Research article

Soil Loss Mitigation by Applying Animal Waste Slurry

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Abstract The application of excreta wastes is beneficial for soil conservation, especially in degraded soils and soils being susceptible to erosion. In this study animal dung was used as a resource for protecting soils against erosion. The objective of this study is to measure the effectivity of animal waste slurry for mitigating soil loss in leptosol from Mixteca Region, Mexico. For this purpose, a splash erosion model and a surface runoff model were used. Splash erosion model consisted in stainless steel cores of 1.0 cm long with inside diameter at 1.1 cm. Soil was placed inside at a dry density of 1.0±0.1 g/cm^3. Fifty drops of artificial rain were dripped into the soil inside the core and soil loss was measured. On the other hand, surface runoff model consisted of a plot of 91 cm x 3.15 cm x 1.4 cm, with a triangular section. Soil was filled in with the same dry density of raindrop model and 1.2 cm^3/s of deionized water was supplied during one hour on a 12 degrees' slope. Discharge was collected every ten minutes and soil loss was measured. As treatment for both models, animal waste slurry was used. Horse dung was collected in the Horsemanship Club of Tokyo University of Agriculture and passed through a sieve at 212 µm in order to obtain slurry. 2 treatments were set up: the first was cattle slurry incorporated with soil and the second was crust formed with animal waste slurry; and control. Soil losses were compared among these 2 treatments. Raindrop experiment results showed that the addition of slurry decreased significantly soil loss rate from 6.4% to 1.3% in slurry incorporated cores and 0.2% in formed bio-crust cores. The same tendency was observed in the slope model experiment, where the application of slurry reduced significantly the soil losses from 558.6 g/m^2 to around 60 g/m^2 in both plots where slurry was added. Therefore, it can be concluded that the application of animal waste slurry was effective to reduce significantly soil losses by protecting the soil against kinetic energy of raindrops, as well as against shearing force of runoff on a 12 degrees' slope in leptosol soil of Mixteca Region.

Keywords slurry, soil erosion, horse dung, leptosol, Mixteca Region

INTRODUCTION

Several studies point that the application of excreta wastes could be beneficial for soil conservation, especially in degraded soils and soils being susceptible to erosion (Pinamonti and Zorzi, 1996). The use of compost or mulch blankets as a soil cover could help control soil erosion and provide sustainable alternatives to disposal for many biomass resources (Faucette et al., 2009).

Mixteca Region is located in Oaxaca State and has an average annual precipitation of 1988 mm and an average mean temperature of 15.0 ºC (Servicio Meteorológico Nacional, 2010). Oaxaca State is the main state by numbers of goats (Around 952,000 goats), which represents 10.9% of the national production (SAGARPA, 2008). Moreover, according to García Hernández (1996), the majority of units of production are extensive, where goat dung is left in the croplands. Animal dung was used as a resource for protecting soils against soil erosion. For that reason, the objective of this study is to measure the effectiveness of animal waste application for mitigation of soil loss by raindrop and surface runoff and to discuss effective conservation measures with animal waste slurry application based on the amounts of soil and nitrogen component losses.

METHODOLOGY

For this experiment soil samples from Mixteca Region were used. The samples were collected from a rainfed corn field located in a slope of 12 degrees. Physical and chemical properties are summarized in Table 1.

Table 1 Physical and chemical properties of soil experimental design

Soil	Specific gravity	Particle size distribution, %					Soil texture	pH	EC (μS/cm)	IL (%)
		Gravel	Coarse sand	Fine sand	Silt	Clay				
Leptosol	2.59	5.4	25.6	29.9	19.5	19.6	SCL	5.81	15.5	25.76

For this experiment, as animal waste, horse dung was used. It was obtained from the horsemanship club of Tokyo University of Agriculture. Analysis of total nitrogen, total phosphorus and coliform bacteria was conducted (Table 2).

Table 2 Properties of soil and animal waste

Sample	T-N (mg/kg)	T-P (mg/kg)	Coliform bacteria (cfu/g)
Soil	920.20	124.28	0
Slurry	6744.19	13466.06	3.2×10^7

The preparation of slurry was carried out through the sieving of the horse dung through a sieve of 212 μm to eliminate straw residues. Deionized water was used for this process. Since the slurry had a high water content after this process, and for reducing the amount of coliform bacteria (Saito and Mihara, 2010), slurry was dried up during four weeks (Fig. 1).

Horse dung from horsemanship club of Tokvo NODAI

Sieve of 212 μm
Air dried for four weeks

Horse dung slurry

Fig. 1 Animal waste slurry

For measuring the effectiveness of animal waste slurry, two experiments were carried out. The first experiment was splash erosion model conducted with the purpose to measure the ability of slurry added soil to decrease erosion by kinetic energy of raindrops. The second experiment was surface runoff model with the purpose of measure the ability of slurry added soil to decrease surface erosion. For both experiments, two treatments were applied.

Splash Erosion Experiment

For this experiment stainless steel cores were used, which are averagely 1.0 cm long with an internal diameter of 1.1 cm. They were filled with soil under a dry density of 1.0 ±0.1 g/cm^3 to keep a similar compaction between samples. Constant water pressure was controlled by means of a Mariotte's bottle (Fig. 2). A needle from the DIK-6000 rainfall simulator equipment was used for this experiment. The kinetic energy of raindrops was 2.36 x 10^{-5}J, calculated based in the equation $E_k = \frac{1}{2} m v^2$.

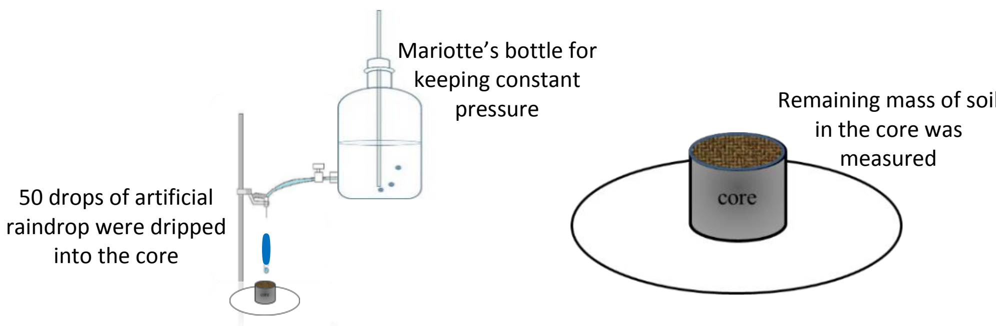


Fig. 2 Splash erosion model

For both experiments (Fig. 2), two treatments were defined. In these two treatments, the same dried mass ratio of soil : slurry was kept at 66:1. The first treatment consisted on incorporating the slurry into the soil by mixing both materials and placing the mixture into the stainless cores (incorporated with soil treatment). The second treatment consisted in placing the soil into the stainless core, compacted under the above mentioned dry density, and then covering completely its surface with animal waste slurry (formed bio-crust treatment).

For each treatment, 10 cores were used. 50 drops of artificial rain (deionized water) were dripped into every stainless core. Then, the remaining mass of soil inside the core was calculated (Eq. 1).

$$\left(1 - \frac{\textit{Remained soil mass in the metal core}}{\textit{Initial soil mass in the metal core}}\right) \times 100 \tag{1}$$

Surface Runoff Experiment

In this experiment, a triangular-section plot was used. The length was 91.0 cm and the triangular section had a height of 1.4 cm and a base of 3.1 cm (Fig. 3). Similar to the previous experiment, the compaction was keep under a dry density of 1.0 ±0.1 g/cm^3. And for this experiment the constant supply of deionized water (1.2 to 1.3 cm^3/s) was done by the use of a Mariotte's bottle during 60 minutes. The slope of this plot was determined as 12 degrees for all the samples.

The percolation water and runoff water was collected every 10 minutes for analyzing the amount of soil loss and the contents of total nitrogen.

Similar to the previous experiment, two treatments were defined for the surface runoff experiment. The first treatment consisted on incorporating the slurry into the soil by mixing both materials and placing the mixture into the plots. The second treatment consisted in placing the soil into the plot and then covering completely its surface with animal waste slurry. In both treatments, dried mass ratio of soil : slurry was kept at 66:1 (equivalent to 10 tons of slurry per hectare with a water content of 5.87).

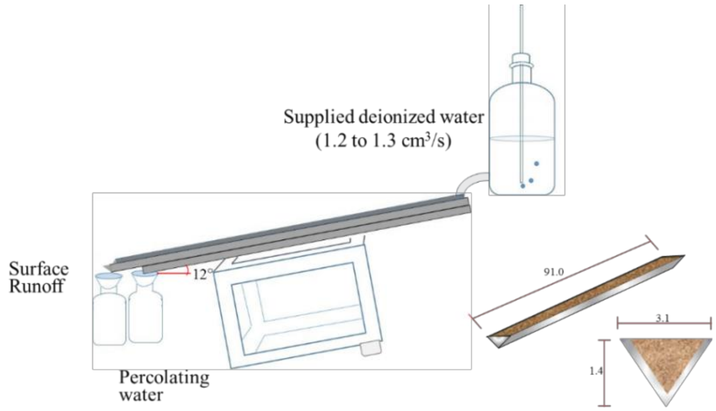


Fig. 3 Surface runoff plot model

RESULTS AND DISCUSSION

Splash Erosion Experiment

For every treatment ten stainless cores were used. After the 50 drops were applied, the samples were dried and then the weight inside every can was measure. Figure 4 shows the cores after the experiment. As can be observed, the cores in control showed a higher dispersion of soil particles.

Control **Incorporated with soil** **Formed bio-crust**

Fig. 4 Cores after raindrop experiment

After the fifty drops were dripped into the stainless cores, the soil loss rate was calculated. As can be observed in Fig. 5, control samples showed a higher dispersion of soil particles caused by the impact of raindrops compared to the treatments were animal waste slurry was added into the soil.

The average soil loss in control was 6.4%. The incorporation of slurry into the soil reduced the soil loss to 1.3%, and the application of slurry into the surface reduced the soil loss until a 0.2%. It was found that there was a significant difference between the control samples and the treatment with slurry. However, there was no significant difference between treatments. This can suggest that either way of applying slurry, being incorporated into the soil as a mixture or just applied on the surface is effective for reducing soil loss caused by the raindrop energy.

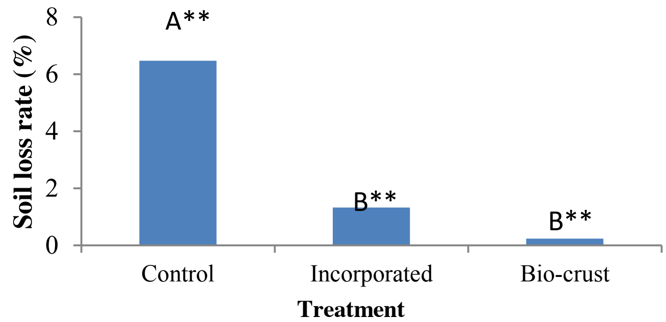
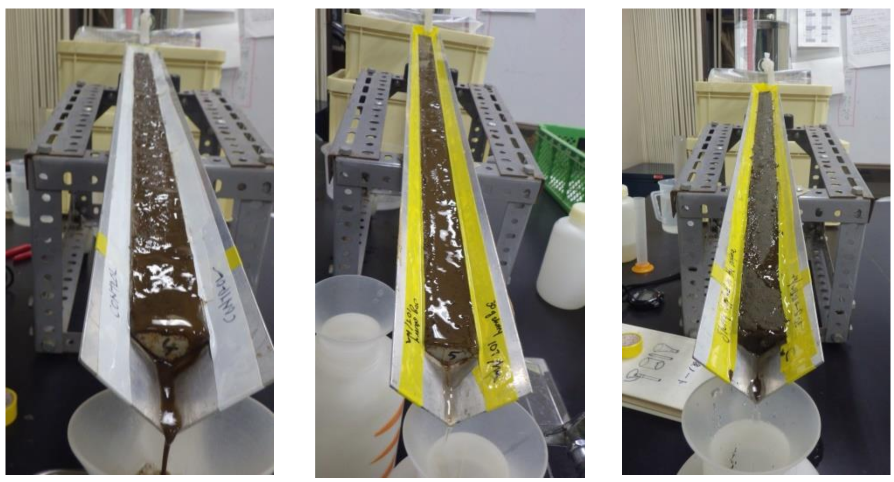


Fig. 5 Soil loss rate between treatment

Surface Runoff Experiment

The collection of runoff samples was carried out every ten minutes during one hour in the surface runoff experiment as shown in Fig. 6.



Control Incorporated with soil Formed bio-crust

Fig. 6 Runoff experiment plots

Figure 7 shows the results of the samples after being analyzed for cumulative soil losses and total nitrogen. Fig. 7(c) showed that there was no significant difference in the amount of discharge among treatments during the hour the experiment last. However, as can be observe in figure 7(a), control plot presented a much higher amount of soil losses, compared to the plots where slurry had been added. Concerning the amount of total nitrogen, in Fig. 7(b) can be observe that control plot shows a higher amount of nitrogen released, compared to treatments where slurry has been added. So even if slurry contains nitrogen, when added to the soil there was a fewer release of nitrogen into the runoff water samples.

It is considered that between the treatments, the addition of slurry, incorporated to the soil as well as applied in the surface to form a bio-crust significantly reduced the amount of soil losses compared to the control plot, in both the raindrop experiment and the runoff model. This could be due to the cohesion force produced by adding organic materials of animal waste slurry into the soil particles being beyond the kinetic energy of raindrops or shearing force of surface runoff.

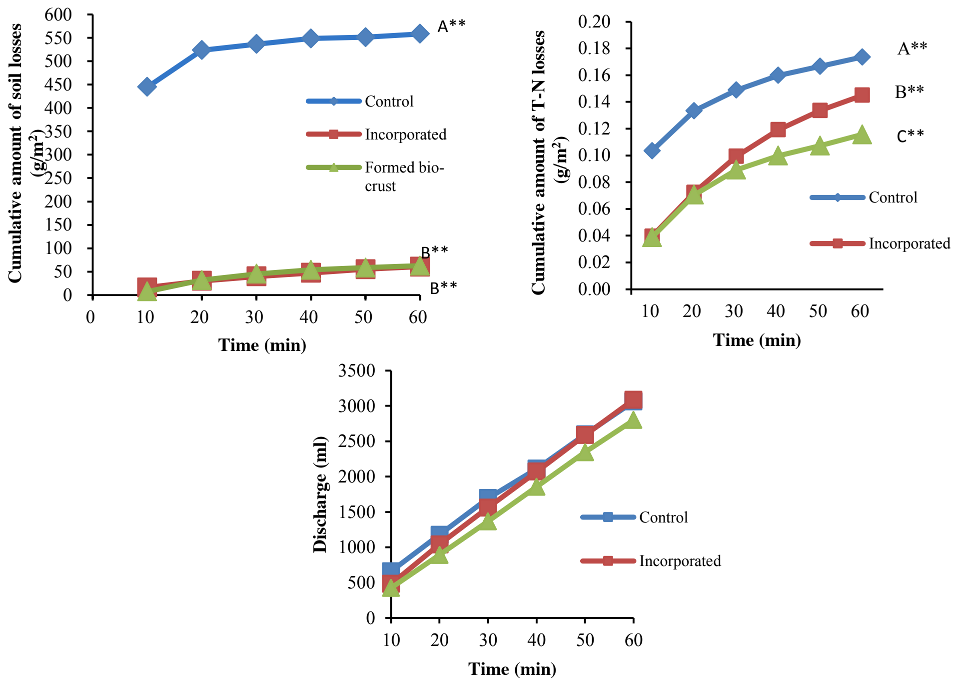


Fig. 7 Analysis of runoff experiment samples

CONCLUSION

Adding slurry into the soil, incorporated or applied on the surface, reduced splash erosion rate significantly in leptosol of Mixteca Region, as well as soil and nitrogen loss in the surface runoff. This could be because the addition of organic matter into the soil in the form of slurry improved the soil aggregation (Six, 1998), making it stronger against the kinetic energy of raindrops or the shearing forces of surface runoff. However, future research has to be conducted in order to ensure that the addition of slurry is not harmful for the environment. Furthermore, from a view point of nitrogen loss in the runoff experiment, formed bio-crust may be recommendable to apply as a conservation strategy above the incorporation of slurry into the soil.

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