

Evaluation of Contour Barriers for Soil and Water Conservation in Western Pare Low Lands, Tanzania

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Abstract

A study was undertaken in Mwanza District in the Western Pare Low Lands (WPLL) for seven seasons (1993 – 1999) to investigate the performance of three soil and water conservation techniques with regard to the production of maize, on land with 8% slope. Conservation treatments were, stone bunding (SB), contour ridging (CR), and live barriers (LB). Control treatments were flat cultivation (FC) and zero tillage (ZT). The treatments had no significant effect on profile moisture content. However, averaged over the entire study period and during long rains, SB, CR, and LB performed equally well with grain yield of between 2.5 to 2.7 tons per hectare. Flat Cultivation had 2.2 tons ha⁻¹ while ZT had only 1.7 tons ha⁻¹. Between treatments and during short rains, grain yield varied within a very narrow range of 0.8 to 0.9 tons ha⁻¹. If the 1997/98 season which was abnormal (El Nino rains) is excluded, overall mean grain yield would be very low at 0.3 tons ha⁻¹. Stone bunding and live barrier treatments had an additional advantage in that the barriers (5m apart) had over the years been transformed into bench terraces. Given the small increment in yield which was realized, the techniques can not be recommended for moisture conservation in this agro-ecological zone. However, since the barriers were effective in controlling soil creep down slope, they could be recommended as a long term strategy for soil erosion control where this is considered a threat.

Key words: Contour barriers, soil and water conservation, erosion, stone bunding, vetiver grass, soil bunding.

Introduction

The problem of soil-water losses through surface runoff and evaporation is one of the major limiting factors in agricultural production in semi-arid areas (Rockstrom and de Rouw, 1997). Contour barriers comprise a group of techniques, which involve laying barriers along the contour to control surface runoff. These include techniques such as soil bunds, ridges, stone lines, trash lines and live hedges of grass, crops, bushes and trees. Examples of soil bunds include techniques such as

fanya- juu and *fanya-chini* popularly used in Kenya (Thomas, 1997; Tiffen *et al.*, 1994) and the *Matengo* or *ngoro* pits used in south-west Tanzania (Tarimo *et al.*, 1998). Trash lines are barriers formed by placing crop residues or other plant material along the contour or across the field. Stone bunds are preferred in stony areas and are often formed as part of the process of clearing stones from the cultivated part of the field (IFAD, 1992). Live barriers involve the growing of strips of grass or other vegetations to intercept and slow down surface runoff. Vetiver grass (*Vetiveria zizanioides*) is

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one type of grass which has been widely promoted for soil and water conservation (Truong and Scattini, 1990). Work carried out at ICRISAT, India by Rao *et al.* (1991) revealed that vetiver grass was superior in reducing soil and water losses when compared to stone bunds, lemon grass and bare ground (control). They reported that the vetiver grass reduced rainfall runoff by 57% and soil loss by over 80%. At CIAT, Colombia, Laing and Ruppenthal, (1991) reported that vetiver hedges reduced soil loss from 142 tons/ha for bare fallow to 1.3 tons/ha for cropped cassava between vetiver hedges. Rainfall runoff was reduced from 11.6% to 3.6%.

Runoff plots involving flat and ridge cropping on a 4% slope at SUA, Morogoro showed that these treatments had no effect on maize grain yield (Gebremedhin, 1996). The yield was 2,300 kg/ha and 2,600 kg/ha respectively in flat and ridge cropping. The above was against the background of 1,570 m³/ha⁻¹ (157mm) and 352 m³/ha⁻¹ (35.2 mm) loss in runoff. Soil loss in flat and ridge cropping was 12.5 t/ha⁻¹ and 2.5 t/ha⁻¹ respectively. The lack of statistical significance in grain yield was attributed to adequate and well-distributed rains.

Soil bunding is by far the most effective and widely practiced field measure for controlling or preventing erosion (Singh *et al.*, 1994). The conservation treatments meant to reduce or prevent sheet erosion also desirably conserve moisture. Land configuration options for sustainable crop production in southern India indicate that, for slopes less than 8% with scanty or erratic rainfall, contour soil bunding is practised to intercept the run-off flowing down the slope by an embankment whose ends may be closed or open to conserve moisture as well as reduce soil erosion (Selvaraju *et al.*, 1999). However, by their nature earth bunds can easily be washed away by flash floods. This problem is reduced by using barriers which are permeable.

Permeable barriers do not completely stop the runoff but slow it down and spread the water over the field thus enhancing water infiltration and reducing soil erosion. Silt trapped on the higher side of the barrier build-up to form natural terraces (Hudson, 1995). Compared with impermeable soil bunds, permeable contour-line barriers have the advantage of low risk of being damaged (Reijntjes *et al.*, 1992).

The new approach to soil and water conservation in semi-arid area is to focus on productivity enhancement rather than just erosion control (Stocking and Peake, 1987). This is because, in the semi-arid areas, crop yields are likely to be reduced more by loss of water rather than by that of soil. Therefore, it is important to reassess existing soil and water conservation techniques, in terms of their effects on water conservation and hence productivity.

The main objective of this study was therefore to compare the performance of three soil conservation techniques, in relation to productivity of maize on fields with a 8% slope, in drought prone areas.

Materials and methods

Site description

The study was conducted in the Western Pare Lowlands (WPLL) in Kisangara village, Mwanza District, Kilimanjaro Region. The experimental site was located on an 8% slope. Before 1993 the area was under sisal. The climate is semi-arid with two rainy seasons. The short rains (*Vuli*) last from October to January. The long rains (*Masika*) last from February to June. Monthly rainfall amounts from 1993 to 1999 during *Vuli* and *Masika* are presented in Tables 1 (a) and (b), respectively. The soils on the experimental site are *Acri Ferric Luvisol* (FAO) or *Typic Plinthustalf* (USDA) (Ngatoluwa *et al.*, 1995).

Table 1 (a): Monthly rainfall data during *Vuli* at Kisangara from 1993 to 1999

Month	1993/94	1994/95	1995/96	*1997/98	1998/99
October	45.4	18.5	10.0	97.0	0.0
November	18.7	51.1	2.0	200.0	95.8
December	90.8	246.0	115.0	272.7	34.8
January	14.0	3.0	69.5	367.0	32.4
Season total	168.9	318.6	196.5	936.7	163.0

(**El Nino* rains).

Table 1(b): Monthly rainfall data during *Masika* at Kisangara from 1993 to 1999 (**El Nino* rains)

Month	1993	1994	1995	*1998	1999
February	47.5	66.0	61.5	77.2	5.0
March	74.1	189.6	196.5	20.5	194.1
April	99.7	36.5	149.5	299.7	92.7
May	43.8	88	102.1	164.5	75.0
June	0.0	1.0	0.0	1.6	29.8
Season total	265.1	381.1	509.6	563.5	396.6

Experimental design and lay-out

The study comprised of three (3) conservation treatments and two, (2) control treatments. Conservation treatments were: stone bunds (SB), contour ridges (CR), and live barriers of vetiver grass (LB). Control treatments were flat cultivation (FC) and zero tillage (ZT). A Complete Randomised Block Design (CRBD) with three replicates was adopted. The blocks (replications) run across the general slope. Each plot measured 25 m along the slope and 5 m across. Contour ridges, live barriers and stone bunds were spaced 5 m apart in each plot. Thus, each plot had four barriers. The stone bunds were built to a height of about 0.4 m.

Agronomic practices

Tillage for the SB, LB, CR, and FC treatments was done using a hand hoe, which is the common means of land preparation in the area. For

the ZT treatment, the soil was loosened only where seed was sown. The land is usually clear of vegetation at the beginning of the rain season. The grass had since long died or been eaten by termites (or grazing animals under traditional practice). Thus, sowing without any primary tillage was not much of a problem.

Maize cultivar TMV1 was used as a test crop. Seed was sown at a spacing of 30 cm x 75 cm by placing two seeds per hill. Phosphatic fertilizer was applied at planting at a rate of 40 kg P/ha as TSP 46%. Sulphate of Ammonia (SA) at a rate of 40 kg N/ha was applied between the 2nd and the 3rd week after planting depending on soil moisture condition.

Measurements

Plant height was determined on 20 randomly selected plants from the central row in each treatment. Measurements were taken at 14, 25, 33, 41, 48 and 58 days after planting. Grain yield and biomass were determined at harvest.

Three sub-sampling plots were marked out in the upper, middle and lower parts of the main plot. Each subplot had an area of 6.6 m² and measured 2.2 m wide and incorporated 4 crop rows. Maize ears were removed from the stem leaving the husks intact and still attached to the stems. Stems were then cut at ground level for biomass determination. The grain and vegetative parts were oven dried to constant weight at 60°C. The weights were used to calculate grain and biomass yield. The sampling area was used to extrapolate yield per hectare.

The deposition of soil material on the upper side of the barriers was monitored at the end of each season by determining the depth of the deposition.

Rainfall was recorded using a standard rain gauge located at about 30 m from the plots. An automatic tipping electronic rain gauge (with data logger) was installed during the last two seasons.

Soil moisture was monitored fortnightly using a Theta Probe at 10, 30 and 50 cm depth. A soil auger was used to make a hole to the desired depth before introducing the probe.

Analysis of variance (ANOVA) was performed

with Statgraphics Version 5 (Statistical Graphics Corporation, USA).

Results

Rainfall data

During *Vuli*, total rainfall amount varied from 163 mm (in 1998/99) to 937 mm (in 1997/98) (Table 1a). In *Masika*, seasonal rainfall varied from 265 to 564 mm respectively for 1993 and 1998 (Table 1b). It is important to note that *El Niño* affected the 1997/98 *Vuli* and 1998 *Masika* seasons cited above. The rainfall amount during *Vuli* was for example, more than three times the average amount that is usually less than 300 mm. More detailed analysis of rainfall patterns in the study area is given by Mhoo *et al.*, (1999).

Changes in plot configuration

Initially (i.e. in 1993), all plots had a uniform slope of 8% (Figure 1 a and c). Gradually plots with treatments involving barriers (live barriers and stone bunds) were transformed into bench terraces (Figures 1(b) and 1(d)). When the study ended in 1999, the terrace steps measured between 0.35 to 0.40 m in height.

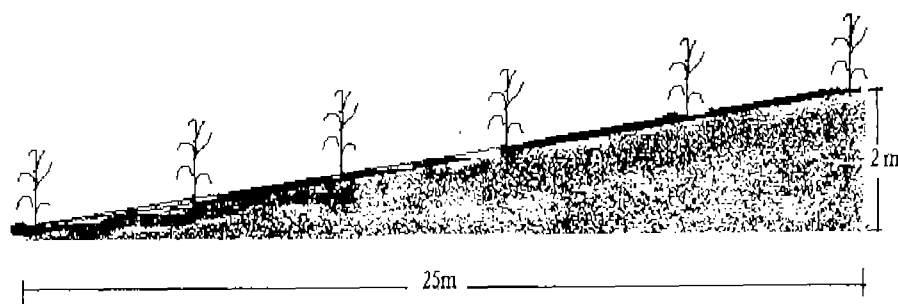


Figure 1a: Live barrier treatment in conservation tillage experiment at initial stage in *Masika* 1993

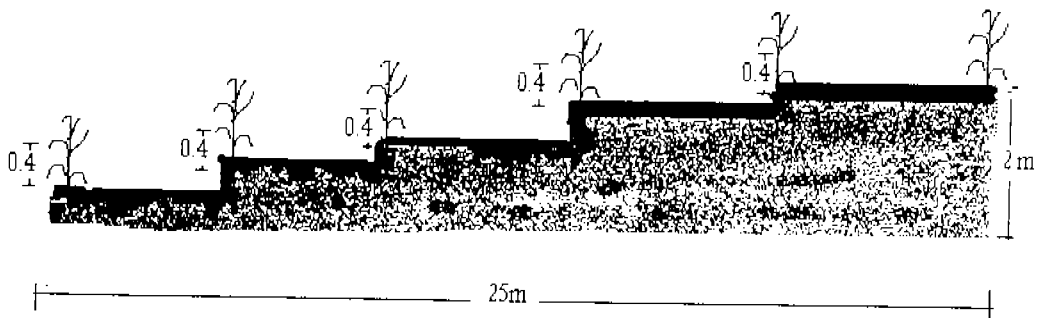


Figure 1b: Live barrier treatment in the conservation tillage experiment at final stage in *Masika* 1999

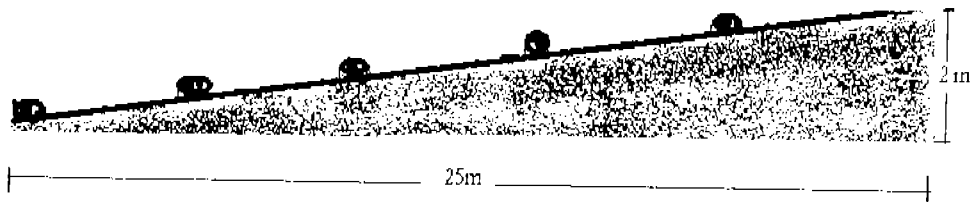


Figure 1c: Stone bunding treatment in the conservation tillage experiment at initial stage in *Masika* 1993

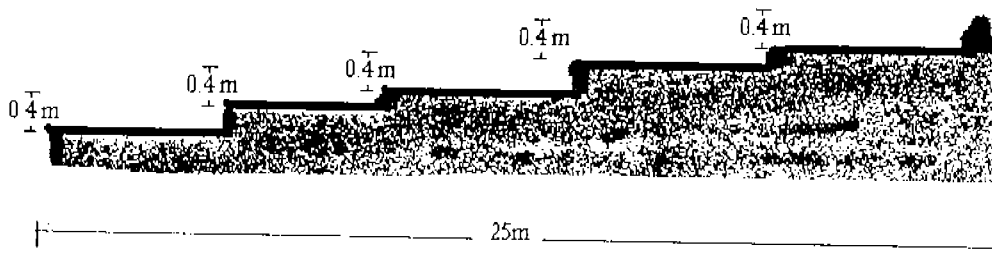


Figure 1d: Stone bunding treatment in the conservation experiment at final stage in *Masika* 1999

Soil moisture

Soil moisture measurements for the 1998 and 1999 *Masika* seasons are presented in Figure 2. Differences in soil moisture between treatments were not statistically significant ($P=0.05$). However, SB, CR and LB had more profile moisture than the controls (ZT and FC). In all soil layers, SB had slightly less soil water than LB and CR.

Plant height

Plant height was affected by the treatments as shown in Figure 3. There were no conspicuous differences between treatments with regard to this parameter except for ZT, which tended to have shorter plants than in other treatments.

Biomass

Total biomass was affected by the treatments as presented in Figures 4 and 5. During *Masika* seasons, total biomass yield followed almost the same trend as that for grain yield

(Figures 6 and 7). Overall, ZT produced least biomass closely followed by FC.

Grain yield

Grain yield was affected by the different treatment as shown in Figure 6 for long rains in Figure 7 for short rains. During the rains, ZT had the lowest grain yield over entire study period. For most seasons except 1998, the yield under ZT was significantly ($P=0.05$) lower than in treatments with better. During short rains between 1993-1999, statistical analysis indicated no significant difference between treatments. With exception of 1997/98 (*El Nino* effect), yield was always less than 700 kg/ha. In 1998 season for example, grain yield varied between 70 to 210 kg/ha. There was no grain yield during 1993/94 *Vuli* season. During 1998 *Vuli* season, the rains failed (see Table 1) thus the sown seed did not germinate.

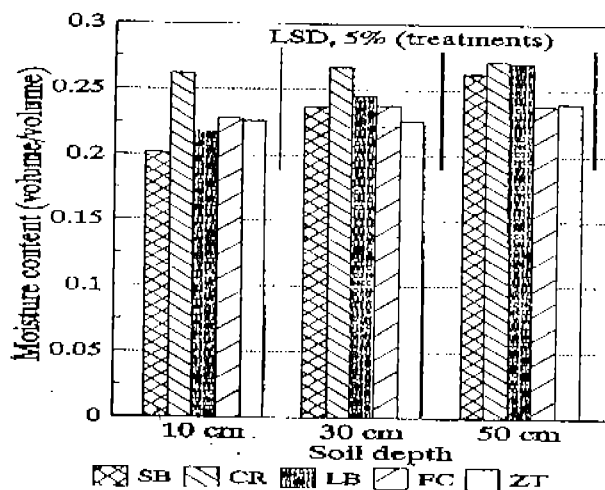


Figure 2: Average soil moisture content in different conservation treatments during *Masika* 1998 and 1999 seasons at 10, 30 and 50 cm depth.

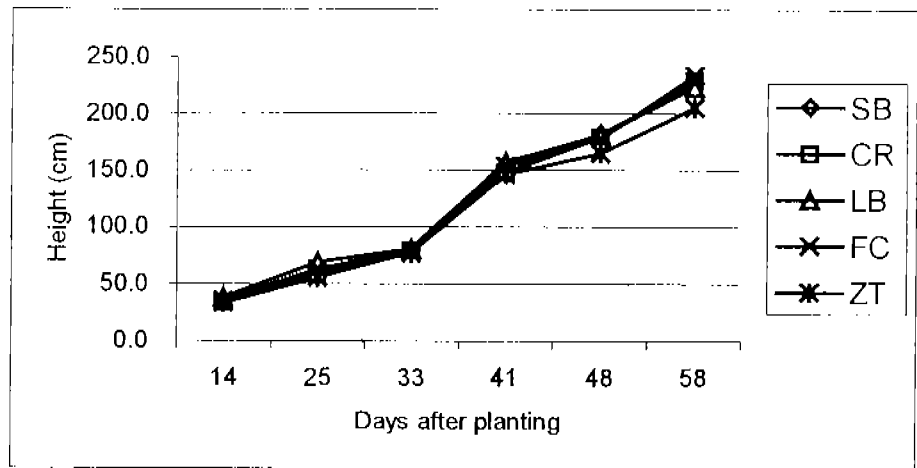


Figure 3: Plant height as affected by conservation treatments during *Masika* 1999 season

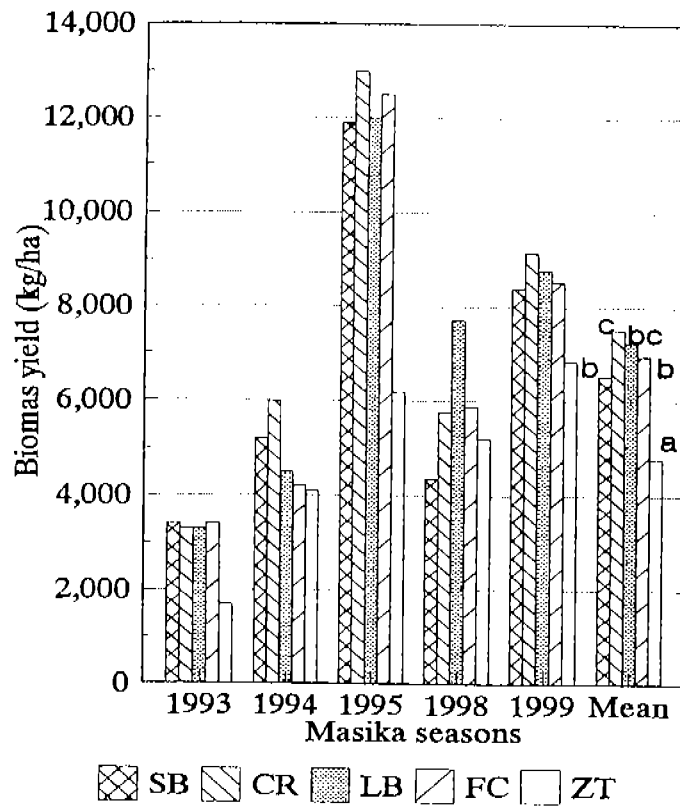


Figure 4: Effect of the different treatments on biomass yield of maize during long rains (*Masika*)

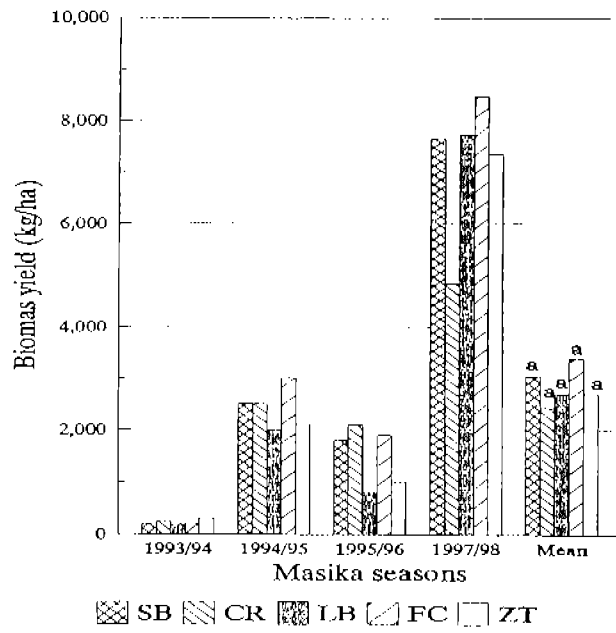


Figure 5: Effect of different treatments on biomass yield of maize during short rains (*Vuli*)

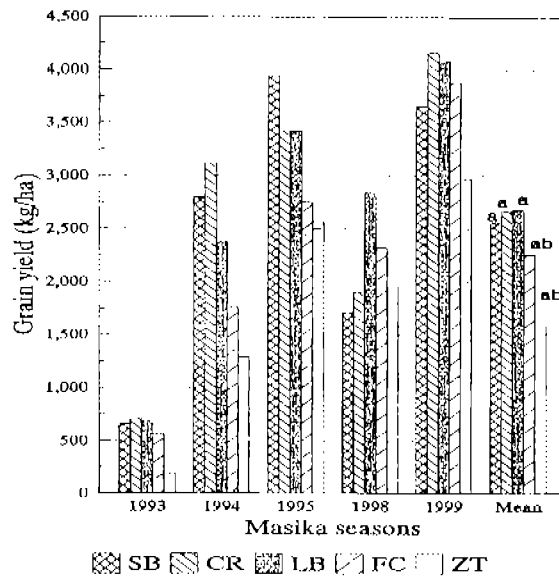


Figure 6: Effect of different treatments on grain yield of maize during long rains (*Masika*)

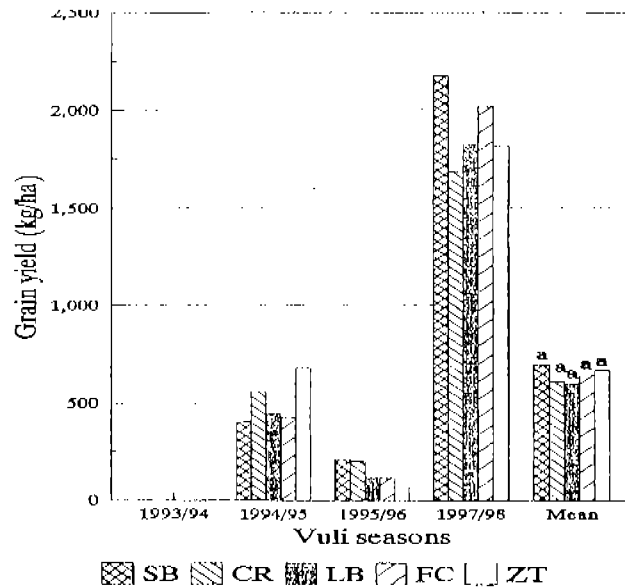


Figure 7: Effect of different treatments on grain yield of maize during short rains (*Vuli*)

Discussion

Rainfall data indicated that the amount is low and the distribution is very erratic. Over the study period and during *Vuli*, the amount varied from 0 mm to 97 mm in October, 2 mm to 200 mm in November, 35 mm to 273 mm in December, 3 mm to 367 mm in January, and 163 mm to 937 mm, in total. Short rains are indeed very inadequate. The *Vuli* rains are often lower than 200 mm which is too low to support a maize crop. Maize in WPLL requires at least 600 mm of well distributed rain (Hatibu *et al.*, 1999). The amount of rainfall received would still be insufficient even for drought tolerant crops for example sorghum which requires 450 mm per season (Dorenboos and Kassam, 1979). That in a way explains the poor performance of the maize crop observed in this study. At times, the amount of water received from individual rainfall events was too low and very poorly distributed to even permit germination and emergence. The 1993/94 and 1998/99 *Vuli* seasons were such examples as the crop failed completely at establishment resulting in low biomass and no

grain yield at all. There was no demonstrated advantage in terms of grain yield between different treatments during *Vuli*. It is evident from this study that when seasonal rains are very low compared to crop water requirements as was the case during *Vuli*, the benefits in terms of increased crop yield from SWC measures may not be realised. This may explain the low adoption rates of SWC measures in semi-arid areas (Hudson, 1991).

During all the *Masika* seasons except in 1994, flat cultivation (FC) had slightly lower grain yield that was not statistically different from that in treatments with barriers (SB, CR and LB). The above can be attributed to lack of significant differences in soil moisture between treatments. Similar findings were reported by Gebremedhin (1996) for a maize crop planted on flat and on ridges during long rains. Adequacy of rainfall and its good distribution were given as explanations which ruled out moisture differences despite enormous runoff losses from flat cropping. Results from almost similar studies by Critchley (1989) in Kitui District in Kenya, showed that crop yield

responses to water conservation can be obtained only in seasons of below-average rainfall.

Given the small increment in yield which was realized, farmers are unlikely to adopt the above conservation measures in this agro-ecological zone and especially for lowly valued maize in light of the investment costs in terms of labour and capital. According to Singh *et al.* (1994), SWC measures such as stone bunds or those involving earth movement require specialized knowledge, high labour and therefore cost. Such measures are therefore unlikely to be readily adopted if there are no tangible benefits to the farmer.

The gradual and natural formation of bench terraces, was an indication of the net movement of the soil down slope. In the absence of barriers, the almost invisible soil movement can not be checked, and its eventual loss from the crop fields can not be stopped. Thus, if the long term goal is to conserve soil on the slopes and pediments of western Pare (>8% slope) rather than water, then, any of the contour barrier practices evaluated in this study could be adopted.

Conclusions

Contour barriers had no significant effect on soil moisture conservation and on maize grain yield compared to the control. Given the small increment in yield which was realized, stone bunds, contour ridges and live barrier practices can not be recommended for moisture conservation in this agro-ecological zone. However, since the barriers were effective in controlling soil creep down slope, they could be recommended as long-term measures for soil erosion control where this is considered a threat.

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