Economic Benefits of Combining Soil and Water Conservation Measures with Nutrient Management in Semiarid Burkina Faso

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Résumé

Deux dispositifs semi-perméables de conservation des eaux et des sols (cordons pierreux, bandes enherbées) et deux sources de fertilisation azotée (compost, urée) appliquées seules ou en combinaison ont été étudiées dans le plateau central du Burkina Faso. L'installation de cordons pierreux ou de bandes enherbées seule sans apport de fertilisants n'est pas économiquement rentable, bien que ces pratiques entraînent une augmentation de rendement de 12 à 58%, particulièrement en année de mauvaise pluviosité. L'effet additif de l'interaction des cordons ou des bandes enherbées avec l'apport de compost a été positif (185 kg ha^{-1} avec les cordons, 300 kg ha^{-1} avec les bandes enherbées). Les revenus substantiels qui y ont résulté (109480 à 138180 FCFA ha^{-1}) pourraient renforcer les capacités financières des paysans à investir dans la gestion des sols pour une intensification durable de la production.

1. Introduction

Soil degradation and nutrient depletion have steadily increased and have become serious threats to agricultural productivity in sub-Saharan Africa (Vanlauwe et al., 2002). In semiarid western African zone, plant nutrient use efficiency in cereal-based farming systems is often very low because of limited soil moisture conditions (Buerkert et al., 2002). The low soil quality combined with the harsh Sahelian climate leads to a low efficiency of fertilizers (Breman et al. 2001). In order to be effective, application of nutrient inputs in semiarid areas need to be combined with water harvesting and water conservation schemes or where possible, with small-scale irrigation (Dudal, 2002). Also, studies by Zougmoré et al. (2002) reported that the beneficial effect of soil & water conservation (SWC) measures such as stone bunds on soil productivity was limited under continuous non-fertilized cereal cropping. This implies that there is no effective nutrient use efficiency without improved water management and vice versa. In addition, the lack of economic motivation has been one of the major constraints to increased use of plant nutrient sources in sub-Saharan Africa. Interactions of SWC measures with organic or mineral source of nutrients may boost crop production and therefore, could be economically profitable to farmers. This work aims to analyze the added effects of combining SWC measures with organic or inorganic fertilizer inputs during two successive cropping seasons in semiarid Burkina Faso. It is hypothesized that application of SWC measures can increase the added benefits of organic or mineral inputs in the Sahelian smallholder farming systems.

2. Materials and methods

The experimental field was located at Saria Agricultural Research Station (12°16' N, 2°9' W, 300 m altitude) in Burkina Faso. Average annual rainfall during the last 30 years is about 800 mm. The trial (2001–2002) consisted of a randomised Fisher bloc design with nine treatments where two types of semi-permeable barriers (stone rows and grass strips of *Andropogon gayanus* Kunth *cv. Bisquamulatus* (Hochst.) Hack.) were combined with the application of compost or urea. Each plot (100 m long, 25 m wide) was isolated from the surrounding area by an earth bund 0.6 m high. Stone rows and grass strips had been installed during the 1999 rainy season, spaced 33 m apart (i.e. 3 barriers per plot) along the contours. In relevant plots, compost was applied each year once before sowing at a equivalent dose of 50 kg N ha^{-1} (4800 kg ha^{-1} in 2001 and 5600 kg ha^{-1} in 2002). Urea was also applied at the dose of 50 kg N ha^{-1} in two splits (25 kg N ha^{-1} was applied 21 days after planting and 25 kg N ha^{-1} 56 days after planting). All plots received a base dressing of 20 kg ha^{-1} P in the form of triple super phosphate to eliminate phosphorus deficiency as a factor in the experiment. In all plots, a 110-day improved sorghum (*Sorghum bicolor* (L.) Moench*)* variety (Sariasso 14) was sown in rows across the slope by hand at the rate of 31250 seedlings per hectare.

Assuming x_1= Stone rows or grass strips, x_2= Application of compost-N or urea-N, x_0= Control (no SWC measures, no N input), Y= yield, (x_1+x_2) = Combined SWC measure (x_1) and compost-N or urea-N (x_2). From definitions of 'added effect' and 'interaction effect' given by Vanlauwe et al. (2002), Giller (2002) and Iwuafor et al. (2002), we consider that the interaction effect (IE) in crop yield is the benefit in crop yield (in comparison to the control treatment) of the combined application of both SWC measure and urea-N or compost-N $(\Delta Y(x_1+x_2))$ minus the sum of the benefits from the two components (ΔYx_1 and ΔYx_2) when applied in isolation.

$$\Delta Yx_1 = Y(x_1) - Y(x_0) \quad (1)$$
$$\Delta Yx_2 = Y(x_2) - Y(x_0) \quad (2)$$
$$\Delta Y(x_1+x_2) = Y(x_1+x_2) - Y(x_0) \quad (3)$$
$$IE = \Delta Y(x_1+x_2) - (\Delta Yx_1+\Delta Yx_2) \quad (4)$$

There is positive interaction between x_1 and x_2 when IE > 0, and negative interaction between x_1 and x_2 when IE < 0. In order to be able to determine the economic benefit of single or combined N-input and SWC measures, a minimum yield value was calculated per treatment. It corresponds to the minimum excess yield that supports the annual cost of the applied technology. To that end, the yield increase per kg N ($\Delta Y/\Delta N$) was calculated for the applied 50 kg ha^{-1} urea-N or compost-N. ΔY stands for yield increase and ΔN for applied N amount i.e. 50 kg N ha^{-1}. $\Delta Y/\Delta N (x_2) = \Delta Y(x_2)/50$ (5)

In 2001 and 2002, the price of 1 kg urea-N was about 544 FCFA (1 euro= 655.957). The average of 140 FCFA for 1 kg sorghum and a minimum of 3.9 kg sorghum per kg of urea-N were used in this paper. The discounted average cost for stone rows using truck transport was 48312 FCFA ha^{-1} yr^{-1} while grass strips installation cost using root transplanting was 26240 FCFA ha^{-1} yr^{-1}. The discounted annual cost for the pit establishment was 37900 FCFA ha^{-1} and the price of 1 kg of nitrogen deriving from compost was 758 FCFA. Sorghum grain and straw yields were measured after sun drying at harvest from the 36 subplots in each plot. STATITCF package was used for statistical analyses, including ANOVA and Newman-Keuls test for significant differences between treatments at $p < 0.05$.

3. Results and discussion

Effects of SWC measures and nutrient management on sorghum performance

Sorghum yields were significantly different among treatments in 2001 and 2002. In 2001, sorghum yields with stone rows alone (T_{SR}) increased by 12% whereas with grass strips alone (T_{GS}) sorghum yield decreased by 18% when compared to the control (T_0). In 2002, single

stone rows plots induced 12% grain yield increase whereas in single grass strips plots, grain yield decreased by 15% compared to the control. In 2001, application of compost (T_C) or urea (T_U) alone greatly increased sorghum yield by respectively 107% and 92% compared to the control (T_0). Thus, applying nutrient inputs alone (T_C, T_U) induced much higher grain yields than laying SWC barriers without nutrient inputs: 80% compared to stone rows plots (T_{SR}) and 145% compared to grass strips plots (T_{GS}). In 2002, as in 2001, single application of N-input (T_C, T_U) induced higher grain yield than single application of SWC measures. Combining compost with stone rows (T_{SRC}) induced a yield increase of 106% when compared to plots with stone rows alone (T_{SR}). Similarly, combining grass strips and compost (T_{GSC}) induced a grain yield increase of 160% when compared to plots with grass strips alone (T_{GS}). Also, adding urea to plots with barriers (T_{SRU}, T_{GSU}) increased grain yield by 46% and 71% respectively compared to plots with barriers only (T_{SR}, T_{GS}). In general, only slight differences were observed between treatments combining barriers with N-input (T_{SRC}, T_{GSC}, T_{SRU}, T_{GSU}) and receiving-N treatments without barriers (T_C, T_U). These results were confirmed in 2002.
Positive interactions ($\Delta Y(x1 + x2)$) of combined SWC measures and N-inputs were observed apart for T_{GSU} in 2001 (-367 kg ha^{-1}) and T_{SRU} in 2001 (-437 kg ha^{-1}) and 2002 (-36 kg ha^{-1}). The high response of sorghum yield to added N-inputs only (T_C, T_U) suggests that nutrient supply more than water retention by the filtering barriers (T_{SR}, T_{GS}) increased the yield in combined SWC and nutrient plots.

Economic benefit of water and nutrient management

Yield increases did not cover annual costs of stone rows or grass strips alone (Table 1).

Table 1: Economic benefits of single stone rows or single grass strips in 2001 and 2002

	Stone rows		Grass strips	
	2001	2002	2001	2002
Annual cost (FCFA ha^{-1})	48312	48312	26240	26240
Sorghum average price (FCFA kg^{-1})	140	140	140	140
Minimum yield (kg ha^{-1})	345	345	187	187
ΔY (kg ha^{-1}) [a]	127	144	-203	-181
Excess yield (kg ha^{-1})	-218	-201	-390	-368
Economic benefit (FCFA ha^{-1})	-30520	-28140	-54600	-51520

[a]ΔY stands for yield increase for stone rows or grass strips treatments compared to the control treatment.

Table 2: Economic benefits of combining stone rows or grass strips with compost-N or urea-N in 2001 and 2002 at Saria, Burkina Faso[a]

	2001				2002			
	T_{SRU}	T_{GSU}	T_{SRC}	T_{GSC}	T_{SRU}	T_{GSU}	T_{SRC}	T_{GSC}
Minimum yield for N inputs (kg ha^{-1})	195	195	271	271	195	195	271	271
Minimum yield for SWC (kg ha^{-1})	345	187	345	187	345	187	345	187
Minimum yield for SWC + N input (kg ha^{-1})	540	382	615	457	540	382	615	457
Excess yield (kg ha^{-1})	158	54	821	782	-193	-135	987	915
Economic benefit (FCFA ha^{-1})	22120	7560	114940	109480	-27020	-18900	138180	128100

[a]**T**$_{SRC}$: stone rows + compost-N; **T**$_{GSC}$: grass strips + compost-N; **T**$_{SRU}$: stone rows + urea-N; **T**$_{GSU}$: grass strips + urea-N**.**

Conversely, economic benefits of treatments showed that single application of compost-N or urea-N were cost-effective but supply of urea-N was less beneficial (6160 FCFA) in 2002 compared to compost-N (133040 FCFA). The combination of SWC measures with urea-N (T_{SRU}, T_{GSU}) or compost-N (T_{SRC}, T_{GSC}) induced positive economic benefits in 2001 (Table 2), indicating that at least the annual costs for implementing SWC measures and applying compost-N or urea-N were covered by the excess yields in the combined SWC measure and N-input treatments.

4. Conclusions

Results of this study suggest that:

When annual rainfall is well distributed in time (as was the case in 2001 and 2002 at Saria, Burkina Faso), installation of stone rows only induced very limited sorghum yield increase while *Andropogon gayanus* grass strips induced sorghum yield decrease. These yields were not enough to support installation costs due to high labor, transport and material inputs.

Application of the sole compost-N or urea-N induced significant greater sorghum yield increase than SWC measures only.

Stone rows or grass strips combined with compost-N induced positive interaction effects while stone rows combined with urea-N showed negative interactions. A positive interaction of grass strips combined with urea-N was observed only after two years.

Economic benefits when combining compost-N to both stone rows and grass strips were substantial (109000 to 138000 FCFA ha^{-1}) while the greatest amounts observed with added urea-N were small (7560 to 22120 FCFA ha^{-1}).

These results indicate that in the Sahel, opportunities do exist for making more efficient use of local sources of nutrients such as compost in combination with locally accepted SWC measures. This may empower farmers to invest for sufficient nutrient supply in the sub-Saharan soils characterized by poor fertility.

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