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Erosion Impact on Crop Productivity on Sandy Soils of Northern Cameroon

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INTRODUCTION

Because of insidious nature of sheet erosion, farmers, extension officers and agroscientists do not seem to have taken into account the erosion hazards in African countries, though many studies on this subject have shown its importance (Harroy, 1944; Hudson, 1961; Roose, 1977; Lal, 1976; Charriére, 1944; Pieri, 1989).

This could be partially explained by the fact that their main preoccupation has been the crop yield rather than soil loss. Little data are available on the interaction of yields and erosion. Existing information is mostly concerned with soil desurfacing (gradual removal of the top layer of the soil), or by models, mainly based on soil and nutrient losses.

Some authors (Hart and Healy, 1980; De Kimpe et al., 1981; Ross, 1982; El Swaify et al., 1982; Mbagwu et al., 1984a; Mbagwu et al., 1984 b; Jessop, 1985; Rogowski, 1985) reported yield losses of 10 to 80 per cent variable with the plant material, the soil type, rainfall pattern, etc.

On the other hand, mathematical models have experienced difficulties in their adaptation to real situations and generalization: one of the reasons is the variation of the sediment yield with the cropping system.

On small experimental plots such as Wischmeier's standard, the plot length will not generally allow rill erosion that could affect plant population. Therefore, studying erosion impact on crop productivity through desurfacing presents some limitations:

1. In reality, soil is not uniformly eroded but runoff selectively removes fine particles closely related to soil fertility (organic matter and clay);

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2. the small size of the plot (50 m^2)does not allow development of rills and its consequences on plant density;
3. the time factor is not given due consideration: soil desurfacing is immediate, whereas soil degradation by selective erosion is progressive.

Consequently, it is necessary to develop researches on the impact of the erosion on soil productivity in order to predict crop yield and mainly to sensitize farmers and agro-officers to the impact of erosion.

In this paper, an attempt is made to define the framework within which the relation between erosion and crop yield should be evaluated.

THE STUDY AREA

The study was carried out in the village of Mbissiri (lat. 8°23′ N, long. 14°33′ E, lat. 380 MSL) located 250 km southeast of Garoua in the Sudanese zone of North Cameroon.

The annual rainfall varies from 1000 to 1500 mm. High frequency of heavy storms (60–120 mm d^{-1}) and series of storms are observed from May to October.

The arable cropped soils are sandy Alfisols (with less than 10 per cent of kaolinitic clay in the topsoil) developed on granite or ferruginous sandstone. The topsoil is acid (pH 5 to 6) and very poor; the organic carbon content (0.6% under Savannah, 0.3% under cropped fields) and the clay content are very low (see Table 1).

In this region, most of agriculture is rainfed. Intensive cotton/maize rotation has been encouraged since 20 years in this semi-humid area.

Table 1. Analytical data on the topsoil (0–10 cm) of Mbissiri research station.

	Burnt Savannah and grazed	3 years after deforestation		33 years after deforestation
		Block A	Block B	Block D
pH H_2O	6.2	6.0	5.6	5.0
Carbon %	0.65	0.27	0.34	0.25
Coarse Sand%	66.1	65.4	71.5	57.3
Fine Sand %	14.4	14.8	13.4	20.8
Loam %	13.8	15.4	13.0	15.0
Clay %	5.4	5.1	3.5	5.6

The components of the cropping system are:

- blocks of field with basic unit of 1/4 ha (50 × 50m^2),
- rotation of cotton with food-crops (maize, sorghum, groundnut),
- intensification through ploughing, mineral fertilizers, crop protection, improved varieties.

Soil tillage is widely extended; 70 per cent of tillage is done by ox-drawn ploughs. The remaining 30 per cent done by hand or by tractor. Chemical fertilization includes an NPKSB compound (15-20-15-6-1) and urea (45 % N).

- for cotton early planting dates, 200 kg ha^{-1} of the compound plus 50 kg ha^{-1} of urea at sowing, then 50 kg ha^{-1} of urea just before earthing up the plants (30–45 days after sowing).
- for late planting dates (June 20th–July 10th) 100 kg ha^{-1} of the compound NPKSB plus 100 kg ha^{-1} of urea at sowing,
- for maize planting, 100–200 kg ha^{-1} of the compound NPKSB plus 50–75 kg ha^{-1} of urea at planting, and 50–75 kg ha^{-1} of urea before earthing up the plants, according to the level of intensification.

METHODS

The study included the following approaches:

- a survey in the farmers' fields;
- runoff plots: where runoff, soil loss and biomass production were monitored;
- a randomized block design trial on desurfacing.

A survey was carried out from October 1989 to September 1990 (Boli et al., 1991). All cropped blocks (5 to 30 hectares) of seven villages of Tchollire subdivision were visited. The general status of the soil and cropping patterns were observed and the areas severely affected by erosion were quantified.

At our experimental station, 57 runoff plots of 100 m^2 (5 m x 20 m) to 1080 m^2 (18 m × 60 m) where set up in (a) a newly cleared land after 30 years of fallow blocks—A, B with respectively: slope gradient of 1.0 and 2.0 per cent, and (b) an old cleared land of 30 years' continuous cropping and abandoned in 1989—Block D, slope gradient 2.5 per cent.

Cropped plots were alternatively under cotton (1991, 1993) and maize (1992, 1994) with various cultural practices.

Each block carried one 100 m^2 plot conventionally tilled and receiving each year before tillage the equivalent of 3 $t.ha^{-1}$ of goat mannure (3% N) in addition to the uniform chemical fertilizers. The three blocks represented three levels of soil sensitiveness to erosion due to age of cropping, slope gradient and slight change in texture.

In 1993, a soil desurfacing trial was set up near the runoff plots, after a homogeneity test (N maize, no-till planting without fertilizer) in 1992. The design was a randomized complete block with six treatments (0.0; 5.0; 7.5; 10.0; 12.5; and 15.0 cm of topsoil removed) and three replications. The experimental plot was 50 m^2 (10 m × 5 m). Ground was removed by hand using pickaxes and shovels, then plots were ploughed using oxen traction. A uniform chemical fertilization of 100 kg ha^{-1} of compound N_{15} P_{20} K_{15} S_6B_1 and 50 kg ha^{-1} urea at sowing then 50 kg ha^{-1} urea just before earthing up the plants 45 days after sowing was applied. Maize variety CMS 8507 was sown at 50000 seed holes per ha. Plant population was checked at germination and harvesting time. General observations were carried on during the vegetative growth. Ears, grains and straw were sundried and weighed.

RESULTS

Survey

On the newly cleared land (1–5 years) under ox-drawn or manual tillage, erosion was low and very localized movement of detached sand was limited to decimeter scale. The crops did not seem to be affected by erosion.

On the plot lands that had been cropped for ten years and more, erosion was more serious, sometimes spectacular. One could see three main sites where crops were affected by rill erosion:

- the centre of the rills, where plants were uprooted and removed,
- the surrounding area of the rills, where plant roots were exposed,
- the sedimentation area, where plants were partially or entirely buried by sediments.

In this case, average area affected by erosion was 10 per cent of the field.

Runoff Plots

The responses of maize and cotton to goat manure fertilization under three levels of soil sensitiveness to erosion are given Table 2.

Table 2. Comparison of erosion and yields of maize and cotton from plots (blocks A, B, D) under goat manure fertilization

Year crop	Blocks	Erosion $t.ha^{-1}yr^{-1}$	Grain yield t ha^{-1}	Straw yield t ha^{-1}
1992	A	6.3	9.6	5.4
Maize	B	21.1	5.8	4.1
	D	31.4	5.3	5.25
1993	A	3.2	2.95	8.25
Cotton	B	6.2	2.7	7.2
	D	15.6	2.07	5.1

The table shows that, the higher the erosion (therefore the depletion of nutrients) the lower the yield.

In each block, the plot with goat manure gave the highest yield.

In 1993, heavy storms affected the cotton population from the germination stage in relation with the sensitiveness of each block to erosion (Table 3).

Table 3. *Cotton stands count at harvest compared to erosion of the manured plots of blocks A, B and D (1993)*

Crop (year)	Blocks	Stand count at harvest on 100 m^2	Erosion t ha^{-1} y^{-1}
Cotton 1993	A	321	3.2
	B	306	6.2
	D	244	15.6

The table shows that the higher the erosion, the lower the plant population at harvest.

Desurfacing Trial

Table 4 shows the decline of yield with increasing reduction of topsoil. From the early stage, discolorations of the leaves, characteristic of zinc deficiency were noted on all the desurfaced plots.

Table 4. Effect of soil desurfacing on yield of maize grain and straw (t ha)

Desurfacing depth (mm)	0.0	50	75	100	125	150
Grain yield (t ha^{-1})	2.2	1.5	1.5	1.4	1.3	0.9
Straw yield (t ha^{-1})	5.6	5.3	4.9	5.1	4.4	4.6

Desurfacing did not affect germination or plant stands at harvest, but it affected ear filling (Table 5).

Table 5. Effect of desurfacing on maize stands count at germination and harvest, and on number of empty ears.

Desurfacing depth(mm)	Germination in seed holes, %	Stands at harvest compared to germination, %	Empty ears compared to total harvested, %
0.0	94.3	99.8	5.6
5.0	96.4	100.0	12.5
7.5	95.6	99.1	9.3
10.0	96.5	99.5	13.7
12.5	96.5	99.7	10.6
15.0	96.5	99.7	11.5

DISCUSSION

Yield is affected by erosion at two levels:

- decrease of plant population.
- selective losses of nutrients, clay and organic matter.

One can quantify the effect of erosion on plant density:

- some seeds are taken away by splash and runoff during heavy storms on unstable soils (missing plants at germination),
- some plants are uprooted by rill erosion, and,
- others are buried under sediments.

Around rills, plants cannot cover up the gap of production left by missing plants. Rills, gullies and sedimentation areas are parameters limiting soil production. Generally, this kind of action occurs when soil has reached an intense degradation stage, characterized by its high instability to water. It starts after some years of continous cultivation and progressively increases like the Wischmeier K erodibility factor (Roose and Sarrailh, 1989). Depletion of nutrients, fine mineral particles and organic matter are the more insidious characteristics of sheet erosion. Maize yield (grain and straw) continuously decreases with progressive removal of topsoil, despite NPKSB fertilizer applications (Fig. 1). Topsoil removal did not affect the number of plants at germination and harvesting stages, but it affected grain formation. The average number of empty ears in the plots where topsoil was removed was twice that in the control plot (see Table 5).

On the other hand, the maximum amplitude of grain yield decrease (56%) was higher than that of straw yield decrease (21%). This difference is likely due to mineral deficiencies, for example of zinc, and to other soil characteristics (decrease in soil water content) as consequences of topsoil desurfacing. These factors seem to affect more grain formation more than straw production. Removal of the five first centimetres resulted in a yield reduction of 30 per cent against 4 per cent for the next 5 cm. The difference is due to the distribution of the organic matter between the two layers.

After desurfacing of 15 cm of topsoil, ploughing brought up to surface ferruginous gravels; because a decrease of fine earth, the grain yield decreased by 56 per cent (Fig. 1).

On the other hand, on manured runoff plots, we observed a decrease of production when erosion increased (Fig. 2). Goat manure (3t ha^{-1}) added 90 kg ha^{-1}/y^{-1} of progressively available nitrogen and slightly improve soil physical properties. It is obivious that if fertilizer are eroded off, fertilization will not benefit to the plants. On these plots, yield losses by one mm of soil eroded were much higher (30% for 1 mm) than on desurfaced plots (30% for 50 mm) (Table 6).

Table 6. Yield variations compared to erosion variations (soil loss differences between manured runoff plots)

Soil losses differences (d.E)		Yield differences (d Yd) 100 kg ha^{-1}		Percentage	
t ha^{-1} y^{-1}	mm y^{-1}	cotton	maize	cotton	maize
3.0	0.25	2.5	—	8.5	—
9.4	0.62	6.3	—	23.3	—
10.3	0.66	—	5.0	—	8.6
12.4	0.82	8.8	—	30.0	—
14.8	0.98	—	38.0	—	39.5
25.1	1.67	—	43.0	—	44.8

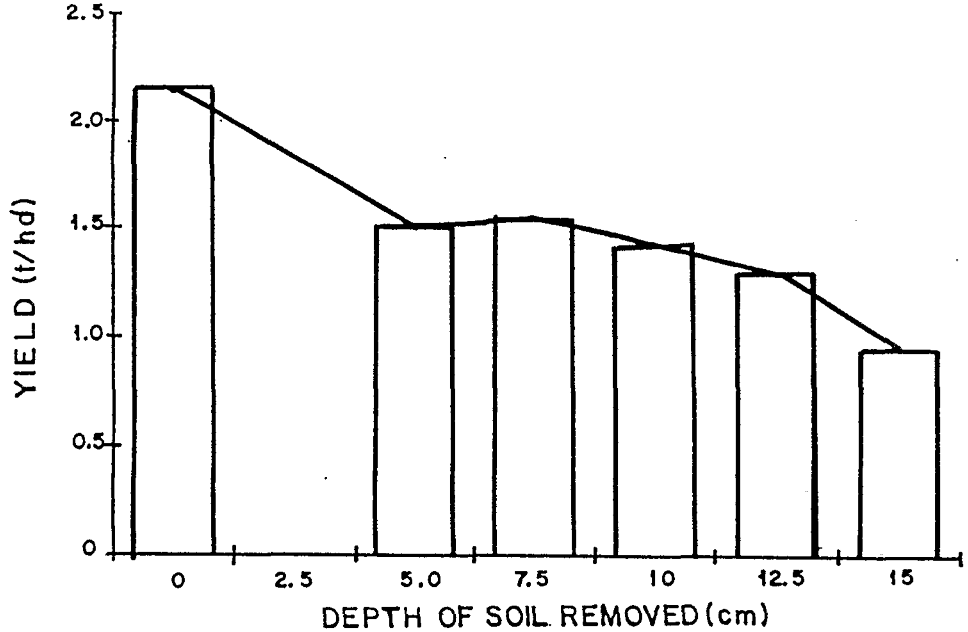

Fig. 1. Yield of dried grain maize as affected by topsoil progressive removal.

These results suggest that tolerance to soil erosion is very closely related to distribution of fertility factors in the soil, and to erosion processes involved (selective or otherwise).

Data from Table 6 suggest that yield of maize varies more than that of cotton.

This difference of yield in relation to the crop, increases with the importance of soil losses (Fig. 3). This could be explained both by crop type and amount of rain fall during the cropping period.

The relation between differences yields and soil losses, dYd = f (dE) is a curve of "S" shape (Fig. 3). It means that, once fertility factors are exhausted by runoff and drainage water, the additional soil losses will give less depletion on yields.

CONCLUSION

This study shows that on the sandy Alfisols of northern Cameroon Sudanese Savannah Zone, erosion negatively affects crop yields by reducing the plant population and by depleting fertility factors.

It appears evident that to secure acceptable yields in the long run, soil must be kept stable, so that runoff must not take away seeds, plants, and fertility factors.

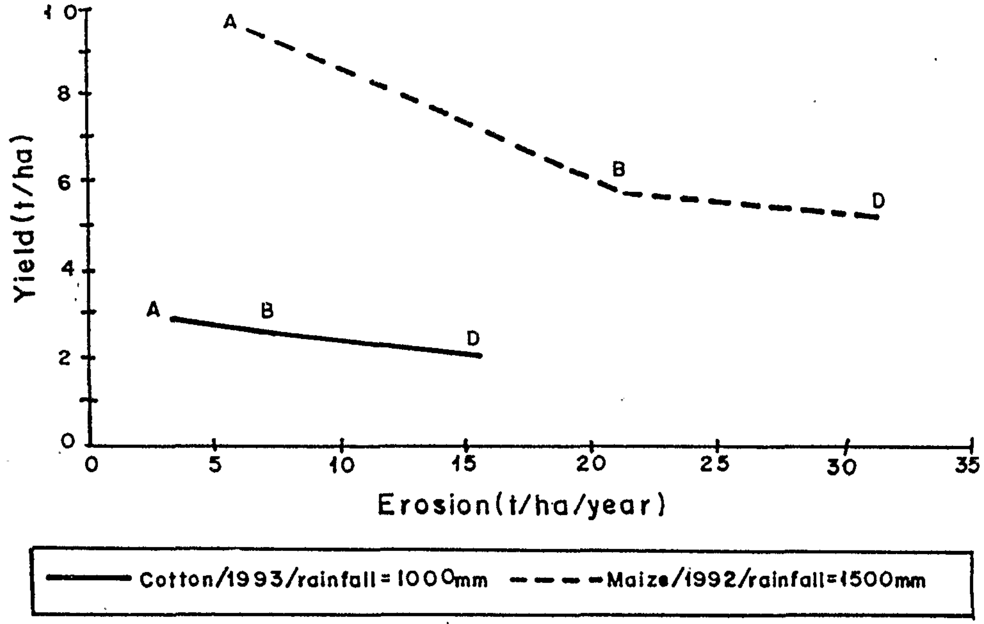

Fig. 2. Yields of maize and cotton as affected by erosion in the goat manured plots (Mbissiri 1992 and 1993).

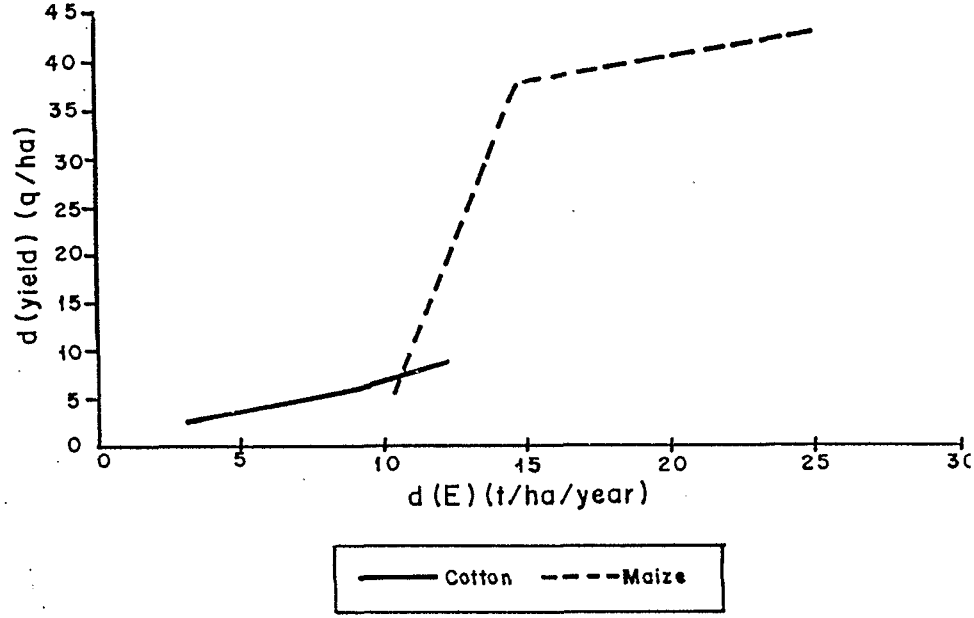

Fig. 3. Differences in yields of maize and cotton, compared to difference of erosion of the corresponding plots.

In the case studied, the reduction of yield after artifical removal of soil is not linear; the removal of the 5 top cm had a more greater impact on the productivity than removal of the next ten cm.

Also, application of chemical fertilizers did not compensate for the depletion of fertility factors by erosion.

Finally, soil losses(in mm) by sheet erosion were more harmfull than by simple desurfacing. The notion of tolerable erosion (1–12 t $ha^{-1}y^{-1}$) appears to be very relative and dependent on fertility distribution down the soil profile and the type of plant (less effect on cotton than on maize).

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