Don Au
Pole 1

Advances in GeoEcology 31, 395-401 Reiskirchen 1998

Degradation of a Sandy Alfisol and Restoration of its Productivity Under Cotton/Maize Intensive Cropping Rotation in the Wet Savannah of Northern Cameroon

Z. Boli Baboule & E. Roose

Summary

On the sandy alfisols of the cotton belt of Northern Cameroon, conventional intensive cropping based on soil tillage and mineral fertilizers application does not prevent soil degradation or free farmers from shifting cultivation. The aim of this study was to characterize degradation of these soils under intensive cropping, and to develop ways for restoring the productivity of these degraded soils that have been rendered unsuitable for intensive cultivation. The study was based on evaluation of soil constituents, structure and functions as affected by time. Run-off plots were used in two locations at different stages of soil degradation.

Degraded soils were characterized by a low organic carbon content (around 0.2%) in its upper 10 cm, a high erodibility, and a high compaction of the upper layers when not recently tilled. Restoration of productivity on these soils should start by aerating and stabilizing the compacted layers. Only then can fertilizer application and other improvements be profitable. Soil mulching after tillage and incorporation of farm manure, adoption of conservation tillage practices and short duration fallows, allow restoration of productivity on these degraded soils.

Keywords: Northern Cameroon; sandy alfisols; conventional vs no-tillage; soil compaction erosion, restoration of productivity.

1 Introduction

In the wet Sudanese savannah of Northern Cameroon, cotton (*Gossypium hirsutum*) and maize (*Zea maidis*) are grown in an intensive cropping system with conventional soil tillage, mineral fertilization, application of insecticides and improved varieties. However, this intensive cropping system does not prevent soil productivity from declining. Lands where inputs are no longer profitable are abandoned and new fields are opened from savannah bush fallow. In a previous survey carried out in the main area of intensification of the cotton belt of Cameroon, Boli et al. (1991) noticed that soil degradation and erosion were major causes of the continuous yield decline.

To better understand how disfunctioning of the "soil - plant - atmosphere system" occurs, an experimental design with 57 run-off plots of 100 to 1000 m² was set up and observed both on a new and an old field at Mbissiri, from 1991 to 1994. Experiments presented in this paper had two objectives : (1) characterization of sandy alfisol degradation under different tillage systems and, (2) restoration of productivity of soil degraded by conventional tillage.

ISBN 3-923381-42-5

Roose no 211

2 Material and methods

2.1 Climate

The region falls within the wet Sudanese zone. Its annual rainfall varies from 1000 to 1500 mm. The length of the rainy season is six to seven months, from April to October (Suchel, 1988).

2.2 Soils

Sandy alfisols are the most representative soils for rainfed farming in this region (Brabant and Gavaud, 1985). The Mbissiri soils are developed on a sandstone and have less than ten per cent clay content in the upper 15 cm, a poor organic matter content (1.2%) and a low cation exchange capacity (1.5 to 3 meq/100g). Depth of arable soils above parental rock or ferruginous hard pan varies with the position on the slope (from 0 to 100 cm). Average slope is two per cent.

2.3 Field methodology approach

Soil constituents, structure and functions are compared for two situations: (1) recent fields and (2) degraded old fields. In each field, conventional and conservation tillage are compared. The basic experimental unit is a run-off plot of 100 m² (50 × 20). Three of the four cropped blocks have 16 plots each. Not all kinds of treatment are replicated in the third block located on degraded soil. The evolution of the constituents is evaluated by comparing the mineral and organic fractions and the pH of the 0 - 10 cm soil layer between February 1991 (t_1) and February 1995 (t_5). For the evolution of the soil structure, the status of the soil surface is considered after one or several rainfall events occurring after tillage. The soil water content at the pF values of 1.8 and 4.2 also gives an idea of the change in soil structure. The determination of the soil bulk density after the first two cropping cycles, the visual estimation of macroporosity and the counting of roots of the cultivated plants in the 0 - 40 cm layer were also considered. Run-off, soil loss and crop yield are considered in this study as descriptors of soil functions (Boli, 1996).

2.4 Treatments

Two groups of treatment are tested: (1) the conventional tillage group and (2) the no-tillage group (Table 1). Mineral fertilizers were applied to cotton and maize.

Conventional tillage	No-tillage
• Control, which is the intensive cropping system: soil ploughing, sowing, weeding and moulding up six weeks after sowing • Bare fallow control • Ploughing after application of 3 t/ha of goat farm manure, then sowing ... • Ploughing after two years rest (without ploughing) on the degraded soil	• No-tillage on soil that has not been loosened (new and old fields) • No-tillage on degraded field after loosening • No-tillage on degraded field after two years of fallow (one plot of bush fallow and another one of improved fallow with Calopogonium mucunoïdes)

Table 1: Tested groups of treatment

3 Results

3.1 Rainfall

The rainfall characteristics of the four years are indicated in Table 2. The low number of days with run-off in at least one plot in 1991 is due to late planting (July 10) as compared to the other three years (June 20). The year with the highest total rainfall (1992) was also the year with the highest soil losses. The driest year (1993) recorded the most aggressive single rainfall event.

Year	Total annual rainfall (mm)	Total rainfall cycle (mm)	Number of days with run-off	Maximum $I_{max}30'$ observed (mm/h)	RuSA index	Rainfall series occurrence
1991	1209	673	13	-	419*	yes
1992	1570	1184	24	97	785	yes
1993	1072	772	19	117	496	no
1994	1352	1073	23	91	433	yes

*estimated

Table 2: Main rainfall characteristics of the 4 cropping cycles

3.2 Evolution of soil organic carbon content

Figure 1 indicates the evolution of the soil organic carbon content in the upper 10 cm layer of the savannah soil (SAV), bare soil (NUE), the control (TRM), and no-tillage (ZT) for new and old fields. Four years after land clearing, the soil organic carbon content has dropped down to the level of 0.3 % found on the degraded soil after many years of continuous cultivation.

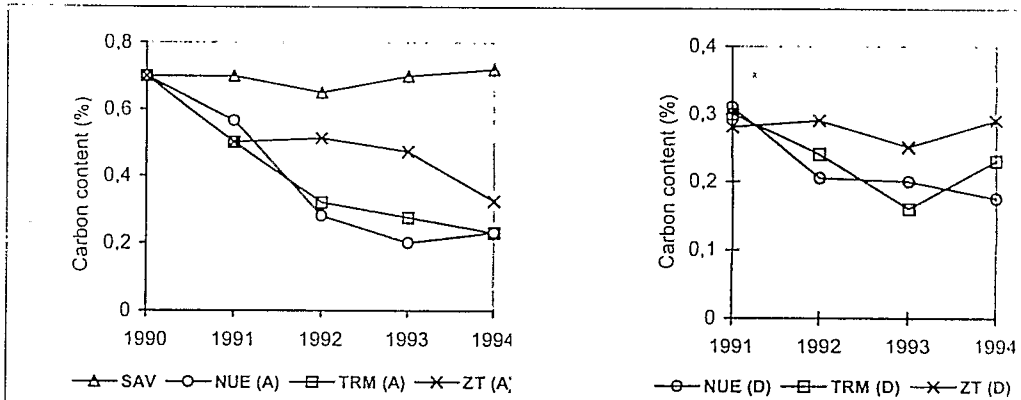


Figure 1: Evolution of organic carbon content in the 0 to 10 cm soil layer as affected by soil treatment between February 1990 and February 1994

3.3 Changes in soil structure

The evolution of the structure of the topsoil is determined through the evaluation of soil crusting (Table 3) and the soil water content at the specific values of pF (Table 4). When conventionally tilled, 90 % of sandy soils surface can be crusted after 50 to 100 mm rainfall, depending on the rainfall intensity. The general tendency is a decrease in water content at pF 1.8 and an increase of the one at pF 4.2.

Period	Treatment	Crusted surface (%)		Total rainfall in the period (mm)	
		New field	Old field	New field	Old field
First rain After Ploughing	Conventional tillage	85.6	56.1	35.0	12.5
	No-tillage	2.1	1.2		
Before Moulding Up	Conventional tillage	92.8	84.2	214.6	219.4
	No-tillage	18.3	20.9		

Tab. 3: Frequencies of crusted soil surfaces as affected by cultural practices and rainfall distribution

pF	Savannah		Conventional tillage				No-tillage			
			New field		Old field		New field		Old field	
	T1	T5	T1	T5	T1	T5	T1	T5	T1	T5
1.8	13.7	11.5	15.0	11.9	15.0	10.9	18.5	12.2	15.9	13.2
4.2	2.1	2.2	2.6	2.7	3.0	2.3	4.1	5.2	2.3	3.2

Tab.4: Soil water content at pF 1.8 and 4.2 as affected by treatment and time in new and old fields

3.4 Soil functions

Among other variables, run-off, soil loss and crop yields demonstrate how soil response to climate and management is affected by tillage (Tables 5, 6 and 7). Fields degraded by many years of continuous cropping and conventional tillage lose two to three times more soil than new fields . The effect of farm manure on yields of degraded fields is reduced. Under no-tillage, soil erosion is low (six to 16 times less than with conventional tillage), irrespective of the degradation stage. Degraded soils are more compacted under no-tillage systems and soil compaction/crusting appears as a limiting factor for the productivity of these systems, especially when it rains frequently during the first two months after sowing. Run-off and soil losses increase with the frequency of soil tillage. Compacted soils can be aerated by deep ploughing or by a fallow, even of short duration (2 years).

	Conventional tillage			No-tillage			
	Erosion (t/ha/yr)	Yield control (t/ha)	Yield Manure* (t/ha)	Erosion (t/ha/yr)	Bulk density (kg/l)	Number roots 40cm	Yield (t/ha)
New fields	6-16	C = 2.1 M = 4.5	C = 2.9 M = 7.0	1.3	1.4 - 1.6	88	C = 2.1 M = 2.2
Old fields	18 - 38	C = 1.8 M = 5.0	C = 2.1 M = 5.7	2.2	1.6 - 2.0	32	C = 1.4 M = 2.2
* control + 3t/ha of goat manure before ploughing			C: cotton	M: maize (dry grain)			

Table 5: Comparative soil behaviour in new and old fields

Treatment	Run-off (%)		Erosion (t/ha/yr)	
	1993	1994	1993	1994
Conventional tillage since 1991	34	35	15 + 7*	25 + 8*
Conventional tillage since 1993 after two years of no-tillage	12	23	3 + 1*	7 + 4*
No-tillage since 1991	5	7	0.9 + 0.1*	1.7 + 0*
* coarse sediments + suspensions				

Table 6: Effect of the frequency of soil tillage on run-off and soil loss in the degraded lands

Treatment	Cotton yield 1993 (t/ha)	Maize grain yield 1994 (t/ha)
No-tillage (control)	1.4	2.8
No-tillage after loosening	1.9	3.6
No-tillage after two years fallow	2.1	3.6

Table 7: Improvement of crop productivity under no-tillage systems on degraded soils

4 Discussion

Soil carbon content appears to be the best indicator of soil degradation. It drops from 0.7 % in the savannah to 0.3 % in the cultivated field, within three years after clearing a thirty years old savannah fallow. Later on, the carbon content hardly changes. Similarly, the surface status of sandy soils changes rapidly before reaching a new equilibrium. But it varies widely from one location to another as the rainfall characteristics change.

The texture of the mineral fraction, however, does not show a clear change either in newly opened savannah or in older fields. Cropping systems that leave the soil uncovered after tillage and sowing are exposed to rapid soil surface crusting. As the surface becomes crusted, water infiltration and aeration of underlying layers are limited. The macroporosity of these layers decreases. It was noticed that the macroporosity generated by soil tillage was fugacious and soil compaction fast, except where goat manure was incorporated to the soil.

The high cohesion of degraded soil under no-tillage systems appeared more harmful to crop yield than to water infiltration. Run-off, soil loss and crop yield are directly related to soil instability.

Various definitions have been given to soil degradation. Many of them refer to crop production (Riquier, 1977 ; Oldeman, 1988 ; Piéri, 1989 ; IFAD, 1992 and Roose, 1994). It follows from our observations that soil degradation has many causes and appears under different forms. However, one can observe a convergence of its effects on the macro-porosity and water distribution in the soil, resulting in reduced water infiltration. Soil degradation appears as the action by which physical, chemical and biological processes destabilise soil surface layers, resulting in a reduction of water and air flows between the atmosphere and the soil.

A comparison of soil functions of new and degraded fields (Table 5) reveals significant differences in soil loss between conventional and no-tillage systems. Degraded soils are characterized by a high instability to water under conventional tillage and a high compaction under no-tillage. Besides these two characteristics associated with a low organic carbon content, degraded fields are not necessarily unproductive. Good yields comparable to those obtained in new fields were recorded when some conditions were met. These included soil stabilization and aeration prior to any other chemical or physical improvement and a favourable rainfall pattern for no-tillage systems.

Run-off and soil loss from degraded fields could be reduced considerably by changing from conventional tillage to mulching, fallowing or no-tillage. Crop productivity of degraded soils under no-tillage could be improved by deep ploughing or by fallowing (two years bush or improved fallows). While some authors have indicated that short duration fallows have no potential in improving chemical soil fertility (Piéri, 1989; Hien and Sédogo, 1991 ; Roose, 1994), this study clearly shows the important role of a two years fallow in aerating and stabilizing the soil surface layers (Boli, 1996). It confirms results obtained by Morel and Quantin (1972) in Central African Republic and by Valentin (1989) in the northern part of Ivory Coast. We observed that a factor like grass roots plays an important role in soil stability. However, such a factor is seldom used by other authors.

When aeration and stabilization conditions of a degraded soil are met, the next steps for soil productivity restoration could be effective. These mainly consist in applying major and minor nutrients through mineral and organic fertilizers in order to meet crop needs and control soil acidity. In addition, crop rotations need to be respected as degraded soils were heavily attacked by *Striga hermontica* (120 stands/m² against 0.4 in the new fields; Boli et al., 1991).

5 Conclusions

It follows from this study that soil degradation is mainly related to tillage systems. Conventional tillage results in soil instability and increased water erosion. Soil erosion in turn affects soil productivity by depleting soil fertility and reducing plant growth and biomass production. On the other hand, applying no-tillage to degraded soil, compaction of the surface layers is the main constraint to crop productivity.

Finally, when a degraded soil still has an acceptable depth (> 50 cm) above the hard rock or ferruginous pan, it may regain its productivity without rebuilding up its initial texture or organic matter content. But it will be necessary to aerate and stabilize the surface layers before any other chemical or physical improvements.

References

Brabant, P. and Gavaud, M. (1985): Les sols et les ressources en terre du Nord-Cameroun (Provinces du Nord et de l'Extrême-Nord). Cartes à 1/500000è; éd. ORSTOM Paris, 285p.

Boli, Z., Bep à Ziem and Roose, E. (1991): Enquête sur l'érosion pluviale dans la région de Tcholliré (Sud-Est Bénoué), Nord-Cameroun. Bull. Rés. Erosion n° 11: 127-138.

Boli Baboulé, Z. (1996): Fonctionnement des sols sableux et optimisation des pratiques culturales en zone soudanienne humide du Nord-Cameroun (expérimentation au champ en parcelles d'érosion à Mbissiri). Thèse de doctorat en sciences de la terre à l'Université de Bourgogne, 344p.

Hien, V. and Sédogo, M.P. (1991): Etude des effets de la jachère de courte durée sur la production et l'évolution des sols dans différents systèmes de culture du Burkina Faso. In La Jachère en Afrique de l'Ouest; pp.221-232.

IFAD (1992): Soil and water conservation in the Sub-Saharan Africa. Towards sustainable production by rural poor, 110 p.

Morel, R. and Quantin, P. (1972): Observations sur l'évolution à long terme de la fertilité des sols cultivés à Grimari (Rép. Centrafricaine). Agron.Trop., **27, 6**: 667-739.

Oldeman, L.R. (1988): Directives pour une évaluation générale de l'état de la dégradation des sols par l'homme. Document de travail et première épreuve GLASSOD, n°88/4, 12p.

Piéri, C. (1989): Fertilité des terres de savanes. Bilan de trente ans de recherche et de développement agricole au sud du Sahara. Min. Coopération et du développement, 444 p.

Riquier, J. (1977): Philosophy of the world assessment of soil degradation and items for discussion. Assessing soil degradation, FAO Soils Bulletin n°34, sp.

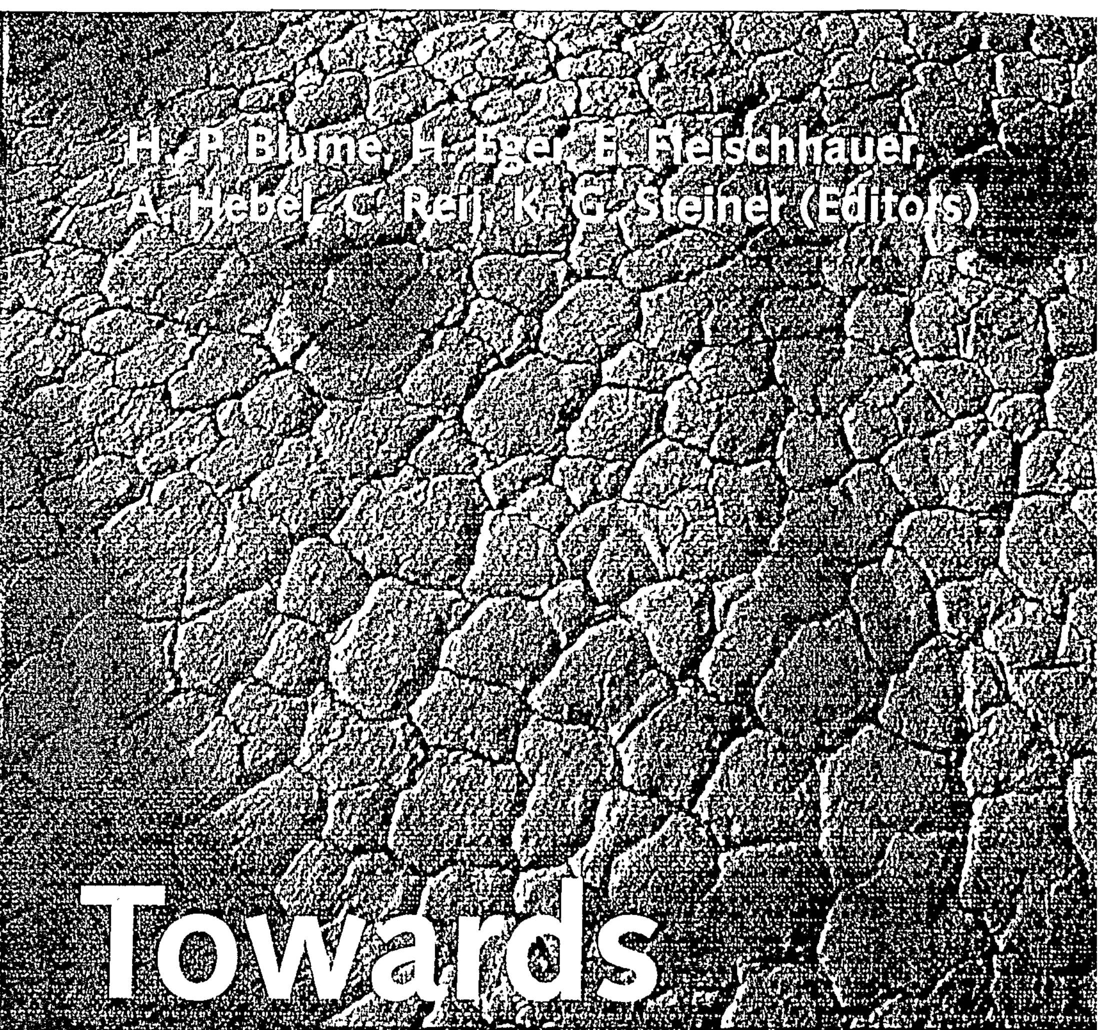
Roose, E.J. (1994): Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols (GCES). Bulletin Pédologique FAO n° **70**, 420 p.

Suchel, J.B. (1988): Les climats du Cameroun. Thèse de doctorat d'Etat. Tome I pp.1-443; Tome III pp.791-1188.

Valentin, C. (1989): Etat de dégradation de deux terroirs Sénoufo - Nord Côte-D'Ivoire. Abidjan IIRSDA, 9p. multigr.

Wischmeier, W.H. & Smitt, D.D. (1978): Predicting rainfall erosion losses. A guide to conservation planning. US Department of Agriculture; Agriculture Handbook N°537: 58p.

Addresses of authors:
Z. Boli Baboulé
IRA
BP 2123
Yaoundé (Messa), Cameroon
E. Roose
ORSTOM – Réseau Erosion
BP 5045
34042 Montpellier, France



H.-P. Blume, H. Eger, E. Fleischhauer,
A. Hebel, C. Reij, K. G. Steiner (Editors)

Towards Sustainable Land Use

Furthering Cooperation Between People And Institutio[ns]

VOLUME I

ADVANCES IN GEOECOLOGY 3[1]

A Cooperating Series of the
International Society of Soil Science (ISSS)

ISBN 3-923381-42-5

CTA

ISC[O]

CONFERENCE