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Effect of Sustainable Land Management Practices on the Soil Erodibility at the Plateau of Abomey (Centre of Benin)

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Abstract

The soils of Benin in general and those of the department of Zou, in particular, are highly degraded. This study aimed to evaluate the effectiveness of sustainable land management practices on soil erodibility in two villages in the Plateau of Abomey. Soil samples were collected on plots under Sustainable Land Management (SLM) measures (direct seeding, maize residue management and soybean-cereal rotation) and on their adjacent control. The soil samples were prepared and analyzed in laboratory to determine variables such as soil permeability, organic matter content, and particle size. Soil erodibility was determined as proposed by Wischmeier & Smith. The effect of SLM practices was significant (0.02) on soil permeability. On plots under SLM measurements, soil permeability is higher with an average of 93.97 mm/h at Folly and 82.43 mm/h at Hanagbo. SLM measurements significantly (0.04) added organic matter to the soil. The average organic matter of the plots under SLM measures in Folly varies from 0.73% to 1.39% while it varies from 0.49% to 0.73% in the control plots. In Hanagbo, the average organic matter of the plots under SLM measures varies from 1.86% to 2.48% against 1.41% to 1.66% for the control plots. Regarding soil erodibility, it was found that the influence of SLM measures is significant in both villages. In villages, direct seeding and maize residue management significantly (0.008) reduced soil erodibility compared to their adjacent controls, while the soybean-cereal rotation measure increased soil erodibility compared to plot witnesses. The average soil erodibility of plots under SLM measures varies by 0.21 t·h/Mj·mm at 0.38 t·h/Mj·mm in the village of Hanagbo and 0.25 t·h/Mj·mm at 0.38 t·h/Mj·mm in the village of Folly. It varies from 0.24 t·h/Mj·mm at 0.28 t·h/Mj·mm for the control plots at Hanagbo and 0.31 t·h/Mj·mm at 0.37 t·h/Mj·mm in Folly. These practices can therefore be used for the sustainable use of agricultural land.

Keywords

Water Erosion, Cropping Systems, Sustainable Land Uses, Soil Erodibility, Centre of Benin

1. Introduction

Soil erosion concerns both developed and developing countries and results in an overall average loss of 0.3% of annual crop yield worldwide [1]. More than three quarters of soil erosion is caused by bad management practices in agriculture and livestock production or by conversion of forest to cropland [2]. While water and wind are the main causes of soil erosion, soil losses by water are more serious than those by wind [3]. Africa hosts more than 45% of the total erosion affected people [4] where it affects millions of hectares of soil [5] [6].

In Benin, soil degradation due to water erosion is a major threat to large agricultural zones [7]. Despite the gently or moderately undulating of Benin [8], these unsustainable agricultural practices combined with high rainfall intensity lead to several forms of erosion [9]. [10] pointed out that the different regions of Benin are sensitive to the energy of wind, rain and runoff. The level of degradation varies among agro-ecological zones. The plateau of Abomey is dominated by ferrallitic soils which are strongly degraded [11]. [12] reported the occurrence of sheet erosion and gully erosion in the plateau of Abomey. [13] and [14] reported averages of 18.82 $t \cdot ha^{-1} \cdot yr^{-1}$ and 15 $t \cdot ha^{-1} \cdot yr^{-1}$ respectively in the watersheds of Linsinlin and Zou located in the plateau of Abomey. As a result, crop yields and the sustainability of production systems are compromised exposing populations to food insecurity [15].

For several decades, sustainable land management has been the subject of research through research and development programs and projects in Benin (PGRN, PGTRN, ProCGRN...). An intercropping program with Leucaena and Cajanus has been initiated but has not been successful in the field [16]. Mucuna was extended in southern Benin in 1990. Rotation techniques based on seed legumes (cowpea, groundnut), cover legumes (Mucuna) and fodder plants (*Stylosanthes guianensis*) have been tested. Short-term fallowing of Mucuna (7 to 8 months) in rotation or in association with maize cultivation has significantly reduced the risk of runoff and erosion, and has significantly increased soil organic matter and nitrogen content [17]. Significative results in the fight against land degradation have been obtained with Mucuna and other cover crops [17]

[18] [19]. These techniques have been adopted very little in the farming environment because of numerous constraints (non-consumption of the seeds of these cover legumes and the difficult management of their residues, etc.). The results of rock phosphate use trials cannot be disseminated due to the lack of an organized source of supply [19]. Since 2015, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) has initiated the project "Soil Rehabilitation and Protection to Improve Food Security" (abbreviated to ProSOL) as part of the special initiative "One World Without Hunger". Since 2014, the program has been promoting a sustainable approach to land development at the farm level. It places particular emphasis on sustainable land management and climate change adaptation measures (Integrated Soil Fertility Management; Conservation Agriculture; Water and Soil Conservation; Agriculture and Livestock Integration; Agroforestry and Adaptation to Climate Change).

Water erosion control is a key component of ProSOL and control methods such as no-tillage, maize residue management, and contour tillage were extended to farmers [20] [21]. These efforts have certainly had a positive impact on soil health in the areas where SLM measures have been implemented.

The primary drivers of water erosion are rainfall intensity, topography, soil properties, vegetation cover, and erosion control practices [22] [23]. Soil properties determine its ability to resist both detachment and transport [24]. Some soils are naturally more resistant to erosion than others. The erodibility of soil depends on its particle size composition, infiltration rate, structural stability and organic matter content [25]. Indeed, clayey soil particles are easier to transport [23]. With a slow infiltration rate will be much more prone to erosion. Likewise, soils with low organic matter content would flak and erode quickly. In addition, the intensity of soil erosion is highly dependent on soil management practices [26]. Thus, good management of soil organic matter, good tillage and conservation tillage practices can reduce soil erosion by water [27] [28]. The objective of this study was to evaluate the effectiveness of some selected sustainable land management practices on soil erodibility in two villages in the Plateau of Abomey.

2. Materials and Methods

2.1. Experimental Site

This work was carried out in two sites (Za-kpota and Djidja) in central Benin (**Figure 1**). In Za-kpota, the village of Folly was selected while Hanagbo was selected in Djidja. The soil at Folly is a weakly desaturated ferrallitic soil. The relief is dominated by a uniform plateau bordered by a slight slope towards the bed of the Zou River. Hanagbo is characterized by a leached tropical ferruginous soil. The relief consists of plateaus with depressions, but also granite outcrops (Lô, Lalo…) reaching 100 m of altitude. At Folly, the natural vegetation is dominated by Imperata grass (*Imperata cylindrica*) while at Hanagbo, it is dominated by guinea grass (*Panicum maximum* Jacq.). In both locations, the climate is a subequatorial climate with two rainy seasons and two dry seasons. The annual rainfall

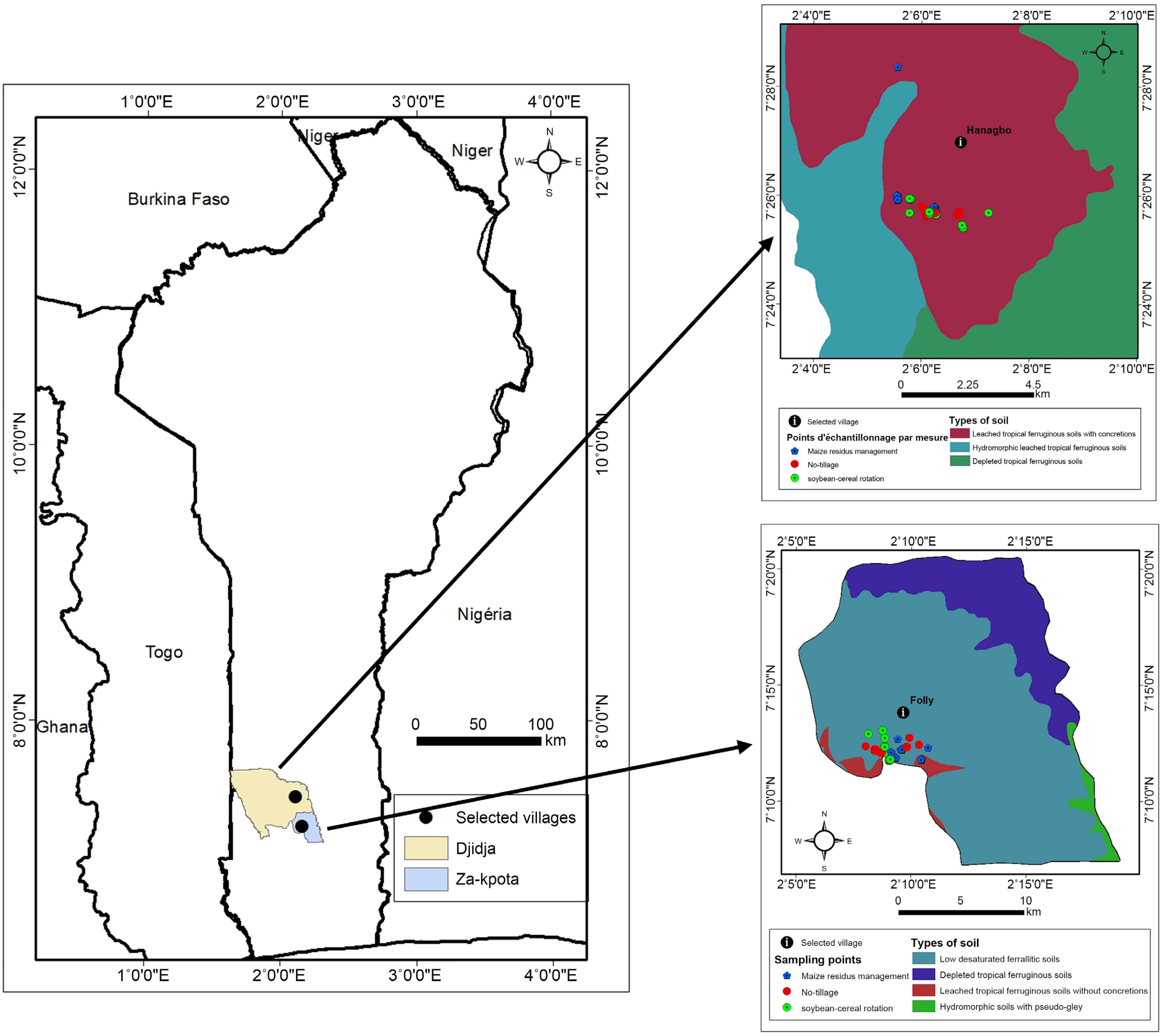

Figure 1. Location of soil sampling points by SLM measurement [Projection: UTM WGS 1984 Zone 31N; Data source: Topographic Map of Benin (IGN 1992), Soil Map of Benin, Authors' fieldwork].

in 2020 was on average 1200 mm and the temperature varies from 25˚C to 30˚C [29].

2.2. Methods

2.2.1. Description of the SLM Measures Studied

The Sustainable Land Management (SLM) practices investigated are Integrated Soil Fertility Management measures (ISFM measures). The studied SLM practices were 1) soybean inoculated in rotation with maize; 2) incorporation of maize residues (*Zea mays*) at the tillage time and 3) no-tillage. These measures are the most adopted in the study zones. They were identified through an exploratory survey. The sites where the soils were sampled are intervention sites of the ProSOL project. The soil was sampled three years after the adoption of SLM practices.

In the inoculated in rotation with maize system, maize was growth from April to July and soybean was growth from July to November. The maize was sown at spacing of 0.80 m × 0.40 m and without mineral fertilizer input. Soybean was coated with *Bradyrhizobium japonicum* inoculum and sown at a spacing of 0.15 m × 0.70 m. After the soybean is harvested, the maize is sown either without tillage on the crop residues or following incorporation of the residues by minimum tillage. For the second SLM practices, the residues of maize were buried by ridging or flat plowing. Farmers sow crops such as maize, cowpea and groundnut without mineral fertilizer input. For the no-tillage practices, farmers cleared land at the beginning of the rainy season and residues were spread on the ground or lined up in the furrows. The plots of no-till treatment did not undergo any additional tillage. The seedpots were manually made with the hoe.

2.2.2. Soil Sampling Design

The studied sites were selected from the ProSOL project database. The selection criterion was based on the number of farmers that had adopted SLM Using this criterion, the communes of Djidja and Za-kpota were identified. Within each commune, the same criterion was used to select the village with the most SLM adopter. Hanagbo was selected in Djidja while Folly was selected in Za-kpota. In each surveyed village, four SLM farmers were selected for each practice. The studied SLM practices were 1) soybean inoculated in rotation with maize; 2) incorporation of maize residues (*Zea mays*) at the tillage time and 3) no-tillage. The sampling design was an adjacent control device (**Figure 2**). Indeed, next to each SLM plot, an adjacent control plot was selected. This control plot is a plot that has not had any SLM measurements for at least 3 consecutive years.

In each village, four (4) plots were selected for each SLM practice. On each sampling plot, a square grid of 400 m^2 was installed in the middle of the plot [30]. Soil samples were taken from five different points: in the center and at the four corners of the square grid. Indeed, at each SLM plot, 05 soil samples were collected. The same sampling strategy was used on the control plots. A total of 240 soil samples were collected. Soil samples were collected with a cylindrical auger at 30 cm depth. These samples were carried to the laboratory, air-dried and then sieved with a 2 mm sieve.

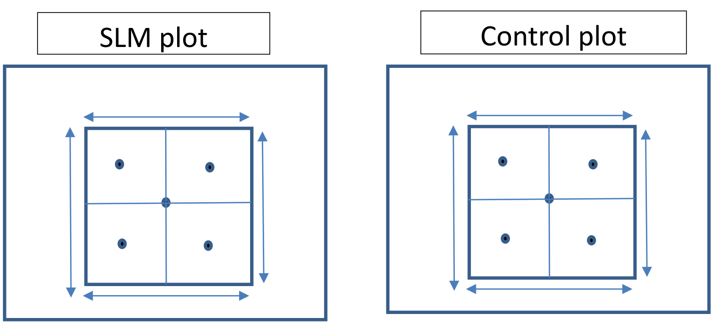

Figure 2. Soil sampling plan.

2.2.3. Parameters Studied

The erodibility factor expresses the soil vulnerability to water erosion. It depends on the physical and chemical properties of the soil [31]. The erodibility was determined by soil unit according to different parameters such as permeability, organic matter and the textural code and the structural code. These parameter differences occur in the original formula of [22] and that of [32]. Soil parameters such as structure, permeability, organic matter content and texture greatly contribute to influencing the soil erodibility [33]. The original formula of [22] and that of [32] were adopted. According to [22], the erodibility of soil factor (K) is expressed by the following relationship:

$$K = \left(2.1 * 10^{-4} * (12 - a) M^{1.4} + 3.25(b - 2) + 2.5(c - 3)\right) / 100$$

with M = (% fine sand + % silt) * (100 − % clay).; a = organic matter content (%).

b = soil structure code between 1 and 4; c = soil permeability code between 1 and 6.

As part of this study, a first estimate of erodibility was made using the formula of [22]. For points where the value of the first estimate is less than 0.2; a second estimate was made as recommended by [32].

$$K = 0.091 - 0.34 * k_1 k_2 + 1.79 * (k_1 k_2)^2 + 0.24 * k_1 k_2 * A + 0.033 * (P - 3)$$

whither

$$k_1 = 2.77 * 10^{-5} * M^{1.14} \text{ et } k_2 = (12 - MO)/10$$

M is the particle size factor; M = (% silt + % very fine sand) (100 − % clay); $M.O$ is the organic matter rate (%).

The particle size analysis was determined according to the Robinson pipette method [34]. The considered fractions were clay (0 - 2 µm); silt (2 - 50 µm); very fine sand (50 - 100 µm); fine sand (100 - 200 µm) and coarse sand (200 - 2000 µm). The soil organic matter content (%) was determined using the method of [35].

Water infiltration was measured on the SLM plots and their adjacent control using the method of Porchet. Measurements of the water infiltration in the soil were carried out. A cylindrical hole 6 cm in diameter and 30 cm deep was dug using a probe. After having filled it with water, it was observed that the variation of the level (h_1 and h_2) of the water as a function of time (t_1 and t_2).

The infiltration rate k was calculated by the following formula:

$$k(\text{cm/s}) = \frac{r}{2} * (t_2 - t_1) * \log\left(h_2 + \frac{r}{2}\right) \Big/ \left(h_2 + \frac{r}{2}\right)$$

with r, the radius of the hole

The permeability codes (**Table 1**) established by [36] were used.

2.2.4. Statistical Analysis

Statistical analyses were performed with SAS 9.4 (SAS Institute 2015). Two rounds of statistical analysis were performed. First, the Student t-test of comparison

Table 1. Soil permeability code and class.

Code	Class	Value
1	Rapid drainage	>60 mm/h
2	Moderate to rapid drainage	20 - 60 mm/h
3	Moderate drainage	5 - 20 mm/h
4	Slow to moderate drainage	2 - 5 mm/h
5	Slow drainage	1 - 2 mm/h
6	Very slow drainage	<1 mm/h

of two means was used to compare organic matter rates, infiltration rates and erodibility values between the SLM measurements and their respective adjacent controls. In addition, the differences in erodibility between the SLM measurements and their respective adjacent controls were subjected to a one-way analysis of variance following the General Linear Model procedure. The effect tested is that of the SLM measures. Means separation was done using Student-Newman-Keuls test. The significance threshold used was 5%.

3. Results

3.1. Soil Texture

The percentages of clay, silt and sand in the soils under the SLM measurements are summarized in Table 2. At both Folly and Hanagbo, the soils had a sandy silty texture for all three measurements studied.

3.2. Soil Organic Matter

The results of the comparative analysis of the organic matter rate of the plots under SLM practices and their control are presented in Table 3. In Hanagbo and Folly, the organic matter rate obtained for the soils under the maize residue management measures and direct seeding is significantly ($p = 0.04$) higher than the rate of organic matter obtained on their respective adjacent controls. In fact, at Folly, maize residue management increased the organic matter rate by 86% compared to its adjacent control, while an increase in the organic matter rate of more than 90% was observed with no-tillage. In Hanagbo, maize residue management and no-tillage increased organic matter content by 54% and 32% compared to their respective adjacent controls (Table 3).

3.3. Soil Permeability

In general, the water infiltration is higher in the plots under SLM practices compared to the control plots in the two villages (Figure 3). The two villages obtained the highest infiltration rate under under the crop residue management practice (111.60 in Folly and 93.30 mm/h in Hanagbo). In Folly, water infiltration into the soil is lower under no-tillage than under soybean-cereal rotation. Same trend is observed in Hanagbo. In other words, water infiltration into the

Table 2. Textural composition of soils under SLM measures (mean ± standard deviation).

Villages	SLM Practice	Clay (%)	Silt (%)	Sand (%)	Texture class*
Folly	No-tillage	5.31 ± 2.34	10.62 ± 3.52	84.07 ± 19.14	Sandy silty
	Crop residue management	4.68 ± 1.97	10.93 ± 3.08	84.39 ± 24.29	Sandy silty
	Soybean-cereal rotation	5.62 ± 4.20	10 ± 1.81	84.38 ± 24.99	Sandy silty
Hanagbo	No-tillage	6.25 ± 2.84	8.75 ± 1.31	85 ± 6.32	Sandy silty
	Crop residue management	6.25 ± 2.53	8.58 ± 2.53	85.17 ± 8.12	Sandy silty
	Soybean-cereal rotation	5.93 ± 2.17	9.68 ± 1.51	84.39 ± 19.32	Sandy silty

*the system of particle sizes of USDA was used.

Table 3. Determination of the rate of organic matter (mean ± standard)

Site	SLM Practice	Organic Matter Content (%)		Difference	P-value
		SLM	Control		
Folly	No-tillage	1.39 ± 0.84	0.73 ± 0.45	−0.6598	0.0039**
	Maize residue management	0.91 ± 0.41	0.49 ± 0.20	−0.4129	0.0003**
	Soybean-cereal rotation	0.73 ± 0.33	0.55 ± 0.24	−0.1829	0.0563^{ns}
Hanagbo	No-tillage	1.86 ± 0.72	1.41 ± 0.53	−0.4402	0.0353*
	Maize residue management	2.48 ± 0.86	1.61± 0.58	−0.8652	0.0007**
	Soybean-cereal rotation	1.93 ± 0.59	1.66 ± 0.61	−0.2613	0.1797^{ns}

ns: not significant at 5% level; *: significant at 5% level ($p < 0.05$); **: highly significant at 1% level ($p < 0.01$); ***: very highly significant at 0.1% level ($p < 0.001$).

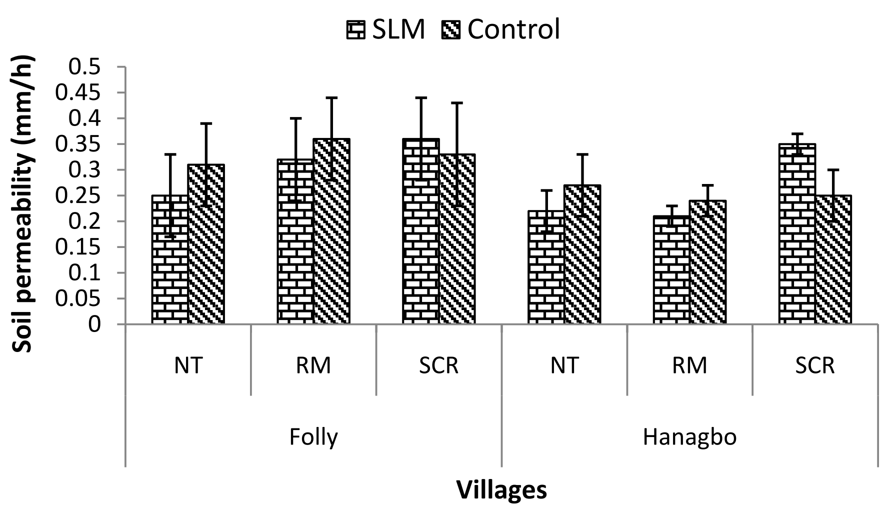

Figure 3. Soil permeability (mm/h) of the two villages. RM: maize residue management, NT: No tillage and SCR: Soybean-Cereal Rotation.

soil is higher under maize residue management than under soybean-cereal rotation and direct seeding (Figure 2).

3.4. Soil Erodibility

The SLM practices significantly reduced soil erodibility compared to the control in Hanagbo (Table 4). No-tillage, maize residue management and soybean-cereal rotation significantly influenced soil erodibility in Hanagbo village. In Folly, no-tillage significantly influenced soil erodibility, however maize residue management and soybean-cereal rotation did not significantly influence soil erodibility in Folly. The average erodibility is 0.25 t·h/Mj·mm under no-tillage was lower than the average soil erodibility of the control which is 0.31 t·h/Mj·mm.

3.5. Adjusted Soil Erodibility

Table 5 presents the effect of cropping systems on soil erodibility. In Hanagbo, direct seeding and maize residue management significantly decreased soil erodibility compared to their respective adjacent controls, while an opposite effect was observed with the soybean-cereals measure. At Folly, the difference was not significant between the erodibility for the soils under SLM measurements and the erodibility of the soils for the controls. Table 6 compares the difference the difference in the erodibility value between the plots under SLM practices and their respective controls. It was observed that SLM practices significantly influenced this difference and the highest value was obtained with soybean-cereal rotation measure in Hanagbo.

Table 4. Effect of cropping systems on soil erodibility (*K* (t·h/Mj·mm).

Site	SLM Practice	Soil erodibility (t·h/Mj·mm)		Difference	P-value
		SLM	Control		
Folly	No-tillage	0.22 ± 0.04	0.27 ± 0.06	−0.0420	0.0238*
	Maize residue management	0.21 ± 0.02	0.24 ± 0.03	−0.0343	0.0005**
	Soybean-cereal rotation	0.35 ± 0.02	0.25 ± 0.05	0.0989	<0.0001***
Hanagbo	No-tillage	0.25 ± 0.08	0.31 ± 0.08	−0.0611	0.0253*
	Maize residue management	0.32 ± 0.08	0.36 ± 0.08	−0.0316	0.2292^{ns}
	Soybean-cereal rotation	0.36 ± 0.08	0.33 ± 0.10	0.0244	0.4185^{ns}

ns: not significant at 5% level; *: significant at 5% level ($p < 0.05$); **: highly significant at 1% level ($p < 0.01$); ***: very highly significant at 0.1% level ($p < 0.001$).

Table 5. Effect of cropping systems on adjusted soil erodibility (*K* (t·h/Mj·mm)) (mean ± standard deviation).

Site	SLM Practice	Adjusted soil erodibility (t·h/Mj·mm)		Difference	P-value
		SLM	Control		
Folly	No-tillage	0.25 ± 0.04	0.28 ± 0.06	−0.03	0.0200*
	Maize residue management	0.23 ± 0.02	0.27 ± 0.03	−0.03	0.0002**
	Soybean-cereal rotation	0.38 ± 0.02	0.28 ± 0.05	0.09	<0.0001***
Hanagbo	No-tillage	0.29 ± 0.08	0.34 ± 0.07	−0.05	0.0525^{ns}
	Maize residue management	0.35 ± 0.08	0.35 ± 0.08	−0.03	0.2610^{ns}
	Soybean-cereal rotation	0.38 ± 0.09	0.37 ± 0.08	0.01	0.6800^{ns}

ns: not significant at 5% level; *: significant at 5% level ($p < 0.05$); **: highly significant at 1% level ($p < 0.01$); ***: very highly significant at 0.1% level ($p < 0.001$).

Table 6. Comparison of soil erodibility according to SLM measurements.

Villages	Maize residue management	Direct seeding	Soybean-cereal rotation
Folly	−0.03 ± 0.00 b	−0.03 ± 0.01 b	0.09 ± 0.01 a
Hanagbo	−0.03 ± 0.01 b	−0.05 ± 0.00 b	0.01 ± 0.01 a

Values with the same alphabetical letter are not significantly different for the same factor and the same variable.

4. Discussion

4.1. Soil Parameters

The sensitivity of soils to being eroded depends on its intrinsic properties such as organic matter content, permeability, structure and particle size [22]. Our results showed that no-tillage, residue management and soybean-cereal rotation significantly increased the amount of soil organic matter compared to the control plots. This can be explained by the fact that these practices play two main roles: 1) they provide organic matter which is gradually transformed into humus, 2) they minimize the adverse effects of excess water, the main cause of the dispersion of clay and humus. "Organic matter promotes the aggregation of particles between them and the development of biological activity which leads to greater infiltration at the expense of runoff." [36] Therefore, increased organic matter content influences a decrease in soil erosion [14]. Similar results have been found by several researchers [37] [38] [39] [40]. Organic matter contributes to soil erodibility reduction by increasing its permeability, moisture and improving its structure. As a result, the humus-enhanced structure will reduce the inherent susceptibility of soil particles to being loosened by raindrops and then washed away by moving water.

A tailings cover protects the soil from degradation caused by the impact of raindrops and increases the structural stability of surface aggregates by increasing the organic matter content. This presence of organic matter maintains or creates a high microporosity from the surface created either by the work tools or by biological activity; porosity ensures effective vertical transfer of [41]. Our results show that all plots under SLM measures evaluated recorded the highest organic matter content, unlike the control plots. This fact highlights the relationship between permeability and organic matter content. These results showed that all the SLM practices evaluated considerably protected the soil and increased its permeability. This reflects higher water retention in the plots under SLM practices compared to the control plots. The high level of permeability observed on the plots under SLM practices would be linked, on the one hand, to the high vegetation cover of these soils. [42] also recognized that reducing tillage combined with the presence of significant plant cover on the surface (or keeping crop residues on the surface) reduces the risk of runoff, and even more the risk of erosion. According to [43], if the soil cover is at ground level (case of mulch and pebble beds), erosion will be reduced to less than 5% of that of a bare plot. Indeed, this cover will dissipate not only the energy of the raindrops, but also the runoff. Cropping systems such as direct seeding, residue management and soybean-cereal rotations are practical tools for reducing runoff.

4.2. Soil Erodibility

Our results showed that the cropping systems significantly influenced the erodibility in Hanagbo. Based on the classification of [44], it appears that plots under SLM practices are moderately sensitive to erosion. On the other hand, the control plots have a high sensitivity. This result could be explained by the particularity presented by the control plots to erosion which present low organic matter contents and high permeability compared to the plots under SLM measures. The values obtained are close to those found by [45]. [45] found K values between 0.10 t·h/Mj·mm and 0.15 t·h/Mj·mm for ferralitic soils and between 0.20 t·h/Mj·mm and 0.30 t·h/Mj·mm for tropical ferruginous soils. In Folly, no-tillage significantly influenced soil erodibility. Soil erosion reduction effect of no-tillage practice has been documented frequently and is mostly attributed to increased organic carbon content and the retention of crop residues at the soil surface [46]. Appropriate tillage is considered an important management tool to combat water erosion risks, promote in situ water conservation, improve crop yields and stabilize rainfed agricultural systems [6].

5. Conclusion

This study aimed to evaluate the effect of sustainable land management practices on soil erodibility in two villages in the Plateau of Abomey. Organic matter content varied between 0.69% and 2.05% for the plots under SLM practices and between 0.31% and 0.59% for the control plots. The infiltration rate of the sampled plots is between 67.94 mm/h and 111.60 mm/h for the plots under SLM practices. The control plots have an infiltration rate of between 44.64 mm/h and 75.34 mm/h. Soil erodibility is lower under the SLM plots in both locations and ranged from 0.21 t·h/Mj·mm to 0.7 t·h/Mj·mm. Sustainable Land Management practices such as 1) soybean inoculated in rotation with maize; 2) incorporation of maize residues (*Zea mays*) at the tillage time and 3) no-tillage can be promoted to reduce soil erosivity on the plateau of Abomey in central Benin.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] FAO (2015) State of the World's Soil Resources—Technical Summary Food and

Agriculture Organization of the United Nations and Intergovernmental Technical Group on Soils. Rome, 92.

[2] Pimentel, D. (2006) Soil Erosion: A Food and Environmental Threat. *Environment, Development and Sustainability*, **8**, 119-137. https://doi.org/10.1007/s10668-005-1262-8

[3] Lal, R. (2000) Physical Management of Soils of the Tropics: Priorities for the 21st Century. *Soil Science*, **165**, 191-207. https://doi.org/10.1097/00010694-200003000-00002

[4] Assefa, D.Z. (2009) Assessment of Upland Erosion Processes and Farmer's Perception of Land Conservation in Debre-Mewi Watershed, near Lake Tana Ethiopia. Thesis of Cornell University, Ithaca, 90 p.

[5] Bashagaluke, J.B., Logah, V., Opoku, A., Sarkodie-Addo, J. and Quansah, C. (2018) Soil Nutrient Loss through Erosion: Impact of Different Cropping Systems and Soil Amendments in Ghana. *PLOS ONE*, **13**, e0208250. https://doi.org/10.1371/journal.pone.0208250

[6] Akplo, T.M., Kouelo Alladassi, F., Zoundji, M.C.C., Avakoudjo, J., Houngnandan, P., Dagbénonbakin, D.G., Saïdou, A., Benmansour, M., Fulajtar, E., Amadji, G.L., Azontondé, H.A., Assogbadjo, A.E. and Kakaï, R.G. (2022) Impact of Conservation Tillage on Runoff, Soil Loss and Soil Properties on Acrisols and Ferralsols in Central Benin. *Canadian Journal of Soil Science*. https://doi.org/10.1139/CJSS-2021-0080

[7] Kouelo, A.F., Houngnandan, P, Azontondé, H.A., Benmansour, M., Rabesiranana, N. and Mabt, L. (2015) Assessment of the Level of Soil Degradation in Three Watersheds Affected by Intensive Farming Practices in Benin. *Journal of Experimental Biology and Agri-Cultural Sciences*, **3**, 529-540. https://doi.org/10.18006/2015.3(6).529.540

[8] Adam, S. and Boko, M. (1993) Benin [Le Bénin] Les éditions du Flamboyant. EDICEF, Cotonou, 6.

[9] Hiepe, C. (2008) Soil Degradation by Water Erosion in a Sub-Humid West-African Catchment: A Modelling Approach Considering Land Use and Climate Change in Benin. Thesis Dissertation, Rheinischen Friedrich-Wilhelms-Universität, Bonn, 335 p.

[10] Barthès, B., Azontonde, A., Boli, B.Z., Prat, C. and Roose, E. (2000) Field-Scale Run-Off and Erosion in Relation to Topsoil Aggregate Stability in Three Tropical Regions (Benin, Cameroon, Mexico). *European Journal of Soil Science*, **51**, 485-495. https://doi.org/10.1046/j.1365-2389.2000.00322.x

[11] Azontondé, H.A., Igué, A.M. and Dagbénonbakin, G. (2016) Soil Fertility Map of Benin by Agro-Ecological Zone [La carte de fertilité des sols du Bénin par zone agroécologique du Bénin]. Rapport Final, 139 p.

[12] Floquet, A., Mongbo, R., Aguémon, D., Tohinlo, P., Nansi, J. and Aboki, J. (2006) Runoff Water in Abomey and Bohicon, Nuisance or Opportunity. First Results of Consultations between Local Actors [Les eaux de ruissellement à Abomey et Bohicon, nuisances ou opportunités. Premiers résultats de concertations entre acteurs locaux]. CEBEDES-FIDESPRA, série document de travail Ecocité n°11, 25 p. https://www.ecocite.org

[13] Kouelo, A.F. (2016) Effects of Cropping Practices on Soil Degradation in Three Watersheds in Southern Benin [Effets des pratiques culturales sur la dégradation du sol au niveau des trois bassins versants du sud Bénin]. Thèse de Doctorat en Sciences Agronomiques, Universités d'Abomey-Calavi, Bénin, 239 p.

[14] Akplo, T.M., Kouelo Alladassi, F., Houngnandan, P., Saidou, A., Benmansour, M.

and Azontondé, H.A. (2020) Mapping the Risk of Soil Erosion Using RUSLE, GIS and Remote Sensing: A Case Study of Zou Watershed in Central Benin. *Moroccan Journal of Agricultural Sciences*, **1**, 281-290.

[15] Egah, J., Baco, M.N., Lokossou, R.S., Moutouama, F.T., Akponikpè, P.B.I., Fatondji, D., Djènontin, A.J., Tossou, C.R. and Sokpon, N. (2014) Economic Impact of Exogenous Water and Soil Conservation Techniques in Benin. *Bulletin de la Recherche Agronomique du Bénin* (*BRAB*), **75**, 57.

[16] Douthwaite, B., Manyong, V.M., Keatinge, J.D.H. and Chianu, J. (2002) The Adoption of Alley Farming and Mucuna: Lesson for Research, Development and Extension. *Agroforestry Systems*, **56**, 193-202. https://doi.org/10.1023/A:1021319028117

[17] Azontondé, H.A. (1993) Degradation and Restoration of Bar Land (Ferralitic Soils with Low Desaturation and Sandy Clay) in Benin. *Cahiers Orstom*, *série Pédologie*, **28**, 217-226.

[18] Hougnandan, P. (2000) Efficiency of the Use of Organic and Inorganic Nutrients in Maize-Based Cropping Systems in Benin. PhD Thesis, Universiteit Gent, Belgium, 196 p.

[19] Amadji, F., Adjé, T.I., Maliki, R. and Téblékou, K. (2004) Technical Report of Research and Development Activities. Campagne 2003-2004. R-D Centre/INRABPADSE Savè, Bénin, 86 p.

[20] Igue, A.M., Oussou, B., Adoko, F., Ouorou Barre, I. and Djedje M. (2018) Dégradation chimiques des terres dans dix-sept communes des départements du Zou, des Collines, du Borgou et de l'Alibori. *Acte des résumés du premier Atelier Scientifique de la Journée Mondiale des Sols*, 18-19.

[21] Akplo, T., Dan, B., Houessou, L., Houinato, M. and Sinsin, A. (2019) Typologie et structure des systèmes agroforestiers dans la commune de Djidja Bénin. *Revue Internationale des SciencesAppliquées*, **1**, 29-39.

[22] Wischmeier, W.H. and Smith, D. (1978) Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Vol. 537, chez Agriculture Hanbook, de USDA, 58 p.

[23] Hiepe, C. (2008) Soil Degradation by Water Erosion in a Sub-Humid West-African Catchment. Doctoral Dissertation, Universitäts-und Landesbibliothek, Bonn.

[24] Chen, D., Lan, Z., Hu, S. and Bai, Y. (2015) Effects of Nitrogen Enrichment on Belowground Communities in Grassland: Relative Role of Soil Nitrogen Availability vs. Soil Acidification. *Soil Biology and Biochemistry*, **89**, 99-108. https://doi.org/10.1016/j.soilbio.2015.06.028

[25] Lu, D., Li, G., Valladares, G.S. and Batistella, M. (2004) Mapping Soil Erosion Risk in Rondonia, Brazilian Amazonia: Using RUSLE, Remote Sensing and GIS. *Land Degradation & Development*, **15**, 499-512. https://doi.org/10.1002/ldr.634

[26] Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder D.C. (1997) Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). US Department of Agriculture Agricultural Handbook No. 703. USDA, Washington DC.

[27] Akplo, T.M., Kouelo Alladassi, F., Houngnandan, P., Benmansour, M., Rabesiranana, N., Mabit, L., Ahoglé Agassin, M.A. and Alohoutadé, F.M. (2017) Effect of Tillage and Mulching on Soil Water Erosion in Linsinlin Watershed, Centre of Benin. *Journal of Experimental Biology and Agricultural Sciences*, **5**, 515-524. https://doi.org/10.18006/2017.5(4).515.524

[28] Ouattara, V.T., Konate, Z., Messoum, G.F., Kassin, E.K., Tahi, M.G., Koko, L.A. and Camara, M. (2018) Effects of Organophosphate Fertilization on the Organic Matter and Adsorbent Complex Fertility of a Ferralsol under Cocoa Trees in the Divo Re-

gion (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences*, **12**, 2901-2921. https://doi.org/10.4314/ijbcs.v12i6.33

[29] ASECNA (2020) Climatique Data of Bohicon [Données climatiques de la station synoptique de Bohcon (Bénin)].

[30] Ballot, C.S.A., Mawussi, G., Atakpama, W., Moita-Nassy, M., Yangakola, T.M., Zinga, I. and Koffi, A. (2016) Physico-Chemical Characterization of Soils to Improve Cassava (*Manihot esculenta* Crantz) Productivity in the Damara Region of South-Central Central Africa. *Agronomie Africaine*, **28**, 9-23.

[31] Akplo, T.M., Kouelo Alladassi, F., Houngnandan, P., Saidou, A., Benmansour, M. and Azontondé, H.A. (2020) Mapping the Risk of Soil Erosion Using RUSLE, GIS and Remote Sensing: A Case Study of Zou Watershed in Central Benin. *Moroccan Journal of Agricultural Sciences*, **1**, 281-290.

[32] Foster, G.R, Toy, T.E. and Renard K.G. (2003) Comparison of the USLE, RUSLE 1 and RUSLE 2 for Application in the Highly Disturbed Lands. *First Interagency Conference*, Benson, 27-30 October 2003, 154-160.

[33] Roose, E. and Sarrailh, J.M. (1990) Erodibility of Some Tropical Soils—Twenty Years of Measurements in Erosion Plots under Natural Rainfall. *Pédologie*, **25**, 7-30.

[34] Day, R.P. (1965) Pipette Method of Particle Size Analysis. In: *Methods of Soil Analysis*, Agronomy No. 9, ASA, Madison, 553-562.

[35] Walkley, A. and Black, I.A. (1934) An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Chromic Acid Titration Method. *Soil Science*, **37**, 29-38. https://doi.org/10.1097/00010694-193401000-00003

[36] Mounirou, A. (2012) Study of Runoff and Erosion at Different Spatial Scales in the Tougou Watershed in the Sahelian Zone of Burkina Faso: Quantification and Data Transposition. Thése de doctorat en cotutelle, Université Montpellier II et 2iE, Montpellier et Ouagadougou, Ouagadougou.

[37] Bottinelli, N. (2010) Evolution of the Structure and Permeability of a Soil in No-Till Context Associated with the Contribution of Livestock Effluent: Role of the Umbrian Activity. Thèse doctorale, 165 p.

[38] Tya, T. and Oluwaseye, A. (2015) Evaluation of Soil Erodibility on the Agricultural Soil of the Central Zone of Adamawa State, Nigeria. *Swift Journal of Research in Environmental Studies*, **1**, 14-17.

[39] Aranyos, J.T., Tomócsik, A., Makádi, M., Mészáros, J. and Blaskó, L. (2016) Changes in Physical Properties of Sandy Soil after Long-Term Compost Treatment. *International Agrophysics*, **30**, 269-274. https://doi.org/10.1515/intag-2016-0003

[40] Sun, D., Zhang, W., Lin, Y., Liu, Z., Shen, W., Zhou, L. and Fu, S. (2018) Soil Erosion and Water Retention Varies with Plantation Type and Age. *Forest Ecology and Management*, **422**, 1-10. https://doi.org/10.1016/j.foreco.2018.03.048

[41] Labreuche, J., C., L.S., Castillon, P., Ouvry, J.F., Real, B., Germon, J.C. and Tourdonnet, S. (2007) Evaluation of the Environmental Impacts of No-Till Farming Techniques (TCSL) in France. ADEME-ARVALIS Institut du végétal-INRA-APCA-AREAS-ITB-CETIOMIFVV, Paris, 400.

[42] Heddadj, D., Gascuel-Odoux, C., Cotin, P. and Hamon, Y. (2005) Tillage Method Runoff and Hydrodynamic Properties on an Experimental Set-Up in Western France. *Étude et gestion des sols*, **12**, 53-66.

[43] Roose, E. and Barthès, B. (2001) Organic Matter Management for Soil Conservation and Productivity Restoration in Africa: A Contribution from Francophone Research. *Nutrient Cycling in Agroecosystems*, **61**, 159-170.

https://doi.org/10.1023/A:1013349731671

[44] Bollinne, A. and Rosseau, P. (1978) Soil Erodibility in Middle and Upper Belgium. *Bulletin de la Société Géographique de Liège*, **14**, 127-140.

[45] Roose, E. (1977) Erosion and Runoff in West Africa. Twenty Years of Measurements in Experimental Plots. Travaux et doc., ORSTOM, Paris, 78, 108 p.

[46] Kasper, M., Buchan, G.D., Mentler, A. and Blum, W.E.H. (2009) Influence of Soil Tillage Systems on Aggregate Stability and the Distribution of C and N in Different Aggregate Fractions. *Soil and Tillage Research*, **105**, 192-199. https://doi.org/10.1016/j.still.2009.08.002