to use kraal manure, we tested cattle and goat manure, and methods of preparation (composted in heaps, heaps covered with soil, and in pits) on farmers' fields in Tsholotsho and Gwanda South. Most methods increased yields, and farmers assessed them as practical and effective. Modelling with APSIM helped promote engagement with farmers. Despite drought and economic conditions, the combination of three research approaches – on-farm participatory trials, modelling, and farmer surveys – has resulted in adoption of manure application, and opportunities for further adoption. While male-headed households tended to adopt fertilizer use, female-headed households accepted FYM. To help farmers invest, extension agents need to escape from ideal recommendations, and offer soil fertility improving technologies.

Media summary

Farmers in dry areas of Zimbabwe can overcome reluctance to invest in soil fertility, and increase yields, by use of under-utilized manure, though capacity to invest varies between differently-resourced households.

Key words

Sorghum, Simulation, Households, On-farm, Economics

Introduction

In Zimbabwe, 55% of land is semi-arid, with 63% of the rural population. These lands are recommended for semi-extensive and extensive farming, and have poor and erratic rainfall averaging 450-650 mm in agroecological region IV and <450 mm in region V. The soils are mainly derived from gneiss, with some deep sands, and some soils derived from basalt. Most are low fertility, after cultivation and erosion. Despite efforts to transfer fertilizer to farmers, few apply it, as it is risky and gives little return under low rainfall. Few farmers have utilized manures (FYM) from kraals believing them to be risky. We sought solutions to low yields, food insecurity and poverty in communal areas. Here we examine (1) results of on-farm testing of FYM, and (2) using simulation to increase efficiency of on-farm studies. We used a participatory approach with emphasis on agronomy, socio-economics and technology transfer. FYM methods, chosen by farmers, were evaluated by researchers and farmers in trials on farmers' fields.

Materials and methods

On-farm testing

We had two locations: Tsholotsho (lat 19 46 S, long 27 44 E, alt 1090 m) av 650 mm rainfall, with cambisols, luvisols, regosols and phaeozems (WRB), and Gwanda South (lat 21 34 S, long 29 02 E, alt 935 m) av 500 mm rainfall, with cambisols and luvisols (WRB). Table 1 is a weather summary in the 1999-00 and 2000-01. From 01 Dec to 31 Mar approximates the sorghum growing season. At Tsholotsho the 1999-00 season was dry, whereas 2000-01 was mildly droughty. At Gwanda South, the 1999-00 season was dry, and 2000-01 was droughty because of poor distribution. The technologies reported here included goat and cattle FYM, and 3 methods of FYM composting – heaped and covered, heaped and uncovered, deposited in a pit and covered. The trials were chosen by farmers who indicated a willingness to test manure.

Table 1. Weather summary for rainy seasons 1999/2001 at Tsholotsho and Gwanda South

Location	Year	**Month**	**Daily rad'n ($mJ\ m^{-2}$)**	**Max temp (^{o}C)**	**Min temp (^{o}C)**	**Rain total (mm)**
Tsholotsho	1999/00	Dec-Mar	20.7	28.6	15.5	340
	2000/01	Dec-Mar	19.8	26.6	15.3	590
Gwanda South	1999/00	Dec-Mar		29.1	19.4	1405
	2000/01	Dec-Mar		30.3	19.4	550

Economic evaluation

Enterprise and whole-farm budgeting was evaluated with @RISK. An enterprise budget was constructed for each FYM-aided production practice. Budgets were constructed using yield and input-output coefficients from survey data, on-farm experiments, and yields predicted by APSIM. Product values were obtained from government and farmer union sources, and input prices from suppliers.

Results

Manure quality aspects

Table 2. Analysis of quality of goat and cattle FYM from farms in Tsholotsho and Gwanda South in 1999-00 and 2000-01 – direct from kraal or composted by heaping/covering

Year	Manure type	Total N g/kg	Total P g/kg	Total C g/kg	C/N	NO_3-N mg/kg	Olsen P mg/kg
1999-2000	Cattle from kraal 1-20 yr (mean of 4)	10.8	1.4	168	15.5	1230	143
	Cattle heaped/covered (mean of 4)	11.0	1.2	167	16.2	1820	154
	Goat from kraal 1-3 years (mean of 3)	21.9	2.2	281	12.9	1180	2430
	Goat heaped/covered (mean of 4)	16.6	1.4	210	12.9	2670	1890
2000-	Cattle from kraal, age unknown (mean of	10.1	3.1	134	13.0	509	182

2001	2)						
	Cattle heaped/covered (mean of 3)	7.3	3.2	111	15.5	661	512
	Goat from kraal, age unknown (mean of 3)	18.7	7.6	235	12.7	2460	747
	Goat heaped/covered (mean of 3)	9.8	1.5	130	13.5	917	481

Total N and P concentrations vary, and generally higher in goat than cattle FYM. Organic C is also higher in goat than cattle FYM, and when <150, there may be greater inclusion of mineral soil. C/N ratio ranges from 13-17, and variation may be influenced by charcoal or lignin-derived material. High nitrate values indicate N mineralization while in the kraal, or during composting, and that any leaching of nitrate is incomplete. Accumulation of mineral P also occurs in the kraal or during composting.

*On-farm trials of FYM types and treatments (combined on-farm trial and simulations)***)**

We report from 4 farms in 1999-00 and 3 farms in 2000-01 where farmers tested goat and cattle FYM, and the effects of 3 pre-treatments, namely preparation by (1) storing the FYM in uncovered heaps, (2) storing in heaps covered with a layer of soil, and (3) storing in a pit covered with a layer of soil. FYM was taken to the field and applied in December prior to seeding. The experimental design was one or two FYM types (cattle and goat), two rates of FYM (0 and 5 t ha^{-1}), 3 treatments of the FYM, and 2 replicates. The experiment and the surrounding area were sown by the farmer using sorghum (cv Macia) in 0.9 m rows and later thinned to 0.25 m between plants within rows. At maturity, the researchers and farmers harvested the experimental plots, and researchers determined grain yield for all treatments. In some cases, the residual value was estimated in the following season. Farmers separately evaluated the plots by observation prior to harvest. Farmers were positive about the effect of FYM type and pre-treatment, but harvested yields showed little difference between cattle and goat FYM (Table 3) or between FYM treatments, except for heaped-covered FYM in 1999-00 (Table 4).

Table 3. Evaluation of cattle and goat FYM for sorghum yield (t/ha) – mean from Gwanda South

Season	No. of farms	Control (no input)	Cattle FYM	Goat FYM
1999/00	4	1.00	0.94	1.22
2000/01	3	1.05	0.99	0.98
Mean		1.03	0.97	1.10

Table 4. Evaluation of FYM methods of preparation for sorghum yield (t/ha) – means from cattle and goat FYM in Gwanda South

Season	No. of farms	No input control	Heaped covered	Heaped uncovered	Pit
1999/00	4	1.00	1.34	1.00	0.91

2000/01	3	1.05	0.97	0.92	1.06
Mean		1.03	1.15	0.96	0.99

On Johnson Nkomo's farm in Gwanda South, on a Chromi-Leptic Cambisol (WRB) site, we compared goat and cattle FYM, and evaluated 3 pre-treatments. This carefully managed site showed good response to FYM (Table 5). Since we were constrained to two years of trials, the APSIM model (McCown et al. 1996) was used to simulate sorghum yield for 1990-01. Outputs were compared with sorghum performance with different treatments in the same seasons, and were in the range of the field values. Encouraged by comments from farmers, we used simulation to assess climatic risk of soil fertility inputs (Table 6).

Table 5. Evaluation of cattle and goat FYM with 3 methods of preparation for sorghum grain yield (t ha^{-1}) on Johnson Nkomo's farm in Gwanda South

	No input	Cattle			Goat		
Season		Heaped covered	Heaped uncovered	Pit	Heaped covered	Heaped uncovered	Pit
1999/00	1.54	1.97	1.58	1.50	3.27	2.26	1.46
2000/01	1.83	2.07	2.82	2.08	1.53	1.81	1.85
Mean	1.69	2.02	2.20	1.79	2.40	2.04	1.65

Table 6. APSIM simulation of FYM with methods of preparation for sorghum grain yield (t/ha) on Johnson Nkomo's farm in Gwanda South – means of treatment groupings.

Season	No inputs	Uncovered	Covered	Pit	Cattle	Goat
Mean for 11 yrs	0.52	0.88	0.87	0.62	0.73	0.94
Range for 11 yrs	0.00-2.89	0.00-2.93	0.00-2.94	0.00-2.92	0.05-2.92	0.00-2.95
Failures per 11 yrs	7	2	1	1	0	1

FYM inputs with and without N fertilizer - combined on-farm trials and simulation

We used 3 farms in Tsholotsho and Gwanda South - S Mlambo (pelli-eutric vertisol (WRB)), B Moyo (eutric-aridic regosol (WRB)), and T Moyo (chromo-leptic cambisol (WRB)), a range of clay to sandy soils. There were 3 FYM inputs (0, 5 and 10 t ha^{-1}) with 2 replicates. FYM was applied in December prior to sowing. Sorghum was sown by the farmer in 0.9 m rows, later thinned to 0.25 m between plants. At maturity, researchers and farmers harvested the plots, and researchers determined yield of all treatments. Farmers evaluated the plots by observation. The simulation package APSIM was used to simulate sorghum growth and yield for 1990-2001 using weather station and soil data. Outputs were compared with sorghum performance of the treatments, and used to assess climatic risk of soil FYM inputs.

Table 7. APSIM simulation of effect of 3 levels of FYM inputs, and 3 levels of N fertilizer on sorghum grain yield (t/ha) on three farmers' fields in Tsholotsho and Gwanda South.

Farmer	Soil type		Zero FYM			FYM 5 t/ha			FYM 10 t/ha		
			0 N	9 N	18 N	0 N	9 N	18 N	0 N	9 N	18 N
B Moyo (Tsholotsho)	Sand	Mean	0.67	1.12	1.45	0.95	1.28	1.45	1.10	1.42	1.44
		Failures	6/11	0/11	0/11	0/11	0/11	0/11	0/11	0/11	0/11
T Moyo (Gwanda South)	Loam	Mean	1.01	1.47	1.81	1.28	1.75	1.95	1.53	1.85	2.34
		Failures	5/11	0/11	0/11	1/11	0/11	0/11	1/11	0/11	0/11
S Mlambo (Tsholotsho)	Clay	Mean	2.83	3.37	3.47	2.95	3.57	3.69	3.20	3.36	3.94
		Failures	1/11	0/11	0/11	1/11	0/11	0/11	0/11	0/11	0/11
All soils		Mean	1.50	1.99	2.24	1.73	2.20	2.36	1.94	2.21	2.57
		Total failures	12/33	0/33	0/33	2/33	0/33	0/33	1/33	0/33	0/33

At the sandy site of B Moyo and the loamy soil site of T Moyo, there were strong responses to inputs of modest amounts of N fertilizer, but only modest yield increase with FYM input (Table 7). Both fertilizer and FYM reduced the frequency of crop failure. At the S Mlambo clay soil site, there was a small trend towards FYM response (Table 7), and a strong response to N fertilizer. Risk of crop failures in dry years was less in the clay soil, and both FYM and N fertilizer reduced the risk of failure.

Discussion

On farm studies of manure inputs

This work showed that FYM gave suggestions of responses, but results were variable even though farmers' evaluations were positive. APSIM modelling indicated that without inputs, yields were low and there was high risk of crop failure. With added FYM, there were fewer crop failures, and about 50% higher yields. Both goat and cattle FYM were effective. Local farmers confirmed the idea that FYM had improved sorghum yield and that there was no 'burning'. Simulations were useful in discussions with farmers who were patient with our efforts at simulation. Also farmers know that they need improved record keeping.

Risk-return tradeoffs of smallholder investments in relation to improved soil fertility management options

Rusike et al. (2003) evaluated the returns and risks above fixed costs for sorghum for 11 seasons, 1990/1 to 2000/1, for alternative soil fertility inputs, and for 3 different household categories - male-headed households (resident husband, more labour and use of draft animals), *de facto* female-headed households (absent husband – intermediate resource, better access to cash), and *de jure* female-headed households (most resource-constrained). For FYM inputs, each category performed similarly, with good returns from sorghum with kraal or pit FYM as seen for *de jure* female-headed households (Table 8). Returns were higher at the wetter Tsholotsho site. Higher returns came with higher risks, and lower expected returns with lower risks. Surveys show that most farmers prefer maize even where conditions favour sorghum and millet. They grow some sorghum and millet to diversify risk and as insurance against complete crop loss. Two-thirds of households face regular food deficits because of crop loss. Further simulation has suggested that small inputs of fertilizer, composted FYM, and FYM-fertilizer have potential for *de facto* female-headed households, legume rotations in male-headed households with draft animals, labour and land, and small inputs of fertilizer and legume intercrops in the *de jure* female-headed households.

Table 8. Expected returns and risk (Zimbabwe $ ha^{-1}) of sorghum FYM management for *de jure* female-headed households in Gwanda South and Tsholotsho, 1990/1-2000/1.

Household type		Gwanda South		Tsholotsho	
	Activity	Return	Risk	Return	Risk
De jure female-headed	Sorghum + kraal FYM	-13023	3668	-7821	4410
	Sorghum	1704	8129	5419	6018
	Sorghum + pit FYM	122	6398	6405	8531

Farmer surveys provided information about farmers' knowledge and adoption of technologies (Table 9). Most farmers who hosted trials were adopting some ideas from the sites, and about half of farmers not hosting trials were adopting some ideas from trial plots. Most popular methods included heaped/covered FYM, and pit-composted FYM. Constraints to adoption were erratic rainfall and drought, lack of animals, 'burning' of crops by FYM, insufficient FYM, and lack of knowledge.

Table 9. Knowledge/adoption, and why not use FYM, Tsholotsho and Gwanda Sth (% respondents)

		1998/99		2002/03	
		GwandaS	Tsholotsho	GwandaS	Tsholotsho
Changed farmers' knowledge/practice	Know FYM	na	na	98	99
	Use FYM in surv yr	3	20	20	15
Reasons for not using FYM	Burns the crop	62	7	20	2

No perceived benefits	22	40	15	24
Not enough FYM av	9	26	5	18
Lack of transport	3	19	1	7
Lack of labour	0	0	3	13
Lack of knowledge	0	0	6	1
Low rainfall	0	0	31	13

Conclusions

Declining soil fertility, and low and erratic rainfall are major constraints to increasing smallholder productivity in communal areas of semi-arid Zimbabwe. Improved soil water and nutrient management is needed, but in the present economic climate, it is not feasible to purchase fertiliser for sorghum. Small quantities of FYM have potential for higher rainfall areas. On-farm research, simulation, and surveys have led to adoption of FYM in all household categories. To help investment, we suggest extension services escape from ideal recommendations, and offer a basket of options. Extension services need to link to marketing to help adoption of fertility technologies for cash, although fertilizer is not yet an option on farms on communal lands for non-cash crops. Legumes will improve soil, are marketable, and provide incentives for farmers to adopt technologies.

References

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