Technical Note on Promoting Integrated Soil, Water and Nutrient Management Technologies in Southern Highlands Zone of Tanzania

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Introduction

Rain water harvesting can be done either through one point collection of water into a dam or pond and later used for different purposes or through insitu collection which spread in micro-catchments basins in the fields for recharging plant available soil water. This work focused on insitu water harvesting. Insitu rain water harvesting is the process whereby rain water is captured in field through creation of surface roughness (Romkens and Wang, 1986) so that runoff is reduced and water infiltration and conservation enhanced for crops use over longer period of time in the fields (Larson, 1962; Zobeck and Onstad, 1984). Apart from water harvesting for crop use in the same field the rough soil surfaces are important for environmental conservation through controlling the runoff and soil erosion (Romkens and Wang, 1986). Insitu rain water harvesting in the sloping lands are conventionally done by using contour ridges, furrows and contour ditches (ICRAF, 1988). Research in the Southern Highlands of Tanzania has identified the potential of traditional soil management and tie ridge techniques that can recharge soil available water, control soil erosion and runoff, improve soil productivity (Malley, 1999; Malley *et al.,* 2004).

The improvements for increasing their effectiveness in soil productivity enhancement and environmental conservation have been introduced and evaluated and proved to be more productive with farmers (Malley *et al.,* 2002a; 2002b). Limited adoption of the improved technologies for land and environmental conservation has been the result of lack of promotion of these technologies. Ridge tillage systems are widely used by smallholder famers throughout the world to enhance land productive quality (Lal, 1990). Smallholder farmers grow a variety of crops in Southern Africa, including Tanzania, and practice a traditional ridge tillage system.

Despite the wide use of traditional practices for mitigating and coping with changes in productive quality and/or quality of environmental resources, little attention is given to understand them and particularly to improve their effectiveness to enhance rural livelihoods. Farmers do not practice soil conservation due to lack of technologies. Promotion of these technologies would contribute to increased crop production and enhanced environmental conservation in the Southern Highlands of Tanzania.

The study aim to promote insitu rain water harvesting technologies based on the earlier work done by potential of ridging in soil surface management undertaken in Mbozi district and improvement of traditional soil and water conservation in Mbinga District (Malley *et al.,* 2002a; 2002b).

Overall objective of this work was to increase adoption of land management technologies that integrate soil, water and nutrient management practices on the farms. Specifically, this work aimed to: (1) promote use of developed Integrated Soil Fertility Management (ISFM) technologies for increased crop yield per unit area through a package of integrated improved land husbandry practices; (2) monitor changes in critical soil fertility properties identified and physical trapping of soil particles.

Methodology

The study area

The field study was conducted for 3 growing seasons in Mbozi plateau, Mbozi district, SW Tanzania (8° – 9°12' S, 32° – 7°2' E). The area receives mono-modal rainfall of 800-1200 mm per annum from late October to April/May. Short dry spells are common in February/March. Mean minimum monthly temperatures vary between 17°C and 19°C and maximum temperatures range from 29°C to 30°C. The Mbozi plateau has an undulating to rolling landscape with rift benches, dominated by deep red sandy clay loam soils that are well to excessive drained. According to FAO classification, the soil at the site is mainly Ferralic Cambisols.

All households in the study area grow maize and beans for livelihoods. Average land holding per household is 1.2 ha. On average, the majority devote 71% of their land to maize-bean rotation. Smallholder households apply small quantities of N-fertilizers for maize, and do not fertilize the bean crop.

Study approach

In 2009/10 -2011/12 seasons, researcher guided and backstopped, farmer-extension driven technology promotion approach, which built on earlier research results and outputs in Mbozi District was undertaken.

Farmer selected package of best-bets in integrated soil, water and nutrient management technologies were promoted through an acre scale demonstrations per farm, village field days and farmer-to-farmer training methods. A package of ISFM technology developed between 2000/01-2004/05 seasons, which included: cross-ridging techniques for water, soil and nutrients trapping into the basins, fertilizers use in beans and maize production, minimum tillage of dibbling maize seeding holes into cross-ridge system instead of open ridges and notorious weeds controlled by roundup herbicides. This was tested against farmers' conservation tillage practices of organic matter incorporation and maize-bean rotation system, In addition, use of improved maize and beans seeds was promoted along with this soil management package. During the period, a total of 260 farmers participated in groups constituted by 10-30 farmers.

Data collection

Baseline data were collected through key informant interviews and existing experimental information of the earlier works. Farmers who participated in research process volunteered to promote the package through forming farmer groups, which committed their resources (land, labour) to demonstrate and organized field days in their villages with assistance of extension workers and support of researchers.

Planning

Joint planning of promotions actions were undertaken and roles divided between researchers, extension and farmer groups. Farmers allocated land for demonstrations and measurements done with assistance of extension workers, prepared land and planted as per agreed prescriptions and managed the plots. Researchers supplied necessary inputs, particularly fertilizers and improved seeds with also collateral contributions from the groups and provided working tools (tape measures, weighing balance and data recording forms) and train farmer-data collectors.

Implementation of the Project

Those farmers who planted beans last year, next year planted maize. So they have two acres (one for maize and one for beans). For both maize and beans the whole acre was 2m cross ridge. This is because the 2m cross ridges was profitable compared to 4m cross ridges.

Crop husbandry

Thionex was used for controlling insects like bean flies and bollworms in beans (1.5 Litres per hectare). First, spraying of insecticide (Thionex) was done 7 days after germination to control bean fly. Second and third spraying was done also by farmers to control bollworms then land preparation was done by farmers by using ox-plough and hand hoes. They made ridges as instructed by researchers. The planting of beans was according to their practice i.e. small holes by using their small hoes.

Beans seeds used were new variety (Yellow). Weeding was conducted as recommended. Farmers harvested the plots and measured grain yield. Farmers conducted other crop husbandry activities as agreed during the planning workshop as use of recommended seeds, planting on time, use of fertilizers as recommended, weeding on time, harvesting on time and treatment of harvested seeds..

Fertilizer application
Fertilizers used for planting both maize and beans is DAP (1bag/acre) equivalent to 20 kg P/ha. Maize was top-dressed with UREA (2 bags/acre) applied in 2 splits after first and second weeding. The N rate used in total was equivalent to 120 Kg N/ha. Data collected were grain yield, costs of inputs (fertilizers, seeds, labour) and farm gate prices of beans and maize.

Data analysis
The maize and beans yields were compared to each village. The farmers' plots were treated as replicates. Profitability of the treatments was compared to traditional practice of farmers by using partial budget techniques. Data analyses for agronomic and profitability were based on baselines in comparison with changes in soil characteristics and grain yield attained in demonstrations carried out in two villages of Ivwanga and Nambala.

Results and Discussion
Soil characteristics
Soils of the intervention area have acidic reactions and low TN, OC and available-P (Table 1). These were mainly targeted for improvement by intervention as they were major nutrient limiting the soil productivity in the area. The ISFM intervention improved available soil phosphorus and organic carbon over the period of 3 years (Table 1).

Table 1: Soil characteristics and changes due to intervention

Village	Property	Critical soil properties monitored	
		Before intervention	After intervention
Ivwanga	pH-H_2O	6.1	6.23
	Total N (g/kg)	1.5	1.50
	Organic carbon (g/kg)	20.2	21.70
	Available-P (mg/kg)	3.7	6.20
	CEC (cmol/kg)	16.89	17.24
Nambala	pH-H_2O	5.85	6.00
	Total N (g/kg)	1.60	1.50
	Organic carbon (g/kg)	22.4	23.8
	Available-P (mg/kg)	6.09	8.72
	CEC (cmol/kg)	16.43	17.89

This means adopting the ISFM package could continuously build soil P-stock and organic matter for sustainable soil fertility management. This finding is supported by farmers reported observations, that there is generally soil fertility build up on these farms using this ISFM package, due to soil, water and nutrients trapping by cross-ridges (Fig. 1).

Bean grain yield
Bean grain yield increased by over 2-folds in ISFM plots as compared with the baseline farmers yield. This increase in yield is attributable to both improved soil fertility and

Figure 1: Trapping of water, soil and nutrients insitu on the field by cross-ridges

use of best agronomic practices, including improved bean varieties. Partitioning of the effects in earlier work by Malley *et al.,* (2009) showed that, soil fertility improvement alone contribute about 46% to increase in yield. In this promotion work, increases in bean yield ranges from 128-257% averaging at 174%. This was above contribution of the soil fertility changes alone. This suggest that, improvement in soil productive quality should be accorded with other good husbandry practices of the specific crop, such as improved varieties, diseases and pest control, spacing, timing in planting.

Table 2: Bean productivity (kg/ha)

Village	N	Season	Farmers	ISFM package	Increase (%)
Baseline	50	2000-2009	250	-	-
Ivwanga	17	2009/10	-	571.10	128
	12	2010/11	-	692.30	177
	16	2011/12	-	661.60	165
Nambala	21	2009/10	-	778.10	211
	28	2010/11	-	892.40	257
	27	2011/12	-	600.00	140
Shaji	7	2009/10	-	567.86	127
	9	2010/11	-	795.60	218
	10	2011/12	-	600.00	140
Average		**2010-2012**	**-**	**684.33**	**174**

Maize productivity (kg/ha)

In plots with ISFM interventions, maize productivity was higher by 65-194% compared to traditional yield achieved without application ISFM package. Average yield increase in maize was 125%. As for beans the yield increases observed are attributable to soil fertility improvement due to ISFM as well as other good agronomic practices incorporated in growing maize on the ISFM demonstration plots. In earlier studies the comparison of ISFM package with conventional practices, showed ISFM alone could increase maize yield by 105%. Soil productivity build up is evident from yield increases over years as ISFM is continuously used as maize growing practice on the same farms (Fig. 2).

Profitability analysis for beans and maize

Use of ISFM package, in growing of beans and maize is profitable than conventional practice currently in use by farmers. However, bean gross margin is small due to high labour costs invested in tillage during forming the system

Table 3: Maize grain yield (kg/ha) in ISFM demonstrations, compared to farmer's yield

Village	N	Season	Farmers	ISFM package	Increase (%)
Baseline	50	2000-2001	2000	-	-
Ivwanga	8	2009/10	-	4799.44	140
	17	2010/11	-	4285.00	114
	14	2011/12	-	5214.60	161
Nambala	11	2009/10	-	3994.50	100
	23	2010/11	-	4211.70	111
	27	2011/12	-	5872.20	194
Shaji	6	2010/11	-	3305.00	65
	7	2011/12	-	4242.90	112
Average		**2010-2012**	**-**	**4490.67**	**125**

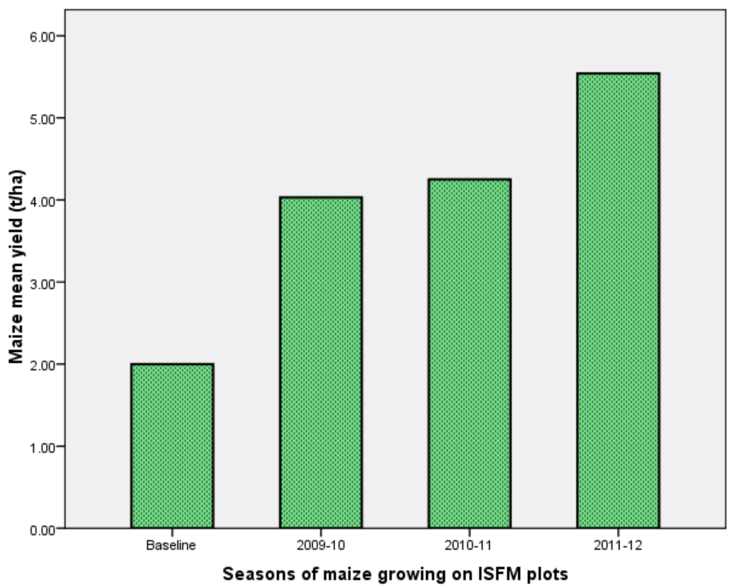

Figure 2: Maize mean yield change over years as ISFM package is used on the same plots

(Table 4). The profit substantially improves as maize are planted with minimum tillage i.e. without the opening of the ridges and re-forming in the following cropping season (Table 5).

Table 4: Gross margin analysis (per ha) for beans

Variable	Practice	
	ISFM package	**Farmer practice**
Seeds costs (Tshs/ha)	202,500.00	112,500.00
Labor costs (Tshs/ha)	200,000.00	120,000.00
Fertilizers costs (Tshs/ha)	150,000.00	-
Pesticides	6000.00	6000.00
Total variable costs (Tshs/ha)	558,500.00	238,599.00
Yield (kg/ha)	684.33	250
Price (Tshs/kg)	1,000.00	1,000.00
Revenue (Tshs/ha)	684,330.00	250,000.0
Gross margin (Tshs/ha)	125,830.00	11,401.00

Table 5: Gross margin analysis (per ha) for maize

Variable	Practice	
	ISFM package	**Farmer practice**
Seeds costs (Tshs/ha)	112,500.00	93,750.00
labour costs (Tshs/ha)	87,500.00	137,500.00
Fertilizers costs (Tshs/ha)	370,000.00	220,000.00
Herbicides costs (Tshs/ha)	30,000.00	-
Total variable costs (Tshs/ha)	600,000.00	451,250.00
Yield (kg/ha)	4,490.67	2000
Price (Tshs/kg)	350.00	350.00
Total revenue (Tshs/ha)	1,571,734.50	700,000.00
Gross margin (Tshs/ha)	971,734.50	248,750.00

Conclusion and recommendations

Use of ISFM package increased productivity of beans and maize farming compared to current farmer practices. In addition, it improved long term soil productivity as evidence in the build up of available soil-P and organic matter.

From the result of this work the pertinent recommendation is that, deliberate efforts are needed for scaling up and out of improved cross-ridge system, in order to realize its wider impact, through reaching more people and more quickly for enhanced livelihoods of farmers and for conservation of the natural resources in similar environments.

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