38 Contour Stone Bunds for Water Harvesting on Cultivated Land in the North Yatenga Region of Burkina Faso

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Climatic conditions, lack of vegetation, tillage and livestock-keeping practices in the Sahelo-Sudanian region are responsible for *surface crusting* and soil and water loss in Yatenga Province in Burkina Faso (Figure 1). In particular, these processes occur at the base of degraded and impermeable uplands. This erosion crust impedes infiltration and fosters self-accelerating erosion processes. In response to drought, farmers do not give up their usual crops and traditional practices. They try to increase the area under cultivation and incorporate microcatchments and ploughing into their usual cropping systems. To combat erosion, they build lines of stone in waterways. But ploughing increases the risk of soil loss and traditional lines of stone have no global influence on water balance and yields.

Since 1980 development organisations have been introducing a new field structure: contour stone bunds (Figure 2). These structures have now been adopted on a large scale by farmers in the Yatenga region (Burkina Faso).

On-farm research has been carried out for five years in the Yatenga region by ORSTOM and partners in Burkina Faso in order to study the evolu-

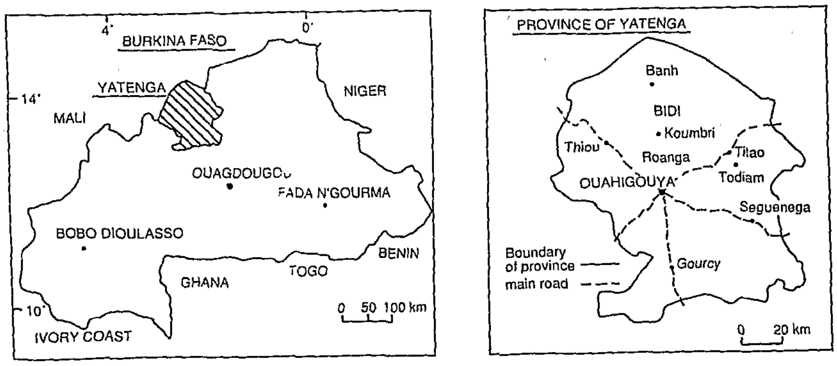

FIGURE 1. Location map.

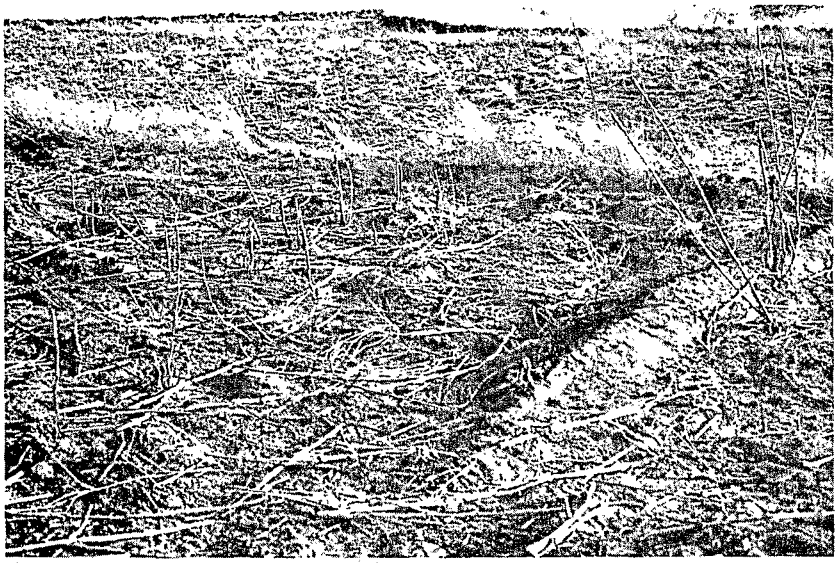

FIGURE 2. A grassed contour stone line crosses the treated Plot 2, with a tied bund on the upper side extending towards the observer (G. Serpantie, 20 March 1990).

tion of farming systems under Sahelo-Sudanian conditions. A field trial was set up on a farmer's plot in the village of Bidi, north of the provincial capital of Ouahigouya, under the management of a scientist in 1985. The trial had several aims. The first was to gain additional knowledge of the influence of runoff and erosion at the field scale. The second was to evaluate the advantages, shortcomings and potential uses of microdam systems, microcatchments, and ploughing when used in traditional cropping systems.

RESEARCH APPROACH

Three plots, each 150 m long and 30 m wide, were set up, including a control plot (Figures 3 and 4). The upper 50 m consisted of an uncultivated microcatchment with three main surface types:

- Erosion crust
- Pavement crust
- Sandy micromounds

The lower 100 m were cultivated. They collected runoff from the upper part. The plots were equipped with two runoff recorders and a sediment trap, 8 sites for neutronic soil moisture measurement, and numerous sites for vegetation evaluation. All were cultivated with a local variety of millet

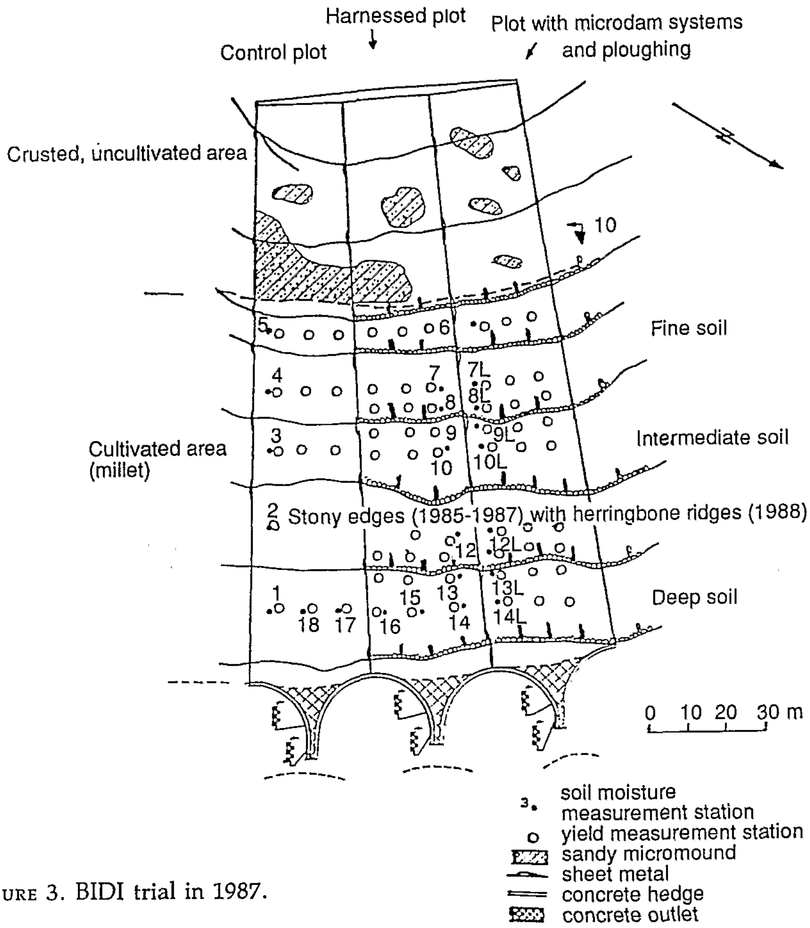

FIGURE 3. BIDI trial in 1987.

using the same traditional "bush fields cropping system": 10 years of millet followed by 5 years of fallow, direct seeding in seed holes, two hoeings and very light fertilising with NPK. No organic manure was used.

The system of stone lines installed on Plot B (harnessed plot) was made of ferrugineous cuirass blocks (40 kg/m). Stone lines were 20 cm high and 40 cm wide. The lines were spaced 20 m apart (mean slope: 2.5%). Plot C was similar to Plot B except for an additional ploughing. This paper will discuss only the results on Plot B and the control plot (Plot A).

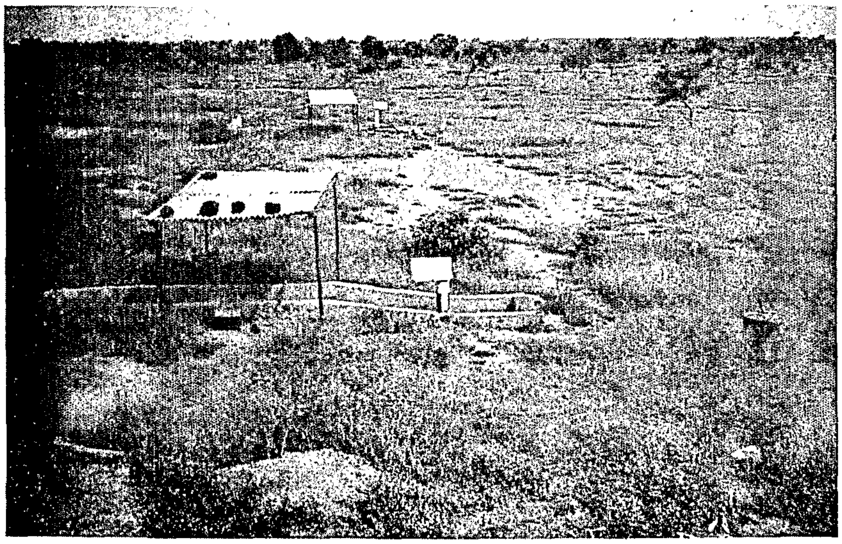

FIGURE 4. Runoff and soil loss collection device from plots 2 and 3 of the Yatenga on-farm research in Bidi. (G. Serpantie, 4 September 1989)

Water running from microcatchments into the cropped plots was estimated using the hydrodynamic formulas of Albergel (1987) and Casenave and Valentin (1986). The microcatchments were partially removed in August 1987.

DATA ANALYSIS AND RESULTS

The following results were obtained based on an annual analysis (Table 1):

- Inflow from the upper part of the plots (the uncultivated catchment areas) provided surplus water equivalent to 15–20% of the annual rainfall.
- The physical structures proved effective in reducing water and soil loss.
- In general, the structures increased yield. The reduction found in 1988 can be attributed to weed infestation and waterlogging of the structures under very rainy conditions.

Data were also processed on a storm-event basis.

Additional variables were also considered. These included antecedent soil moisture, assessed with an antecedent precipitation index, and soil surface conditions, namely, vegetation cover, surface roughness, and porosity associated with surface crusting and compacting.

TABLE 1
Yearly records of BIDI trial

	1985 (7/10 to 10/15)					1986 (6/1 to 10/15)				
	P (mm)	LE (mm)	LR (mm)	Y (kg/ha)	ET (t/ha)	P (mm)	LE (mm)	LR (mm)	ET (t/ha)	Y (kg/ha)
Control plot	239	34	70	163		530	96	127	5.2	196
Harnessed plot	242	43	58	180		528	106	124	3.4	330
Difference (%)			−17	+ 10				− 2	− 36	+ 88
	1987 (6/1 to 10/15)					1988 (4/1 to 10/15)				
Control plot	483	92	53	309	1.7	561	11	96	3.0	395
Harnessed plot	484	107	42	402	0.6	561	22	52	0.6	290
Difference (%)			−21	+ 30	− 68			−46	−69	− 27

P — depth of rainfall at soil level; LE — running water coming from microcatchment into the millet field; LR — runoff measured in outlet of millet field; ET — total soil losses; Y — yield of millet (down half of the field).

The limits of each variable are arbitrarily determined in order to discriminate carefully and, if possible, obtain categories of similar size. Therefore, numerous combinations of these variables are analysed. First, an analysis of runoff and a determination of soil loss are made. The methodology involves graphic analysis and statistical analysis involving these two variables.

Graphic analysis: in a graph of these variables (Figure 5) a "field" is clearly defined by:

- The line representing runoff maxima (slope k max=maximum runoff coefficient after initial rainfall.)
- The line representing runoff minima
- The maximum initial rainfall
- The minimum initial rainfall

Statistical analysis: a statistical group determined by all floods in a special environment may undergo regression analysis and be compared with other groups using covariance analysis if the number of events is sufficient.

RUNOFF EVALUATION

Standard Storms (Figure 6)

Soil roughness and porosity seem to be the principal factors limiting the runoff coefficient. Soil moisture is an important factor in decreasing the period of initial rain without runoff with increasing moisture, but does not modify runoff coefficient in the experiments conducted (steepness of correlation line).

Millet cover seems to have no clear reducing effect on runoff in any soil surface category. An exception is the case of surfaces conducive to runoff (smooth and humid), when initial rain is increased from 10 mm to 15 mm. Millet cover also increases the duration of roughness after hoeing if the first hoeing (growth stage) is compared with the second (fructification stage).

Intense rainfall

Small amounts of intense rainfall generate the same runoff as normal storms. But intense rainfall exceeding 20 mm produces runoff close to 90% of the initial rainfall, even on a rough surface.

Light Rainfall

Light rainfall increases initial rainfall up to 50 mm, particularly on dry surfaces.

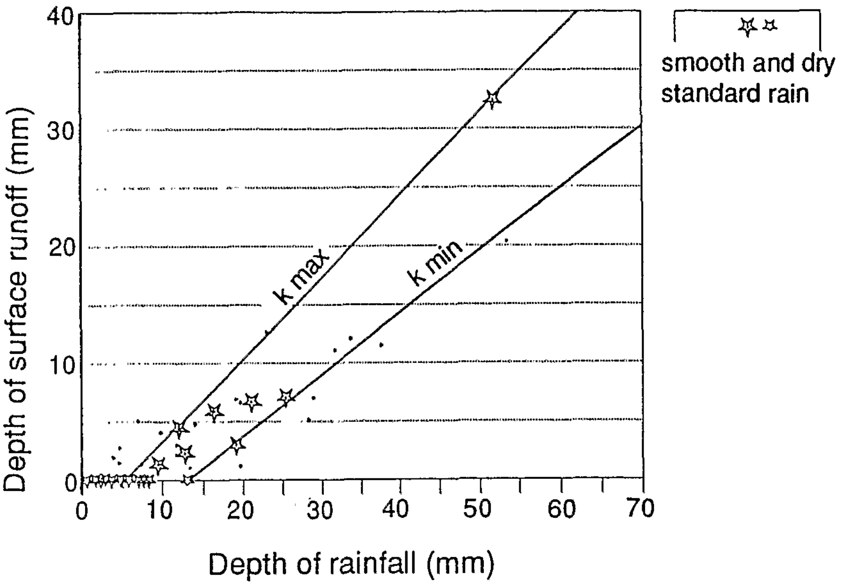

FIGURE 5. Relationship between rainfall and runoff for standard rain and different surface roughness.

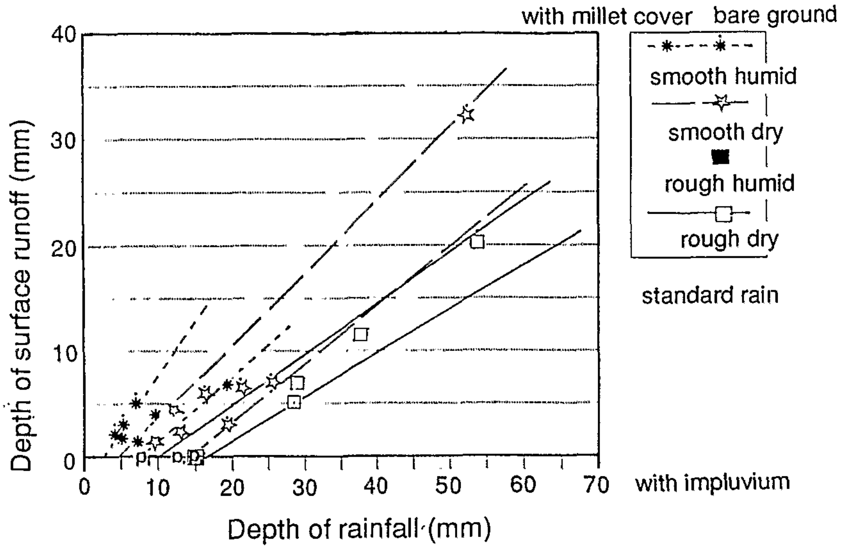

FIGURE 6. Relationship between rainfall and runoff for standard rains, different vegetative cover and surface roughness.

EFFECT OF MICROCATCHMENTS

A comparison of runoff before and after removal of microcatchments shows that microcatchments produce runoff which is partly soaked up in the field. The amount of runoff soaked up depends on the amount of rainfall.

SOIL LOSS EVALUATION

Results are in accordance with familiar theories (Figure 7): Light rainfall: Soil loss depends on the determinants of runoff. Heavy rainfall: The relationship between soil loss and amount of rainfall depends on several factors, including rainfall intensity, millet cover conditions, and soil surface. In a heavy storm, a bare, uncovered, rough surface will be more severely eroded than a smooth surface.

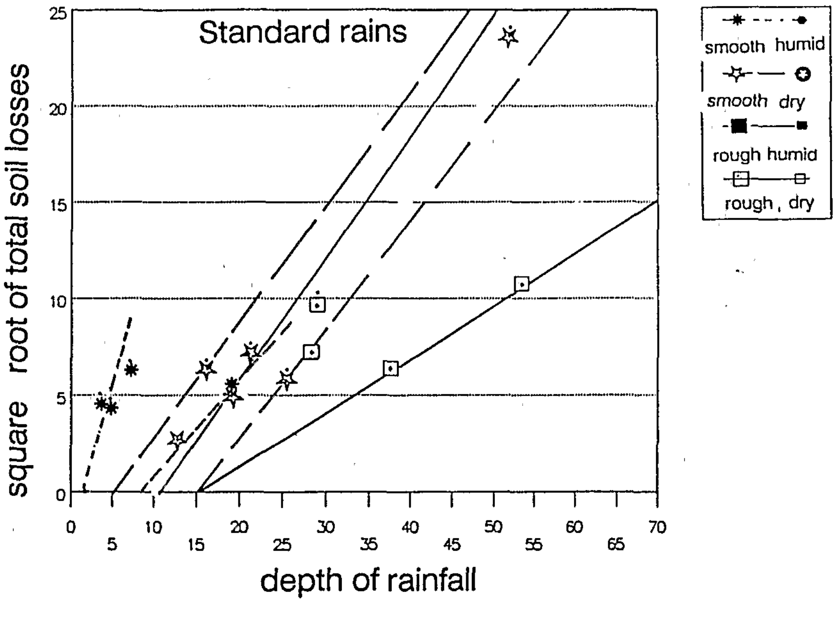

FIGURE 7. Relationship between rainfall and erosion for standard rains, different soil moisture and surface roughness.

EFFECT OF STONE LINE STRUCTURES

RUNOFF

Soil surface conditions and rainfall intensity are two factors which interact strongly with the efficiency of structures. These interactions were found to be significant following a covariance analysis of graphs of the square root of runoff coefficients (Figure 8). Runoff coefficient is defined as:

$$rc = o/(p+n)$$

where rc=runoff coefficient; o=runoff (mm); p=amount of rainfall measured at soil level; n=water running from upper microcatchment

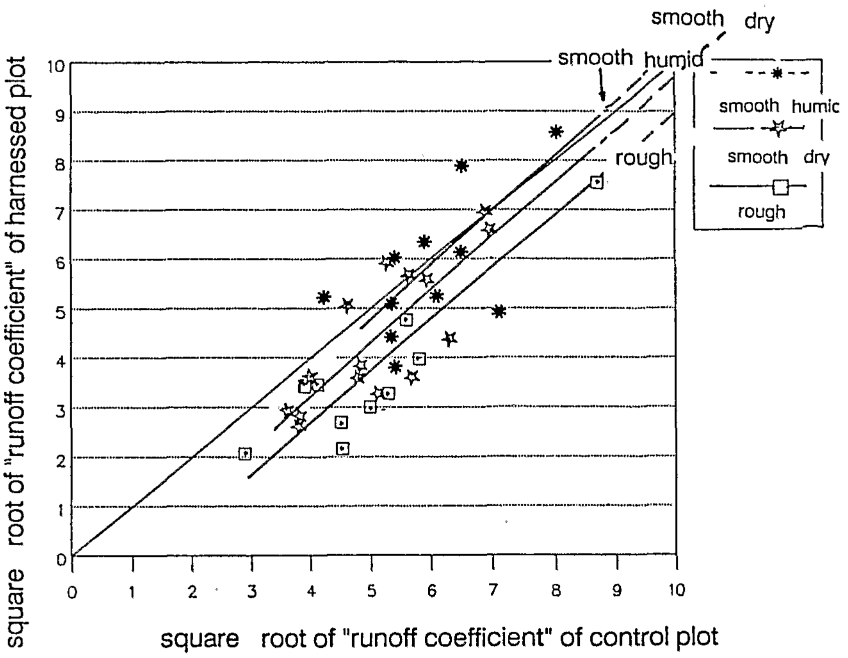

FIGURE 8. Comparison of runoff on control plot and treated plot (all events) for different roughness and soil moisture.

Under very bad conditions (intense or normal rainfall on smooth and humid surfaces), structures have significantly less effect on infiltration.

A further apparent interaction with amount of rainfall was also found due to a bias in the number of events: there are more floods on smooth surfaces after light rains than after big storms, so the effect of surface condition appears to be an effect of storm intensity.

Finally, hoeing the soil between the bunds enhances the beneficial effect of these structures, except when rainfall is intense. This effect is cancelled or even becomes negative as soon as soil is wet and capped with a smooth erosion crust, except when rainfall is light.

These results help to interpret the variations among annual records.

Soil Loss

Regardless of soil moisture, surface conditions and rainfall intensity, there was considerably less sediment from the treated plot than from the control plot. Further analysis of sediment particle size distribution is needed, however.

Flood Patterns

Stone lines reduce and delay peak discharge and greatly foster deposition of the largest detached particles.

OVERALL EVALUATION

Infiltration conditions are a function of the efficiency of structures. Stone lines increase the infiltration of running water. Scale must be taken into account to explain no effect or a negative effect with stone lines in very bad conditions (intense rain, smooth and humid surface). Running water may make different patterns in a large area, such as regular sheet flood, confused rills or localised rills. Even pervious structures increase rilling, but rough surfaces split rills to cause a confused rill flood. Split rill floods should produce more infiltration than rilled floods or perfect sheetflood. This hypothesis correlates with field observations, the effect of compartmentalisation, and interactions found in the present study, as well as with results obtained by Collinet (1988).

CONCLUSIONS

A contour stone bund system can be recommended in Sahelo-Sudanian zones under the following conditions:

First, farmers must be willing to participate. As a result of drought and the traditional economic system, farmers in the Yatenga are usually aware of land degradation and ready to combat it. The only apparent time to do this is during the dry season. But this is also the time during which additional income is earned (commerce, handicrafts, gold washing, market gardening, migration in search of work). Moreover, cutting and transporting cuirass blocks and planting Andropogon during hoeing time are not easy tasks. Appropriate incentives and support should be provided.

Second, it is crucial that stone lines be constructed perfectly on the contour in order to avoid rilling. Experience shows that farmers can be rapidly and properly trained to install them using a simple water tube level.

Once the structures are in place it is essential to obtain optimal distribution of water flow on the surface. Distribution should be neither too concentrated (which will increase rilling, splash erosion and water loss) nor too laminar (which will encourage development of erosion crust).

Mounding, a manual weeding practice, could help achieve these aims. Moreover, ties should be constructed in the flooded area near the stone lines to partition it and avoid flood concentration and rilling (see Figure 2). These structures are more effective in very pervious soils (sandy soils) than in impervious soils (brown soils) unless stone lines are close together.

In order to reduce splash erosion and crust formation and enhance surface roughness, weeding should be done earlier than usual and the surface should be protected by intercropping and growth-accelerating techniques (e.g. early fertilisation).

Finally, under proper conditions, water harvesting in degraded uplands, when combined with this type of stone bund system, improves the water balance and limits soil loss.

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