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International Journal of Recent Scientific Research
Vol. 6, Issue, 3, pp.2922-2925, March, 2015

ISSN: 0976-3031

International Journal of Recent Scientific Research

RESEARCH ARTICLE

WATER EROSION AND LOSS OF NUTRIENTS AND ORGANIC MATTER IN FARMLANDS IN CENTRAL MOROCCO

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ARTICLE INFO

Article History:

Received 14th, February, 2015
Received in revised form 23th, February, 2015
Accepted 13th, March, 2015
Published online 28th, March, 2015

Key words:

water erosion; mineral elements; watershed; Central Morocco

ABSTRACT

Water erosion is an alarming threat to soils in Morocco. It has a direct impact on agricultural land and the country's infrastructure such as highways. In order to evaluate this effect, several studies take place in Northern Morocco, while very few concerned the watersheds of Central Morocco. This paper presents the results of a quantitative study on water erosion and loss of mineral elements in the Ben Ahmed watershed. Rainfall simulation was conducted with an erosive intensity of 60 mm/h, for sites representing the main soils of the watershed. It resulted that their detachability was between 19 and 34 g/l, erosion rates ranging between 4.3 and 12.3 t/ha; 38% to 73% rain turned into runoff depending on soil type. The laboratory analysis of the recovered sediments showed that soil loses 7.1 kg of organic matter, 1.1 kg of potassium and 0.062 kg of phosphorus per hectare in the watershed.

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INTRODUCTION

Erosion is currently causing serious problems for agricultural production, characterized by a high variability and a chronic deficit. The gravity of this phenomenon seems to exceed efforts to curb the various erosion processes (Boutkhil Morsli *et al.*, 2004). This phenomenon distorts lands by taking of the topsoil (the most fertile and the most alive) and by pulling selectively the nourishing elements, the fine particles and the organic matter able at the same time to store useful water and the nutrients, and feed the alive elements in the ground (Rose *et al.*, 1985). The loss of organic matter and nutrients in watershed are closely related to the intensity of erosion, that is to say, the production and the solid flow. The phosphate ions are strongly retained by soil particles and transported by runoff. Potassium ions are adsorbed on the cation exchange complex of the soil or may be dissolved in the soil solution. They end up in runoff water in particulate or ionic form (Giroux and Royer, 2006).

Indeed, the watershed erosion essentially leads to reduction of soil fertility. In the same sense, Dautrebande *et al.* (2006) confirm that water erosion has consequences both on upstream and downstream levels. It can result in upstream to soil loss and loss of organic matter and nutrients including phosphorus and potassium. (Giroux and Royer, 2006).

Water erosion is a natural process accelerated by anthropic activity, and one of the major environmental problems (Kenel and Délusca, 1998) that face watershed farmers of Ben Ahmed (Central Morocco). This study aims not only to quantify the phenomenon of water erosion but also to quantify nutrient losses. In fact, rain simulation tests were carried out at the Ben Ahmed watershed using a rainfall simulator.

MATERIALS AND METHODS

Rain simulation tests were realized in the watershed of Ben Ahmed at 70 km from the city of Casablanca in Central Morocco (33°06’43’’N, 7°24’21’’ W), covering an area of 545 ha. The experiments consist to measure, on five micro-plots of one square meter, the streamed volumes and sediments under the influence of rainfall generated by a rainfall simulator. The study plot is limited by a metal frame of 0.62 square meters down into the soil to a depth of 10 cm. A water collection system, made up of a collecting gutter limits the plot at its base and receives water and runoff sediments. For each of the micro-plots, a rain erosion sequence of 60 mm/h was simulated for 30 minutes. During each test and every 5 min, the volumes of sediment loads were collected and runoff was measured. Runoff water was collected each minute through a gutter system installed at the micro-plots to determine sediment loads associated with runoff flow. In the laboratory Water runoff was

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dried to 105°C. The recovered solid fillers have been subject to chemical analysis.

Other parameters were measured and calculated in the rain simulation, including:

- Runoff (in mm) (LR)
- Infiltrated blades (mm) (Linf) calculated as follows: (Linf = Rain-LR)
- The flow coefficients (in %) (Ke) being: (Ke= (LR/rain) ×100)
- Runoff sediment concentrations (Conc) (in g /l)
- Soil loss (en g m^{-2}) being (Ero= Conc×LR)

The experimental sites represent the main soil types of the watershed. They represent the following features (WRB, 2006)
Site 1: Alluvial soil (cropped with peas).
Site 2: Rendzinas (plough)
Site 3: Alluvial soil with mulch
Site 4: Rendzinas soil
Site 5: Cherno soil

Physico-chemical analysis

Nutrients are transported with small soil particles that form suspended matters by rainwater. These elements were analyzed at INRA soil laboratory in Rabat. Carbon was measured by the Walkely–Black method, phosphorus by colorimetric analysis and potassium by flame photometry. Soil samples were collected at 0-20 and 20-40 cm depths. They were air dried and sieved to 2 mm before analysis.

RESULTS AND DISCUSSION

Soils Characterization

The physicochemical properties of the studied soils are shown in Table 1. For soil (Alluviol soil and Rendzinas), silt and clay are the most representative fractions. The sand fraction remains less represented with less than 20%, except for Cherno soils. For phosphorus and potassium, Cherno soils present higher levels than Rendzinas and Alluvial soils, by against they present a lower content of organic material. These results show that the studied soils are poor in phosphorus, in organic matter and rich in potassium according to Delaunois *et al.* (2008).

Table 1 physical and chemical properties of the studied soils

Sites	Soils	Size			OM (%)	K_2O	P_2O_5
		Clay (%)	Silt (%)	Sand (%)		(mg/Kg)	(mg/kg)
1	Alluvial soil	47.1	36.2	16.7	2.9	253.0	10.3
2	Rendzinas	47.1	26.1	26.8	1.2	232.0	7.0
3	Alluvial soil	41.7	45.1	13.2	1.9	256.0	11.3
4	Rendzinas	22.6	61.7	15.7	3.3	244.0	11.6
5	Cherno soil	26.3	35.8	37.9	1.2	265.0	12.4

Run-off water volumes

Table 2 represents the cumulative data of runoff and erosion recorded in the main soils of the watershed, for each site, during the experimental period. These results show that during the rain simulation test with an intensity of 60 mm / h, in a Alluvial soil (site1), runoff is 27 mm/h, indicating that 45% (Ke) of rain transformed into runoff. For Rendzinas (site2), the runoff is of 36 mm/h, indicating that 60% rain transformed into runoff, this is due to the effect of tillage. For the experimental site 3 (Alluvial soil), the runoff is of the order of 22 mm/h, which implies that 36% of rain is transformed into runoff. This site presents a vegetation cover (mulch) that maintains a strong infiltration and reduces runoff volume through its rooting system. In the case of the last two sites (4 and 5), more than 70% of rain transformed into runoff with a runoff flow of 42mm/h with an intensity of 60 mm/h. For the Site 4, the presence of stones causes a decrease in infiltration by increasing runoff and therefore the increase in the concentration of solid fillers.

Table 2 Runoff during rainfall simulation

Sites	Soils	LR (mm)	Ke(%)
1	Alluvial soil	27	45
2	Rendzinas	36	60
3	Alluvial soil	22	37
4	Rendzinas	43	72
5	Cherno soil	42	70

LR: Run-off, Ke: flow coefficient

Loss of soil

The average loss of soil by water erosion recorded in the experience varies between 34.4 and 19.0 g / L (table 3).

Table 3 Erosion and loss of soil during rain simulation

Soils	Sediment concentrations (g /L)	Ero(t/ha/h)
Alluvial soil	30.4	8.2
Rendzinas	34.4	12.3
Alluvial soil	19.0	4.3
Rendzinas	27.0	11.8
Cherno soil	21,8	9.3

Rendzinas that are shallow soils (site 2) record the highest concentration (34.4 g/L), because the soil surface was ploughed. Concentrations of 19 g/L were recorded in Alluvial soils with mulch. The presence of vegetation cover is probably among the most important factors that reduce the risk of erosion (Fritsch, 1992; Roose, 1994), it slows down the flow of runoff and maintains good porosity at the surface (Roose, 1996, Moussadek *et al.*, 2011).

Erosion rates vary between 4.3 and 12.3 t / ha. Rendzinas soil is the most eroded recording erosion rates of 11.8 to 12.3 t / ha.

The Alluvial soil and Cherno soil are moderately eroded, with average rates between 8.2 and 9.3 t / ha, Alluvial soil with mulch are weakly eroded (4.3t / ha).

Loss of Nutrients

The results obtained from soil and sediment analysis (Table.4 and Figure.1) have shown that the process of erosion impacts the chemical characteristics of the soil. The most significant changes affect the nutrient content especially, organic matter, phosphorus and potassium.

Table 4 shows the results of the chemical analyzes of sediments collected during the rain simulation tests.

Tableau.4 Cumulative soil sediment and nutrients lost during one rainfall event with (60 mm/h)

Site	Soils	Losses in Kg/ha			
		OM	K_2O	P_2O_5	Ero(kg /ha)
1	Alluvial soil	7.05	0.86	0.06	8200
2	Rendzinas	10.7	1.16	0.08	12300
3	Alluvial soil	2.67	0.52	0.02	4300
4	Rendzinas	7.43	1.47	0.1	11800
5	Cherno soil	7.72	1.69	0.05	9300

These results show that the loss of organic matter and nutrients follow the same pace as soil loss. The most important loss rates are in the upper layer (0-20 cm) for erosive intensity of 60 mm/h. The loss of organic matter is very important compared to potassium and phosphorus. The highest values were recorded in shallow tilled fields (site 2), because of tillage that allows the erosion of the finer soil fractions which are associated with the essential nutrients. On the other hand, the average values of the transported elements were recorded in the Alluvial soil (Site 3) with mulch. The loss of organic matter varies between 10.70 and 2.67 kg/ha which represent 69% to 19 %(figure.1). This could be explained by the effect of plowing which desagregates soils. These values are higher than that found by Maiga-Yaleu *et al* (2013). Alluvial and Cherno soil recorded the largest losses due to a greater loss of soil, compared to the Alluvial soil with mulch (Site 3) losses of organic matter of 2.67 kg/ha.

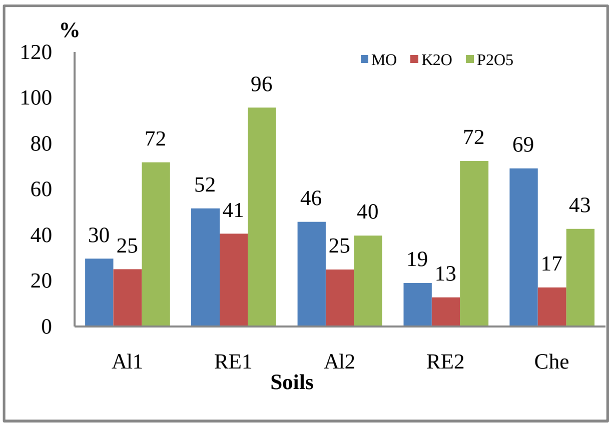

Figure.1 Percentage of organic matter and fertilizer losses in soil sediment by runoff

The potassium losses vary between 0.52 and 1.69 kg / ha, meaning that the 41% to12% of Potassium lost by runoff. The obtained results are similar to those found by Ziibisch *et al* (1995). The most important losses of Cherno soil are due to a higher content of soil potassium. Phosphorus losses representing 96% to 40% vary between 0.02 and 0.10 kg / ha, these results are similar to that found by Kleeberg et al (2008). These low losses can be explained by a very low content of phosphorus in soils. Transporting the organic matter and nutrients by erosion causes the destruction of the soil and the decrease in the water retention capacity, nutrient levels become weak leading to the decrease in the yield, which requires nutrients and organic matter supply in order to restore the soil.

CONCLUSION

The study conducted in the watershed of Ben Ahmed (Central Morocco) showed that we should expect from time to time, very high losses of humus and minerals caused by water erosion. In fact , we lose 7.1kg of organic matter and 1.1 kg of potassium and 0.062 kg of phosphorus per hectare of watershed with an average erosion rate of 9180 kg/ha. Research has shown that better protection against quantitative soil losses was assured by the vegetation, to be taken into account in land development processes, to avoid material and ecological damage that could be caused by such losses.

Acknowledgement

This research was financed by Autoroute Morocco (ADM) with a support of (GIZ-ACCN Morocco).

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How to cite this article:

Assera.Nazha *et al.,* Water erosion and loss of Nutrients and Organic Matter in Farmlands in Central morocco. *International Journal of Recent Scientific Research Vol. 6, Issue, 3, pp.2922-2925, March, 2015*

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