CHAPTER 13

Soil Erodibility Control and Soil Carbon Losses under Short-Term Tree Fallows in Western Kenya

Anja Boye and Alain Albrecht

CONTENTS

13.1 INTRODUCTION

Extensive research has been undertaken to understand the processes of soil erosion by water for different climates and soil types. While soil erosion is a natural process, anthropogenic influence through cultivation has exacerbated the rate of soil erosion. Accelerated soil erosion is the major land degradation process in Africa (Cooper et al., 1996). Soil erosion by water is a three-phase process: (1) detachment of soil particles by rain drops, (2) transport of detached particles by runoff, and (3) deposition of detached and transported particles. Cultivation makes the land more susceptible to runoff and soil erosion by removal of the permanent plant cover. Several studies have reported close relationships between soil erodibility, soil organic carbon (SOC), and macro-aggregation (Le Bissonnais, 1996; Barthès et al., 2000; Barthès and Roose, 2002). SOC is widely acknowledged as one of the most important soil parameters to maintain good soil health (Doran et al., 1996).

However, a considerable challenge exists in maintaining adequate SOC levels in cultivated soils, especially in the tropics, where SOC losses through cultivation, decomposition, and erosion often exceed inputs. The main sources of SOC input in the tropics are biomass (above and below ground biomass) and manures, which are often less than required to maintain adequate SOC levels (Nandwa, 2001). Agroforestry is a good management option to produce sufficient biomass and to maintain or increase SOC. In western Kenya, agroforestry practices such as planted fallows produce 20 ton biomass per hectare in 8 to 18 months, which, when returned to the soil, increases SOC and soil macro-aggregation (Niang et al., 1998; IMPALA, 2001; 2002; Mutuo, 2004). Similar findings have been reported by Ingram (1990). The potential for soils to store SOC has received much attention, and several studies have shown the potential of agroforestry to sequester C above and below ground and in soil (Kursten and Burschel, 1993; Dixon, 1995; Ingram and Fernandes, 2001; Albrecht and Kandji, 2003). However, much less is known about the specific potential of planted/improved fallows to sequester C and reduce erosion-induced C losses. Several studies have reported selective detachment and transport of SOC and fine particles, resulting in depletion of SOC for *in situ* soil and enhanced SOC for depositional areas (Watung et al., 1996; Wan and El-Swaify, 1997; Jacinthe et al., 2002; Owens et al., 2002; Lal, 2003). Some studies have reported eroded C to be subjected to accelerated mineralization and thereby to contribute to CO_2 emissions from soils. In contrast, other studies suggest that deep burial of deposited sediments promotes C sequestration (Jacinthe et al., 2002; McCarty and Ritchie, 2002). Reducing runoff and soil erosion remains crucial for controlling erosion-induced C losses and more research is needed to fully understand the fate of eroded C. In Kenya, agroforestry is widely practiced to control runoff and soil erosion (Cooper et al., 1996). Van Roode (2000) reported that contour strips and hedges in association with terracing increase infiltration under the vegetative strips. However, focus has mainly been on sloping hillsides and catchment scales, and little attention has been given to the role agroforestry can play in controlling interrill erosion.

Minimum and no-till (NT) reduce runoff through accumulation of SOC and enhanced soil aggregation (Arshad et al., 1999; Franzluebbers, 2002). There is a negative correlation between enhanced SOC under NT and runoff. Several studies have found SOC to accumulate in the near surface soil layers for soils under NT compared to conventionally tilled soils (Ingram and Fernande,s 2001). However, the accumulation of SOC under NT has generally been assessed several years after conversion because time is a crucial factor in SOC accumulation. Few studies have focused on SOC accumulation under NT shortly after conversion and in association with agroforestry and planted fallows.

Thus, the aim of this study was to assess runoff and soil loss from long-term cultivated Ferralic Arenosol and Ferralsol under simulated rainfall from planted fallows (improved fallows). Specific objectives were to assess the effects of: (1) short-term improved fallows on runoff, soil, and carbon (C) losses, and (2) no-till on runoff, soil, and C losses. The study was conducted at harvest of the first maize crop after fallowing.

13.2 MATERIALS AND METHODS

13.2.1 Site Description

The study was conducted on two farms in western Kenya, Masai farm and Luero farm in July 2001. Masai farm (sandy loam) is located in Busia District (00°34.407’N, 034°11.554’E) at an

Table 13.1 **Topsoil Characteristics (0 to 15 cm Depth) at the Beginning of the Experiment for the Two Study Sites, Masai and Luero (Kenya)**

Soil Type	Sand (%)	Silt (%)	Clay (%)	SOC (g kg^{-1})	N (g kg^{-1})	C/N	pH$_{H_2O}$	Total P (g kg^{-1})	Exch. Ca (cmol$_c$ kg^{-1})	Exch. Mg (cmol$_c$ kg^{-1})
Sandy loam (Masai)	71	12	17	7.8	0.48	16.3	5.4	0.18	2.27	0.68
Clay (Luero)	35	25	40	16.9	1.40	12.1	5.3	0.47	3.94	1.23

Sand: 50 to 2000 μm; silt: 2 to 50 μm; clay: 0 to 2 μm; SOC: soil organic carbon; N: total nitrogen; P: phosphorus; exch.: exchangeable; Ca: calcium; Mg: magnesium.

altitude of 1290 m. Rainfall is bimodal with an annual mean of 1200 mm. Mean annual temperature is 21°C. The soil is a coarse Ferralic Arenosol (FAO) with 17% clay, 12% silt, and 71% sand. The slope gradient is 6%. The Luero farm (clay soil) is located in the highlands of western Kenya in Vihiga District (00°06.818'N, 034°31.488'E) at an altitude of 1620 m. Rainfall is bimodal with an annual mean of 1800 mm. Mean annual temperature is 22°C. The soil is a fine mixed nito-humic Ferralsol (FAO) with 40% clay, 24% silt, and 35% sand. The slope gradient is 7%. Table 13.1 lists important properties of the surface soil for the two sites.

13.2.2 Experimental Design and Management

The experimental design for each farm was a randomized block design with three replicates, each plot measuring 18 × 16 m. The objective was to compare continuous cultivation (CC) of maize (*Zea mays*) intercropped with beans (*Phaseolus vulgaris*), with intercropping of maize and beans preceded by a 18-month improved fallow of two legumes: *Crotalaria grahamiana* (IF-Cg) or *Tephrosia candida* (IF-Tc). The experiment was established in July 1999 (Figure 13.1). Improved fallows were planted at the end of the cropping season in the former bean rows, which had been harvested in late June. The fallows were allowed to grow until February 2001, when they were slashed and the land prepared for the following maize crop. Maize and beans were harvested every season (December 1999, July 2000, December 2000, August 2000, December 2001, and August 2001) for the control plots. During the first season (short rainy season 1999), all treatments were manually weeded between September and October 1999. Only the control plots (CC) were weeded (IMPALA, 2001; 2002) during the following two seasons (long rainy season 2000 and short rainy season 2000). In February 2001, the fallows (IF-Cg and IF-Tc) were slashed by cutting the stem about 10 cm above the ground level.

After the 18-month fallow phase, maize and beans were planted by splitting each plot into two parts. One part was tilled with a hand hoe, disturbing the soils to 10 cm depth (CT). The other part was left undisturbed (NT) except for planting operations (direct sowing). The returned biomass was incorporated into the soil for the CT plots, whereas it was left on the soil surface for the NT plots. The residue biomass returned (from the improved fallow and the weeds) was 1.7 t ha^{-1} for IF-Cg and 2.1 t ha^{-1} for IF-Tc for the sandy soil, and 3.9 t ha^{-1} for IF-Cg and 7.8 t ha^{-1} for IF-Tc for the clayey soil. The woody stems were removed from the system and used by the farmers. The

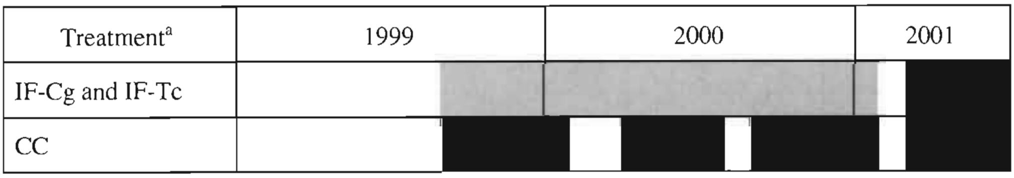

Figure 13.1 Cropping sequences for the cropping systems under study. Black represents the cropping phase and grey the fallow period. CC is continuous cultivation; IF-Cg improved fallow treatment with *Crotalaria grahamiana; and* IF-Tc improved fallow treatment with *Tephrosia candida*.

removed biomass amounted to 8.7 t ha^{-1} for IF-Cg and 10.6 t ha^{-1} for IF-Tc for the sandy loam, and 19.7 t ha^{-1} for IF-Tc for the clayey soil. Maize and fallows were planted at a spacing of 75 cm between rows and 25 cm within row. All plots were weeded twice between April and June 2001, and were harvested in August 2001.

13.2.3 Rainfall Simulation

A field rainfall simulator (ORSTOM type) was used to simulate rainfall. This simulator simulates rainfall over 4 m^2 but measures runoff from a 1-m^2 plot. Rainfall is produced by a single nozzle, which sprinkles water downward. The nozzle is placed at a height of 4 m, enabling the raindrops to reach terminal velocity. More detailed information on the ORSTOM rainfall simulator is given by Asseline and Valentin (1978).

Two rainfall intensities were chosen, 50 and 90 mm hr^{-1}, to simulate low and high intensity rainstorms. Rainfall simulations were carried out at crop harvest (maize intercropped with beans) in August 2001. The simulation regime consisted of three events. The objective was to simulate rain on dry, wet, and very wet soils. The first event was carried out on dry soils with medium rainfall intensity (50 mm hr^{-1}), and it was continued until steady runoff occurred (maximum 90 min). The following day two simulations were conducted on wet soils. The first event had an intensity of 50 mm hr^{-1} and the following one of 90 mm hr^{-1}. The duration was 30 min. There was a break of 15 min between the two rainfall simulations to allow runoff to cease. There were three replicates for each treatment and subtreatment. Runoff was measured on a 1-min interval and sediment samples were collected for every 2 min until steady runoff was achieved. At steady state, runoff sediment samples were collected at 5-min intervals. Before each simulation the loose biomass was removed by hand. Thus, simulations were done on a bare soil surface when soil cover was less than 5%.

The data for only the very wet run are presented in this chapter. The objective is to discuss runoff, soil erosion, and soil C losses for different land use systems and soil types. Majority of soil loss occurs at the on-set of the rainy season during high intensity storms. Thus, the very wet run simulated such scenarios, and provide an indication of soil C losses during natural rainfall.

13.2.4 Soil Sampling and Analyses

Soil samples were collected to determine bulk density, soil aggregate stability, soil C and nitrogen (N) contents, and C/N ratio. Soil was sampled in June 2001 (before harvest of beans) at 0 to 5 and 5 to 10 cm depths using 98-cm^3 cores with three replicates for each plot. Water stable aggregates (WSA) were determined by wet sieving after shaking, with three replicates for each soil sample. Fifty g of air-dried soil was passed through a 2-mm sieve and shaken in 300 ml of water for 1 hour in a tumbler shaker at 50 revolutions per minute. The sample was then sieved through 212- and 20-μm sieves. For both soil types, WSA larger than 212 μm were expressed on a coarse sand-free basis (Albrecht et al., 1992; Feller et al., 1996). These samples were then bulked to form one sample per replicate (n = 3). Soil resistance to penetration and shear stress were measured onsite using a penetrometer CL 700A (kg cm^{-2}) and a torvane CL 600 (kg cm^{-2}), respectively. Soil resistance to penetration and shear stress were measured at the soil surface after each rainfall simulation next to the 1-m^2 plot. Each measurement was replicated six times.

Total C and N contents of soil and sediment samples were determined by the CNS Carlo Erba micro-analyzer method. In the absence of carbonates, all C was considered organic. Soil C stocks were calculated for equivalent depth (0 to 10 cm) and for equivalent mass (this mass was 87.5 kg m^{-2} and corresponded to the smallest mass of the 0 to 10 cm soil layers under study, which was in the clay soil under IF-Tc and NT) basis (Ellert and Bettany, 1995).

13.2.5 Data Analyses

The data were statistically analyzed using ANOVA for a completely randomized block design with final runoff rate, runoff depth, sediment concentration, and soil loss as variables in the first analysis. In the second analysis, the variables were percentage water stable aggregates, soil C content, bulk density, C/N ratio, and soil resistance to penetration and shear stress. The third analysis had enrichment ratio, C losses, and soil C stocks as variables. Statistical significance was determined at the 95% confidence level with Tukey's test. Sediment C content was averaged for the three replicates, thus no statistical analyses were done for this variable and for sediment C/N ratio.

A principal component analysis (PCA) was done with the ADE4 statistical package (Thioulouse et al., 1997), in order to identify the dominant factors explaining eroded C losses for the three land-use systems and two subtreatments. The variables were percentage water stable aggregates, soil resistance to penetration and shear, soil C content, and soil C losses.

13.3 RESULTS

13.3.1 Soil C Content, Bulk Density, C/N Ratio, and C Stocks (Table 13.2)

Soil C content, bulk density (BD), and C stocks were influenced by site ($p \leq 0.001$). The clay soil had significantly higher soil C content for both depth increments regardless of the treatment. Soil C content was more than double for the clay soil: 23.6 vs. 10.4 g C kg^{-1} at 0 to 5 cm depth and 20.5 vs. 8.8 g C kg^{-1} at 5 to 10 cm depth. Soil C content decreased with depth for both sites

Table 13.2 Effect of Cropping System on Soil Organic Carbon (SOC), C/N Ratio, Bulk Density, and Soil C Stock for the Sandy Loam and the Clay Soil

	SOC ($g\ C\ kg^{-1}$)		C/N	Bulk Density ($g\ cm^{-3}$)		SOC Stock ($g\ C\ m^{-2}$)	
Soil Type and Treatment[a]	0 to 5 cm	5 to 10 cm	0 to 5 cm	0 to 5 cm	5 to 10 cm	0 to 10 cm	First 87.5 kg m^{-2}
Sandy loam, CC	8.6Aa[b,c]	8.6Aa	13.9ABa	1.32Ca	1.37Ba	1157Aa	753Aa
Sandy loam, IF-Cg	11.3Aa	8.7Aa	13.5ABa	1.36Ca	1.49Cb	1408Aa	875Aa
Sandy loam, IF-Tc	11.2Aa	9.0Aa	14.5Ba	1.33Ca	1.56Cb	1466Aa	885Aa
Clay, CC	21.0Ba	19.6Ba	13.2Aa	1.08Bb	1.09Aa	2202Ba	1742Ba
Clay, IF-Cg	22.8Ba	20.0Ba	12.9Aa	1.04Bb	1.07Aa	2259Ba	1871Ba
Clay, IF-Tc	27.1Cb	21.6Ba	13.3Aa	0.90Aa	1.03Aa	2382Ba	2131Cb
LSD[d] for the sandy loam	3.7	2.8	1.1	0.16	0.12*	396	260
LSD for the clay	3.3**	2.4	0.8	0.06***	0.09	206	159***
LSD for site effect	3.1***	2.3***	1.2	0.11***	0.11***	284***	193***
Sandy loam, CT	10.4	9.3	14.1	1.30	1.45	1359	861
Sandy loam, NT	10.4	8.3	13.8	1.37	1.49	1328	814
Clay, CT	20.8	20.7	13.2	1.01	1.06	2142	1808
Clay, NT	26.4	20.2	13.1	1.00	1.06	2421	2021
LSD for the sandy loam	2.6	2.0	1.1	0.11	0.08	282	184
LSD for the clay	2.4***	1.8	0.6	0.04	0.09	204**	131**

[a] CC is continuous cultivation, IF-Cg improved fallow treatment with *Crotalaria grahamiana*, and IF-Tc improved fallow treatment with *Tephrosia candida*.

[b] Means followed by the same upper case letter in the same column are not statistically different at $p \leq 0.05$.

[c] Means followed by the same lower case letter for each site are not statistically different at $p \leq 0.05$.

[d] LSD at $p \leq 0.05$.

*, **, *** significant at 0.05, 0.01, and 0.001, respectively.

(15% in the sandy loam and 13% in the clay soil). Bulk density was lower in the clay soil than in the sandy loam for both depths, 25% at 0 to 5 cm depth (1.01 vs. 1.33) and 38% at 5 to 10 cm depth (1.06 vs. 1.47). Bulk density increased with depth for both sites (10% and 5% for the sandy loam and clay soil, respectively). The C/N ratio (0 to 5 cm depth) ranged from 13.2 to 14.5 and was not affected by soil type. However C/N ratio was significantly higher (ca. 10%) in the sandy loam under IF-Tc than in the clay soil under CC and IF. The C stocks were significantly more in the clay soil than in the sandy loam: 70% greater considering the 0 to 10 cm depth layer (2280 vs. 1340 g C m^{-2}), and 130% greater considering an equivalent soil mass (87.5 kg m^{-2}, which was the smallest mass of the 0 to 10 cm soil layers under study: 1920 vs. 840 g C m^{-2}).

Treatment (CC vs. IF) and tillage practices (CT vs. NT) had stronger effect on soil properties in the clay soil than in the sandy loam. For the former, soil C content at 0 to 5 cm depth increased by 29% under IF-Tc (27 vs. 21 g C kg^{-1}, $p \leq 0.01$), and was intermediate under IF-Cg (not significant). In contrast, soil C content did not differ significantly among treatments at 5 to 10 cm depth (it ranged from 19.6 to 21.6 g C kg^{-1}). In the sandy loam, IF did not significantly increase soil C content at 0 to 5 cm and 5 to 10 cm depths (it ranged from 8.6 to 11.3 g C kg^{-1}). NT increased soil C content in the clay soil by 27% at 0 to 5 cm depth, but tillage did not influence soil C content in the sandy loam and at 5 to 10 cm depth in the clay soil. In the clay soil, IF-Tc reduced BD at 0 to 5 cm depth by 17% (0.90 vs. 1.08 g cm^{-3}, $p \leq 0.001$), but no significant effect was observed under IF-Cg and at 5 to 10 cm depth. In the sandy loam, differences in BD were not significant at 0 to 5 cm depth (BD ranged from 1.32 to 1.36 g cm^{-3}), but increased under IF-Tc and IF-Cg at 5 to 10 cm depth (14 and 9%, respectively, $p \leq 0.02$). Tillage did not affect BD for the two sites for both depths. Soil C stocks at 0 to 10 cm depth did not differ significantly among treatments though they were more under IF treatments than under CC (22 to 27% in the sandy loam, 3 to 8% in the clay soil). Considering C stocks on equivalent soil mass basis (the upper 87.5 kg m^{-2}), there were reduced differences among treatments in the sandy loam (16 to 18%) but increased differences among treatments occurred in the clay soil (7 to 22%) so that difference between IF-Tc and CC was significant ($p \leq 0.001$). Both calculations (0 to 10 cm depth and 87.5 kg m^{-2}) indicated that C stock was 12 to 13% and significantly greater under NT than under CT in the clay soil ($p \leq 0.015$), but was not affected by tillage in the sandy loam. Large variations were observed in C stocks depending on the method of calculation. For the sandy loam, C stocks calculated for the 0 to 10 cm depth and equivalent soil mass differed considerably (1157 to 1466 vs. 753 to 885 g C m^{-2}), which was not the case for the clay soil (2202 to 2382 vs. 1742 to 2131 g C m^{-2}). The larger differences in C stocks for the sandy loam can be explained by larger BD. Indeed, soil mass for 0 to 10 cm depth was 1400 Mg for the sandy loam and 1050 Mg for the clay soil.

In short, soil C was more and BD lower in the clay soil than in the sandy loam and at 0 to 5 than at 5 to 10 cm depth. As compared with CC and conventional tillage, soil C content generally increased in fallow treatments or under NT at 0 to 5 cm depth in the clay soil, but neither at 5 to 10 cm depth nor in the sandy loam. The C/N ratio (0 to 5 cm depth) tended to be greater in the clay soil, but was not affected by treatment or tillage. The BD tended to decrease under fallow treatments in the clay soil but not in the sandy loam (it increased at 5 to 10 cm depth), and was not affected by tillage. The C stocks were more in the clay soil than in the sandy loam at 0 to 10 cm depth and on equivalent soil mass. Soil C stocks at 0 to 10 cm depth were not significantly affected by treatment, whereas C stocks on equivalent soil mass basis were more after IF (IF-Tc) in the clay soil. Soil C stocks were not significantly affected by tillage methods.

13.3.2 Water Stable Aggregates and Soil Strength (Table 13.3)

Water stable aggregates (WSA) and soil strength were influenced by site ($p < 0.001$). Soil strength was measured *in situ* as soil resistance to penetration (RP) and soil resistance to shear (RS). The WSA were more in clay soil for both depths (350 to 420 vs. 50 to 60 g kg^{-1} at 0 to 5 cm depth and 350 to 410 vs. 40 to 50 g kg^{-1} at 5 to 10 cm depth). WSA generally decreased with

Table 13.3 Effect of Cropping System on Water Stable Aggregates (WSA) and Soil Strength for the Sandy Loam and the Clay Soil

	WSA (g kg^{-1})		Soil Resistance to penetration (kg cm^{-2})	Soil Resistance to shear (kg cm^{-2})
Soil Type and Treatment[a]	0 to 5 cm	5 to 10 cm	0 to 10 cm	0 to 2 cm
Sandy loam, CC	49.2Aa[bc]	38.6Aa	1.02Db	1.95Bb
Sandy loam, IF-Cg	42.2Aa	52.7Aa	0.62Aa	1.65Aa
Sandy loam, IF-Tc	60.1Aa	49.7Aa	0.68ABa	1.48Aa
Clay, CC	348.3Ba	353.2Ba	0.87CDab	2.38Ca
Clay, IF-Cg	403.1Cb	391.7Cab	1.05Db	2.23Ca
Clay, IF-Tc	421.1Cb	406.1Cb	0.82BCa	2.68Db
LSD[d] for the sandy loam	27.8	17.2	0.17**	0.25**
LSD for the clay	33.9**	45.6*	0.21*	0.18***
LSD for site effect	29.9***	29.6***	0.19***	0.21***
Sandy loam, CT	49.9	42.2	0.73	1.59
Sandy loam, NT	51.1	51.8	0.81	1.80
Clay, CT	368.0	374.4	0.99	2.57
Clay, NT	413.6	393.0	0.83	2.30
LSD for the sandy loam	21.3	12.5	0.13	0.18*
LSD for the clay	24.2**	33.8	0.15*	0.15**

[a] CC is continuous cultivation, IF-Cg improved fallow treatment with *Crotalaria grahamiana*, and IF-Tc improved fallow treatment with *Tephrosia candida*.

[b] Means followed by the same upper case letter in the same column are not statistically different at $p \leq 0.05$.

[c] Means followed by the same lower case letter for each site are not statistically different at $p \leq 0.05$.

[d] LSD at $p \leq 0.05$.

*, **, *** significant at 0.05, 0.01, and 0.001, respectively.

depth, except for sandy loam IF-Cg and clay soil CC. Soil resistance to shear (RS) was 20 to 80% more in the clay soil than in the sandy loam for all treatments (2.2 to 2.7 vs. 1.5 to 2.0 kg cm^{-2}), but the effect of soil type on RP did not observe a clear trend.

Treatment and tillage methods influenced WSA and soil strength. At 0 to 5 cm depth, WSA increased significantly ($p = 0.003$) under both IF treatments in the clay soil (16% for IF-Cg and 21% for IF-Tc), but the effect of IF was not significant in the sandy loam. At 5 to 10 cm depth, WSA also increased significantly under both IF treatments in the clay soil (11% for IF-Cg and 15% for IF-Tc, only the latter being significant), but the increase was not significant in the sandy loam (though it reached 30 to 40%). The NT increased WSA by 12% ($p = 0.002$) in the clay soil at 0 to 5 cm depth, but tillage did not affect WSA at 5 to 10 cm depth or in the sandy loam. Soil strength was higher under CC than under IF treatments in the sandy loam: RP was 50 to 65% higher, and RS 18 to 32% higher. The relatively high soil strength under CC may be attributed to soil crusting. Under CC, the soil surface crusted within the first few minutes of the simulated rainfall event. There was no crusting on the clay soil. For the clay soil, IF-Tc increased RS by 13% but no increase was observed for IF-Cg. Conversely, IF-Cg significantly increased RP by 21%, but the effect of IF-Tc was not significant. No clear trends were observed for RP and RS in relation to tillage: NT increased RP and RS by 11 and 13 % in the sandy loam (significant for RS only) but decreased RP and RS by 16 and 11% in the clay soil, respectively.

In summary, WSA increased under IF treatments and NT in the clay soil at 0 to 5 cm depth and under IF-Tc at 5 to 10 cm depth, but was not affected by treatment and tillage in the sandy loam. Resistance to penetration was not clearly affected by soil type. For the sandy loam RP was 50 to 65% more under CC than under IF treatments but was not affected by tillage, whereas for the clay soil it was not clearly affected by fallowing but was 16% smaller under NT than under CT. Resistance to shear was 20 to 80% more in the clay soil than in the sandy loam, and was 20 to 30% more under CC than IF treatments in the sandy loam, whereas fallow effect was not clear in the clay soil. As compared with CT, resistance to shear under NT was 13% more in the sandy loam but 11% lower in the clay soil.

13.3.3 Runoff, Sediment Concentration, and Soil Loss (Table 13.4)

Final runoff rate (FRR) and runoff depth (RD) were highly influenced by site ($p \leq 0.001$). Generally, FRR and RD were significantly lower on the clay soil than on the sandy loam. When comparing treatment across sites, FRR was 36, 50, and 74% lower; and RD was 32, 78, and 60% smaller under CC, IF-Cg and IF-Tc in the clay soil than in the sandy loam, respectively (however differences in FRR and RD between sites were not significant for IF-Cg). Sediment concentration (SC) was less clearly influenced by site ($p = 0.004$). Under CC, it was twice higher on the clay soil than on the sandy loam, but under IF treatments it tended to be lower on the clay soil. Soil loss was highly affected by site ($p \leq 0.001$) and was two and six times greater on the sandy loam than on the clay soil for CC and IF treatments, respectively.

Treatment significantly affected FRR at both sites ($p \leq 0.001$ and $p = 0.004$ for the sandy loam and the clay soil, respectively), with greater reductions under IF treatments on the clay soil. As compared with CC, FRR was reduced by 71 to 73% for IF treatments on the clay soil and by 66% for IF-Cg and 29% for IF-Tc on the sandy loam. A similar trend was observed for RD: IF-Cg and IF-Tc significantly reduced RD by 89 and 58% on the clay soil, and by 68 and 29% on the sandy loam, respectively. Tillage did not influence the runoff barometers for the two sites. On the clay soil, IF significantly reduced SC ($p = 0.009$), which was three times lower than under CC (0.7 vs. 2.1 g l^{-1}). On the sandy loam, in contrast, the differences in SC between treatments were small (< 10%) and not significant (SC ranged from 0.88 to 0.96 g l^{-1}). Additionally, SC was 45% smaller under NT than under CT on the clay soil, but 50% greater under NT than CT on the sandy loam. However, these differences were not significant. Treatments clearly influenced SL on the clay soil,

Table 13.4 Effect of Cropping System on Runoff and Soil Loss for the Sandy Loam and the Clay Soil

Soil Type and Treatment[a]	Final Runoff Rate[b] (mm hr^{-1})	Runoff Depth[b] (mm)	Sediment Concentration[b] (g l^{-1})	Soil Loss[b] (g m^{-2})
Sandy loam, CC	70Cc[c,d]	28Cc	0.96Aa	28.5Cb
Sandy loam, IF-Cg	24Aa	9Aa	0.88Aa	12.7Ba
Sandy loam, IF-Tc	50Bb	20Bb	0.94Aa	25.5Cb
Clay, CC	45Bb	19Bb	2.12Bb	13.1Bb
Clay, IF-Cg	12Aa	2Aa	0.72Aa	2.1Aa
Clay, IF-Tc	13Aa	8Aa	0.65Aa	4.2Aa
LSD[e] for the sandy loam	18***	8**	0.64	10.5**
LSD for the clay	18**	11*	0.90**	2.9***
LSD for site effect	15***	8***	0.71**	8.0***
Sandy loam, CT	51	21	0.74	20.3
Sandy loam, NT	45	17	1.11	24.1
Clay, CT	26	11	1.50	7.0
Clay, NT	20	9	0.82	5.9
LSD for the sandy loam	15	6	0.49	8.5
LSD for the clay	13	8	0.70	2.3

[a] CC is continuous cultivation, IF-Cg improved fallow treatment with *Crotalaria grahamiana*, and IF-Tc improved fallow treatment with *Tephrosia candida*.

[b] Final runoff rate, runoff depth, sediment concentration, and soil loss were measured over a 30 min period.

[c] Means followed by the same upper case letter in the same column are not statistically different at $p \leq 0.05$.

[d] Means followed by the same lower case letter for each site are not statistically different at $p \leq 0.05$.

[e] LSD at $p \leq 0.05$.

*, **, *** significant at 0.05, 0.01, and 0.001, respectively.

where it was three and six times smaller in IF-Tc and IF-Cg than in CC, respectively (4 and 2 vs. 13 g m^{-2}, p = 0.020). On the sandy loam, SL was twice as small in IF-Cg than in CC (13 vs. 29 g l^{-1}, p = 0.020), but did not differ significantly between IF-Tc and CC (26 vs. 29 g m^{-2}). Tillage did not influence SL for either of the two sites.

In short, runoff was smaller on the clay soil than on the sandy loam (30 to 80%) and for IF treatments than for CC (30 to 90%), but was not influenced by tillage. Sediment concentration was not clearly affected by soil type (for CC it was higher on the clay soil, for IF treatments it tended to be higher on the sandy loam). It was three times lower under IF treatments than under CC on the clay soil, but did not differ significantly between IF treatments and CC on the sandy loam. The influence of tillage on SC neither followed a clear trend nor was it significant. Soil loss was more on the sandy loam than on the clay soil, and was lower under IF treatments than under CC (on the clay soil especially), but was not significantly influenced by tillage methods.

13.3.4 C Content of Sediments, Enrichment Ratio, and Soil C Losses

The effect of soil type on sediment C content was not clearly defined (for CC and IF-Tc it was 63 and 94% higher on the sandy loam than on the clay soil, but for IF-Cg it was 67% lower on the sandy loam; Table 13.5). The C/N ratio of sediments was 26 to 46% higher on the sandy loam than on the clay soil across treatments (14 to 15 vs. 10 to 12). The C enrichment ratio of sediments (ER) and C losses were strongly influenced by site ($p \leq 0.001$). The ER was higher on the sandy loam (3.4 to 6.5) than on the clay soil (1.4 to 2.7), but the difference was significant for CC and IF-Tc only (6.1 vs. 1.5 and 6.5 vs. 1.4, respectively, $p \leq 0.01$). The C losses were 3.4, 3.6, and 14 times more on the sandy loam than on the clay soil for CC, IF-Cg, and IF-Tc, respectively (however the difference was not significant for IF-Cg). They were maximum for IF-Tc on sandy loam (1.95 g C m^{-2}) and minimum for IF-Cg and IF-Tc on clay soil (0.12 to 0.14 g C m^{-2}).

On the sandy loam, C content of sediments was 40% lower for IF-Cg but 40% higher for IF-Tc than for CC (37 and 73 vs. 52 g kg^{-1}). On the clay soil, C content was 95 and 20% higher for

Table 13.5 Effect of Cropping System on Sediment C Content, Sediment C/N, Ratio of Sediment Enrichment in C, and C Losses for the Sandy Loam and the Clay Soil

Soil Type and Treatment[a]	Sediment C (g C kg^{-1})	Sediment C/N	Enrichment Ratio	C Losses (g C m^{-2})
Sandy loam, CC	52.1	14.3	6.1Cb[bc]	1.43Bab
Sandy loam, IF-Cg	37.4	15.1	3.4Ba	0.43Aa
Sandy loam, IF-Tc	73.3	13.9	6.5Cb	1.95Bb
Clay, CC	31.9	11.1	1.5Aa	0.42Ab
Clay, IF-Cg	62.3	12.0	2.7Bb	0.12Aa
Clay, IF-Tc	37.8	9.5	1.4Aa	0.14Aa
LSD[d] for the sandy loam	—	—	1.6**	1.14*
LSD for the clay	—	—	0.2***	0.10***
LSD for site effect	—	—	1.0***	0.77***
Sandy loam, CT	38.5	13.5	3.9	0.76
Sandy loam, NT	70.0	15.4	6.7	1.77
Clay, CT	37.2	10.9	1.8	0.24
Clay, NT	50.9	10.8	2.0	0.21
LSD for the sandy loam	—	—	1.1***	0.92*
LSD for the clay	—	—	0.1	0.08

[a] CC is continuous cultivation, IF-Cg improved fallow treatment with *Crotalaria grahamiana*, and IF-Tc improved fallow treatment with *Tephrosia candida*.

[b] Means followed by the same upper case letter in the same column are not statistically different at $p \leq 0.05$.

[c] Means followed by the same lower case letter for each site are not statistically different at $p \leq 0.05$.

[d] LSD at $p \leq 0.05$.

*, **, *** significant at 0.05, 0.01, and 0.001, respectively.

IF-Cg and IF-Tc than for CC, respectively (62 and 38 vs. 32 g C kg^{-1}). Additionally, sediment C content was 40% (clay) to 80% higher (sandy loam) under NT than under CT. Sediment C/N ratio was slightly lower for IF-Tc than for CC (3% on the sandy loam and 14% on the clay soil), but slightly higher for IF-Cg than for CC (6 and 8%, respectively). On the sandy loam, ER was similar in CC and IF-Tc but was twice lower in IF-Cg (3.4 vs. 6.1 to 6.5, $p = 0.010$). On the clay soil, it was also similar in CC and IF-Tc but was twice as high in IF-Cg (2.7 vs. 1.4 to 1.5, $p = 0.010$). Additionally, ER was 70% higher for NT than for CT on the sandy loam (6.7 vs. 3.9, $p \leq 0.001$), but was not significantly influenced by tillage on the clay soil (though 11% higher for NT). As compared with CC, both IF treatments reduced C losses by 70% on the clay soil (0.12 to 0.14 vs. 0.42 g C m^{-2}, $p \leq 0.001$). On the sandy loam, differences in C losses between CC and IF treatments were not significant though C losses were 70% more for IF-Tc and 40% lower for IF-Cg than for CC (1.95, 0.43, and 1.43 g C m^{-2}, respectively; C losses were 4.5 times more for IF-Tc than for IF-Cg, $p \leq 0.05$). In contrast, C losses were not influenced by tillage on the clay soil, but were 2.3 times more for NT than for CT on the sandy loam ($p = 0.035$).

C losses represented 0.03 to 0.13% of soil C stock at 0 to 10 cm depth in the sandy loam, but 0.01 to 0.02% only in the clay soil. Eroded C as a proportion of C stock (0 to 10 cm) was thus six to 20 times more for the sandy loam than for the clay soil, whereas soil loss was only two to six times more on the former than on the latter. The amount of eroded C as a proportion of soil C stock at 0 to 10 cm depth was not clearly influenced by treatment or tillage. However it was four times more for CC than for IF-Cg on both soil types, and twice more for NT than for CT on the sandy loam.

In summary, sediment C content was not clearly affected by site (it was more on the sandy loam for two out the three treatments) but was generally more for IF treatments than for CC (except for IF-Cg on the sandy loam). Sediment C/N ratio was more on the sandy loam than on the clay soil, with IF-Cg > CC > IF-Tc. The CER of the sediments was more on the sandy loam than on the clay soil, was similar for CC and IF-Tc, and was twice more for NT than for CT on the sandy loam. C losses were more on the sandy loam, generally lower for fallow treatments (except IF-Tc on the sandy loam), and were twice more for NT on the sandy loam. The proportion of soil C stock lost with sediments was much higher for the sandy loam than for the clay, but was not clearly affected by fallow or tillage treatments.

13.3.5 Principal Component Analysis (Figure 13.2)

The eigen values of the principal component analysis (PCA) showed that the first factor accounted for 59% of the total inertia. On the correlation circle, this factor was represented by the horizontal axis (F1), which opposed water stable aggregates (WSA), soil C content, soil resistance to shear (RS), on the one hand, and C losses, on the other (Figure 13.2a). The second factor accounted for 23% of the total variation (F2), and was mainly explained by soil RP. The first two axes accounted for 82% of the inertia.

The factorial map of treatments (Figure 13.2b) showed the effects of soil type and treatment on soil C losses. The points, which represented the plots, clustered into two main groups: the first group, on the right part of the map, included the plots located on sandy loam, whereas the second group, on the left part of the map, included the plots on clay soil. Thus the projection on the F1 axis led to a contrast between the clay soil, which had more soil C content, WSA, and RS but lower C losses, and the sandy loam, where soil C content, WSA, and RS were lower and C losses higher. This projection also showed that on clay soil, the plots representing IF-Tc CT, IF-Tc NT, and IF-Cg NT (Numbers 9, 10, and 12), on the left, had lower C losses than CC CT, CC NT and IF-Cg CT (Numbers 7, 8, and 11). This was interpreted as resulting from more WSA after fallowing, which however was not achieved for IF-Cg CT (Number 11).

The projection on the F2 axis allowed to distinguish among plots on sandy loam between those under CC, toward the top of the map and having more RP, and those under IF treatments, which

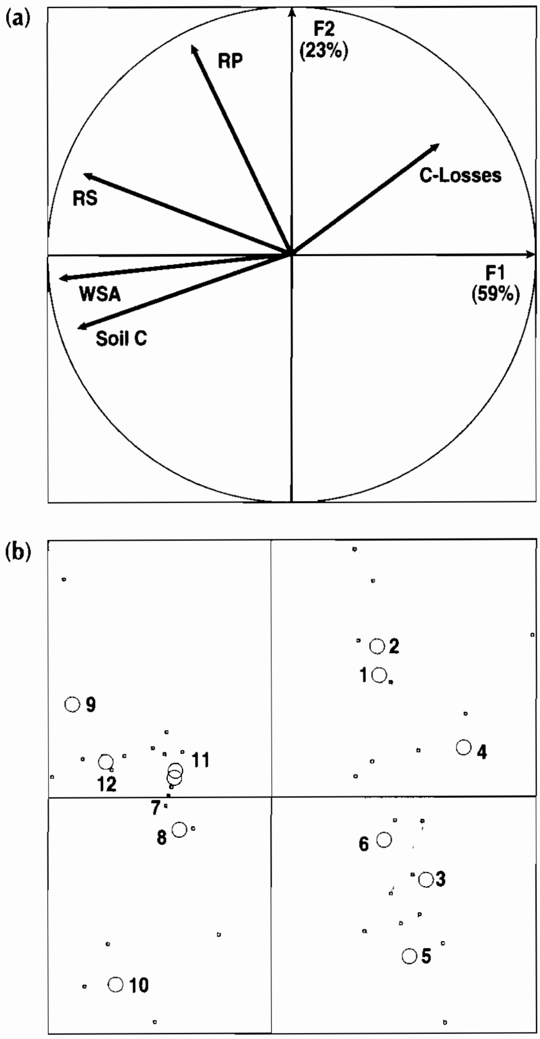

Figure 13.2 Results from principal component analysis (PCA) on soil carbon losses: (a) F1-F2 correlation circle of variables (RP and RS are soil resistance to penetration and shear, respectively, and WSA water stable aggregates). (b) Factorial map of treatments. No.'s 1–6 sandy loam: (1) CC-CT, (2) CC-NT, (3) IF-Tc-CT, (4) IF-Tc-NT, (5) IF-Cg-CT, (6) IF-Cg-NT; No.'s 7–12 clay soil: (7) CC-CT, (8) CC-NT, (9) IF-Tc-CT, (10) IF-Tc-NT, (11) IF-Cg-CT, (12) IF-Cg-NT.

had lower RP (this separation was not possible on clay soil). The projection on the F2 axis also separated the plots according to tillage. On the sandy loam, plots under NT had more RP than their counterparts (same treatment) under CT. On the clay soil, in contrast, plots under NT had lower RP than their counterparts under CT (except for IF-Cg, Numbers 11 and 12). Additionally, IF-Tc NT on clay soil (Number 10) was at the bottom of the map, clearly below the other IF plots (Numbers 9, 11, and 12), and this was related with a lesser RP on the former than on the latter.

In short, the PCA analysis indicated that C losses were negatively related to the soil C content and WSA, which were lower: (1) on sandy loam than on clay soil and (2) among plots on clay soil, under continuous cultivation than after fallow (except on IF-Cg CT). On the clay soil, increases in soil C content and WSA through fallowing resulted in reduction in C loss. In contrast, C losses on sandy loam cannot be easily explained using the PCA, as the plots mainly ranged according to RP, which was perpendicular to C losses.

13.4 DISCUSSION

13.4.1 Impact of Improved Fallows on Runoff

Results of runoff amount and rate indicated that fallowing had a significant effect on reducing runoff. Indeed, runoff was lower for plots previously under improved fallow than for plots under continuous cultivation (30 to 90% reduction). Lower runoff amount and rate may be attributed to improvement in soil structure after the fallow phase. When land is taken out of cultivation (natural fallow or planted fallow for several years, protected from fire and grazing), there is a combined build-up of SOC and soil aggregation (Ingram, 1990; Niang et al., 1996; IMPALA, 2001; 2002; Mutuo, 2004). Several studies have reported close relationship between runoff and soil aggregation (Le Bissonnais, 1996; Barthès et al., 2000; Barthès and Roose, 2002). In this study, improvement in WSA through fallowing was more important for the clay soil than for the sandy loam (18% vs. 4% in average at 0 to 5 cm depth), resulting in a greater reduction in runoff (–70 vs. –50% in average). For the sandy loam, the reduction in runoff after fallowing was mainly caused by a lower susceptibility to crusting. Indeed, the soil surface of the sandy loam crusted quickly (after 10 min), which strongly hindered infiltration. It is well established that surface sealing promotes overland flow (Bryan and De Ploey, 1983; Le Bissonnais, 1996; Rao et al., 1998) and is often prevailing on degraded soils. Values of RP and RS indicated that cropping IF reduced crusting on the sandy loam (on average, RP and RS were reduced by 36 and 20%, respectively). Reduced RS and RP after biomass return were also reported by Zeleke et al. (2004). However, for the clay soil in the present study, there was no significant difference in RP among treatments, and RS increased under IF-Tc (13%). Biomass return also reduces BD, and this was the case for the clay soil in the present study. Differences in BD among treatments were not significant for the sandy loam soil at 0 to 5 cm depth. This is contrary to the findings of Zeleke et al. (2004), who reported that biomass return decreased in BD in a sandy soil but not in a clay soil. Decrease in BD with biomass return has been related to increased infiltration rates, which is also confirmed in the present study.

13.4.2 Control of Soil Loss by Improved Fallows

Plots previously under IF had less soil loss. Improved fallows reduced soil loss by 68 to 84% on the clay soil and by 11 to 55% on the sandy loam, indicating that improvement in soil structure due to IF was highly dependent on clay and soil C contents. On the sandy loam, reduction in soil loss after fallowing depended mainly on reduction in runoff and transportability of detached particles, since topsoil properties such as C content, WSA, and BD were not significantly affected. On the clay soil, reduction in soil loss after fallowing was more clearly associated with increases in C content and WSA and decrease in BD. A close relationship between topsoil WSA and soil susceptibility to runoff and erosion were also reported by Barthès and Roose (2002). The strong impact of fallowing on soil loss reduction was expected for the clay soil, due to its potential to form stable aggregates through the association between organic matter and clay particles. However, this study also showed that soil loss may be significantly reduced (–55%) on sandy loam when *Crotalaria grahamiana* was used as improved fallow.

The soil losses measured in this study were in the same range as those reported in other studies with simulated rainfall (Merzouk and Blake, 1991; Meyers and Wagger, 1996). Soil loss measured from 1-m^2 plots primarily results from splash detachment by rain drops, and, therefore, is an indication of interrill erosion. Scaling up soil loss from 1-m^2 to slope and catchment scales has been widely reviewed. Merzouk and Blake (1991) reported agreement between values of soil erodibility measured under simulated rainfall and the magnitude of soil erosion observed in the field. Other studies reported that soil loss is underestimated on microplots due to the short slope length (Le Bissonnais et al., 1998). However, simulated rainfall on microplots in the field enables detailed investigations on splash detachment and soil erodibility. Additionally, it provides reliable indication of runoff and soil loss for different soil types and land-use systems.

13.4.3 Effect of No-Tillage on Soil Properties, Runoff, and Soil Loss

The NT improves soil structure, due to the stabilization of the soil surface by increased SOC content and the accumulation of crop residues (Ingram and Fernandes, 2001; VandenBygaar et al., 2002), and by the lack of mechanical disturbance and its consequences on biological activity (Beare et al., 1994). In this study, changes in soil physical properties under NT depended on soil texture. For the clay soil, topsoil C content and WSA were significantly more under NT than under CT, but the increase was limited (27% for C content, 12% for WSA). For the sandy loam, topsoil C content and WSA did not differ significantly among NT and CT. Recent conversion from CT to NT probably explained the limited effects of tillage practices on soil properties. Indeed, measurements were made at the end of the first cropping season under NT, after many years under CT. Improvement in soil physical properties under NT is a slow process, especially for degraded soils (Ingram and Fernandes, 2001). Rhoton et al. (2002) observed that topsoil SOC and WSA under NT increased by 17% after 4 years and by 70% after 14 years. Thus, more increase in SOC and WSA under NT may be possible in the soils under this study, but for longer durations. Soil BD did not differ either among tillage systems, which was contrary to the results of Rhoton et al., (2002). These authors found BD to increase with the conversion from CT to NT. In the present study, BD varied according to soil type and depth, as was also reported by Arshad et al., (1999). Moreover, runoff and soil loss were not influenced by tillage in the present study, probably due to the recent conversion from CT to NT. Indeed, several studies have reported that runoff and soil losses were reduced under NT, and are related to the accumulation of SOC under NT (Arshad et al., 1999; Franzluebbers, 2002; Rhoton et al., 2002). Bradford and Huang (1994) reported similar results from experiments under simulated rainfall. In the present study, significant increases in topsoil C and WSA in the clay soil under NT indicated that runoff and soil loss may be reduced over time. Long-term experiments are needed to confirm this hypothesis.

13.4.4 C Content of Sediments and Enrichment Ratio

Soil erosion decreases SOC by selective detachment and transport of fine particles (Watung et al., 1996; Wan and El-Swaify, 1997; Jacinthe et al., 2002; Lal, 2003), resulting in an enrichment of sediments with SOC relative to the *in situ* soil (Wan and El-Swaify, 1997; Owens et al., 2002). This study also showed that sediments were enriched in SOC. The ER was higher for the sandy loam than for the clay soil (3.4 to 6.5 vs. 1.4 to 2.7), indicating that erosion was more selective on the former than on the latter. Sediments had a higher C/N ratio on the sandy loam (14 to 15, close to that of the topsoil and of the plants) than on the clay soil (10 to 12, lower than that of the topsoil), indicating that eroded C was less processed and less protected in the former than in the latter. These results suggested that eroded C in the clay soil was mainly in the form of processed organic matter protected within aggregates and removed along with them, whereas eroded C in the sandy loam was mainly in the form of particulate organic matter.

13.4.5 Effect of Land Management on Soil C Losses and Soil C Stocks

The SOC losses ranged from 0.12 to 1.95 g C m^{-2}, which corresponded with C losses measured by Jacinthe et al. (2002) under simulated rainfall on long-term NT plots. The present study demonstrated the potential of improved fallows in reducing runoff and soil losses (on 1-m^2 plots). A PCA showed that C losses may be explained by topsoil SOC content, WSA, and RS, and were thus influenced by soil type and land use. Indeed, topsoil C content, WSA, and RS were lower and

C losses more in the sandy loam than in the clay soil. For the clay soil, increases in topsoil SOC content and WSA after improved fallows similarly resulted in smaller C losses. For the sandy loam, topsoil SOC content and WSA, as well as C losses, were less clearly affected by improved fallows, but increase in RS under NT was associated with an increase in C losses. Thus, increases in C losses were associated with decreases in topsoil SOC content and WSA for the clay soil (after fallow), but with increase in RS for the sandy loam (under NT).

Topsoil C stocks in the sandy loam and clay soil were less than those reported by Wilson (1997) and Nandwa (2001) for intensively cultivated soils in Kenya. The present study showed that improved fallows increased topsoil C stocks, especially for the clay soil. The only significant increase in topsoil C stock resulting from fallow, which reached 22%, was for IF-Tc on clay soil, when stocks were calculated on an equivalent soil mass basis. The increase was not significant when stocks were calculated for the 0 to 10 cm depth layer (equivalent depth), indicating the importance of calculation on equivalent soil mass when discussing management-induced changes in SOC and nutrient storage, as was recommended by Ellert and Bettany (1995). Additionally, NT resulted in an increase in topsoil SOC stock (on equivalent soil mass or depth) in the clay soil but not in the sandy loam, which also confirmed the findings of Arshad et al. (1999). Their results showed greater SOC stocks under NT for a silty loam but no increase for a sandy loam soil.

13.5 CONCLUSION

The objectives of this chapter were to evaluate the effects of improved fallows (with *Crotalaria grahamiana* or *Tephrosia candida*) and no-tillage on runoff, soil, and C losses for a sandy loam and a clay soil under maize-beans cultivation. The results showed that runoff, soil, and C losses were lower on the clay soil than on the sandy loam. The data also showed that short-term improved fallows reduced and controlled runoff, soil, and C losses during the following cropping phase on both soil types, but that the reduction was more on the clay soil than on the sandy loam. These trends were attributed to a build-up of topsoil C and WSA during the fallow phase, which was less important in general for the sandy loam than for the clay soil. Nevertheless, improved fallow with *Crotalaria grahamiana* was very effective in reducing runoff, soil, and C losses on the sandy loam, mainly due to a reduction in crusting.

Soil C stocks were more in the clay soil and were more clearly increased by improved fallows than in the sandy loam. The C enrichment ratio of sediments was significantly higher for the sandy loam, indicating that higher proportions of topsoil C were removed than on the clay soil. Sediment enrichment was not affected by treatments. Moreover, the proportion of topsoil C stock lost with sediments was much higher for the sandy loam than for the clay soil, but was not clearly affected by treatments.

No-tillage did not significantly influence runoff and soil losses. However, no-tillage increased topsoil WSA, C content, and C stock in the clay soil, and increased sediment enrichment ratio and C losses for the sandy loam. No definite trends were observed for soil strength: under NT, soil resistance to shear and penetration decreased in the clay soil but increased in the sandy loam. However, all the results regarding tillage practices must be confirmed by long-term experiments. Indeed, measurements were made at the end of the first cropping season under NT, following many years under CT. As improvement in soil properties under NT is considered a slow process in general, long-term experiments are needed to further examine the effects of no-till on water, soil, and C conservation.

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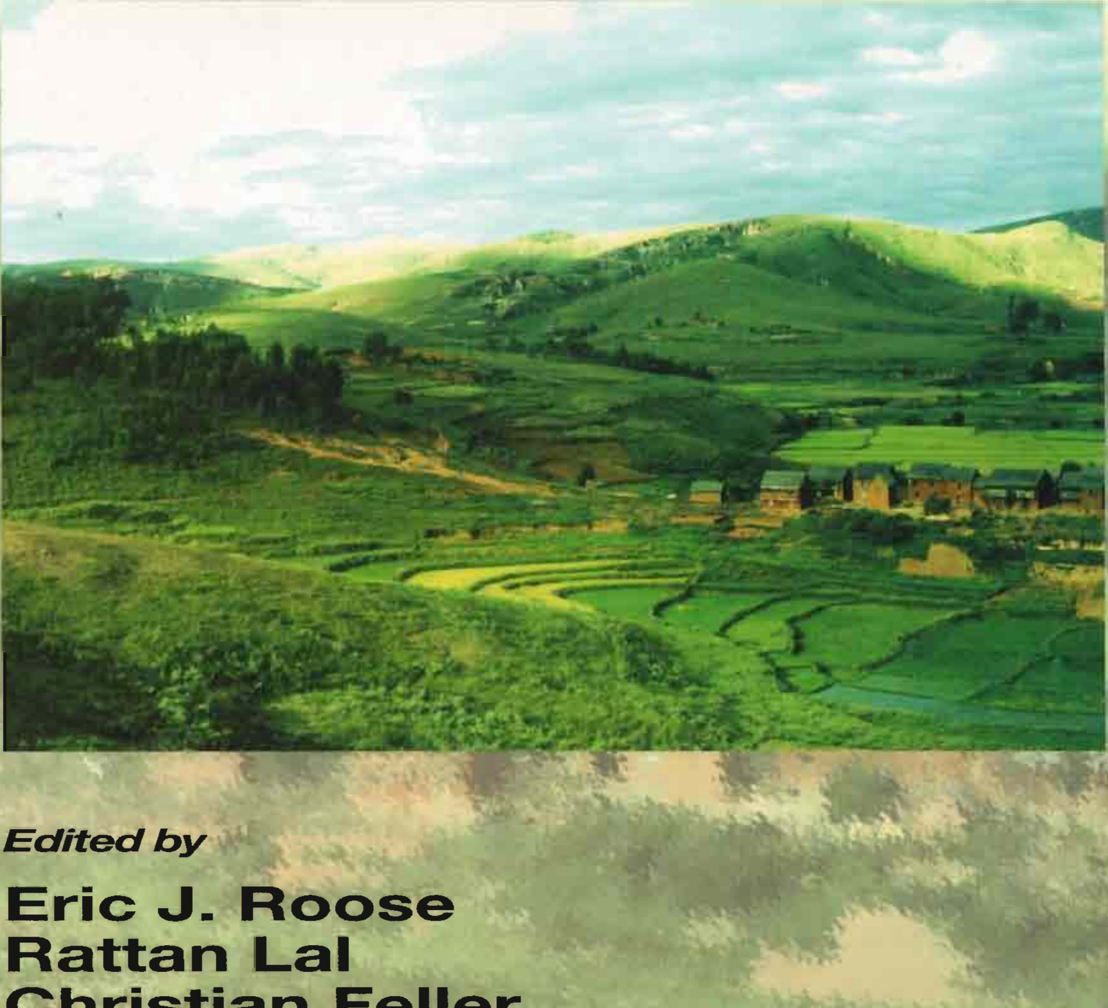
SOIL EROSION AND CARBON DYNAMICS



Edited by

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On the cover: A typical landscape of red ferrallitic soils on the high plateau of central Madagascar near Antananarivo during the rainy season. The hilltop is covered by overgrazed grassland deeply eroded around the cattle trails which join the village and the springs in the valley. The hills lose carbon, nutrients, soil, and water, but might be nourishing the rice paddies below.

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SOIL EROSION AND CARBON DYNAMICS

In addition to depleting nutrients necessary for healthy crops, soil erosion processes can affect the carbon balance of agroecosystems, and thus influence global warming. While the magnitude and severity of soil erosion are well documented, fluxes of eroded carbon are rarely quantified. **Soil Erosion and Carbon Dynamics** brings together a diverse group of papers and data from the perspectives of world-renowned soil scientists, agronomists, and sedimentologists to resolve whether soil erosion on carbon is a beneficial or destructive process.

This book collects quantitative data on eroded organic carbon fluxes from the scale of the agricultural plot to that of large basins and oceans. It quantifies the magnitude of eroded carbon for different soil management practices as compared to normal carbon sequestration and discusses the fate of the eroded carbon and whether or not it is a source or sink for atmospheric CO_2. Finally, the book offers data reflecting the impact of soil erosion on soil, water, and air quality. Other important topics include solubilization, carbon transfer, and sediment deposition, as well as carbon dioxide emissions, global warming potential, and the implications of soil erosion on the global carbon cycle and carbon budget.

Features

- Defines basic concepts and general approaches to the global carbon cycle, carbon sequestration, erosion, and eroded carbon
- Addresses the great debate on "missing" or "fugitive" carbon
- Includes arguments and data that support contrasting viewpoints on the effects of the carbon cycle
- Offers a meaningful look at the impact of soil erosion on the global carbon cycle and the global carbon budget
- Covers solubilization and carbon transfers in rivers and deposition in sediments
- Addresses the impact of soil erosion on crop production systems
- Elucidates the CO_2-to-carbon relationship and organic carbon fluxes

Based on the first symposium of the international colloquium *Land Uses, Erosion and Carbon Sequestration* held in Montpellier, France, **Soil Erosion and Carbon Dynamics** provides data that link soil erosion to the global carbon cycle and elucidates the fate of eroded carbon at scales ranging from plot to watershed.

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