

## Soil Model: Tool to Demonstrate the Effect of Different Cropping Systems on Soil Conservation

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**ABSTRACT:** *The use of soil models is applied to disseminate the importance of soil cover in mitigating erosive processes. The objective of the present study was to compare the effect of different systems of soil cover on the losses of soil and water. For this, an experiment was carried out on soil models containing soil classified as Cambisol, at a slope of 7%. The treatments were maize cultivation more canola straw; canola straw; and uncovered soil. In the treatments that received canola straw, there was used 40 g of straw.pot<sup>-1</sup>, equivalent to approximately 7 t.ha<sup>-1</sup>. For the measurement of the soil and water loss, the infiltrated water and the surface water were collected, and the lost water and soil were quantified. It was possible to verify differences between the treatments in terms of soil losses due to surface erosion, being the treatment without soil cover with the highest soil loss, equivalent to approximately 60 kg soil.ha<sup>-1</sup>, while in the treatment of canola straw with maize crop there were no soil losses. There was a superficial loss of water in all treatments, and there was no difference between them.*

**KEYWORD:** *Soil erosion, Vegetation cover, Rain water runoff, rain simulation.*

### INTRODUCTION

The soil is a natural, slowly renewable and fundamental resource for the production of food, fiber, and fuel to meet the need of a growing global population. Despite its great importance, the soil is a fragile and potentially degradable natural resource if handled improperly.

According to UNU estimates, about 33% of global soils are already degraded by urbanization (UNU, 2014). Soil erosion, nutrient depletion, salinity, aridification, and contamination are additional threats (UNU, 2014). In this sense, given the demands of humanity and given the great fragility of soils, it is fundamental that conservation practices are recommended for soil protection and conservation so that it will serve as a foundation for the prosperity of future generations.

In the state of Rio Grande do Sul in Brazil, in the 1990s, given the importance of conservation practices, the METAS project was implemented, a public-private partnership that had the objective of disseminating the techniques and mechanisms applicable to the cultivation of annual crops in a no-tillage system. The application of the principles of conservation agriculture, among them the diversification of crops for the contribution of 8 to 12 t of straw and root.ha<sup>-1</sup>.ano<sup>-1</sup>, help to the success of the no-tillage system, allowing the conservation of soil structure and the water storage in the crop (DENARDIN; LEMAINSKI, 2017). In addition, the conservation practices of the no-tillage system promote a better distribution of nutrients in the soil, better porosity for root growth and stimulation of soil microbial population responsible for nutrient cycling.

In 2012, it was estimated that approximately 32 million hectares were planted in Brazil under the no-tillage system (FEBRAPDP, 2012). However, what is observed in many cases is a simplification of the no-tillage system, with the absence of plants of crop rotation, the little contribution of straw on the surface, planting in the direction of the hill up-hill below and soil discovered or with very little coverage in the winter. According to an IBGE estimate made in 2015, in the state of Rio Grande do Sul, approximately 7.3 million hectares are cultivated with temporary summer crops, such as soybeans, rice, and corn, but in winter the cultivated area covered by temporary crops is only 1.4 million hectares. Thus, it is estimated that most of the soils cultivated in the state of Rio Grande do Sul are kept fallow or with scarce soil cover during the

winter, at which time the soil is susceptible to erosive processes, with the no-tillage system in its fullness.

In this sense, in order to resume dissemination of conservation practices and their consequent economic, environmental and social benefits, Decree number 52.751, dated December 4, 2015, in the state of Rio Grande do Sul, published in the Official State Gazette, was Established the Policy for Soil and Water Conservation, coordinated by the Secretariat of Agriculture, Livestock, and Irrigation. The purpose of this Decree is to encourage, and coordinate actions for the conservation of soil and water. In this program, it is recommended the dissemination of conservation practices to farmers, agricultural technicians who provide assistance to rural producers, technical schools and students of elementary and secondary education.

With the use of the soil model, it is possible to contribute to this public policy by demonstrating to farmers, students, and technicians the importance of cover crops and straw in soil protection and in mitigating the effects of the impact of rain. In a study aimed at elementary school students, Yoshioka and Lima (2005) visually demonstrate the reduction of soil loss in soil covered with vegetation compared to the uncovered soil when submitted to erosive rainfall. The soil model is applied to promote public awareness of soil and nutrient losses that occur when intensive rainfall reaches portions of soil without straw.

The objective of the present study was to compare the effect of soil cover on the loss of soil and water by erosion. Three different systems were compared for soil and water loss due to erosion: soil exposed; canola (*Brassica napus* L.) straw maintenance on the surface, and the combination of canola (*Brassica napus* L.) straw and maize (*Zea mays*) cultivation on the losses of soil and water.

## MATERIAL AND METHODS

The experiment was installed on October 31, 2016, in a greenhouse in the municipality of Nova Alvorada, in the mesoregion northeast of Rio Grande do Sul, Brazil, georeferenced at latitude 28° 40' 29.83", longitude 52° 09' 54, 82" and altitude of 431 m above sea level. During the study, the average, maximum and minimum temperatures were measured daily, for which the averages were observed 23.5 ° C, 32 ° C, and 15 ° C, respectively.

## CHARACTERIZATION OF SOIL MODELS

To evaluate the effect of vegetation cover on soil and water loss, three models were installed, composed of different systems of use and soil cover. Each model was composed of a rectangular plastic vessel, containing 16 liters of soil classified as typical Eutrophic Haplic Cambisol, according to Streck et al. (2008). The mockups were maintained at 7% inclination, to simulate the effect of cultivations conducted on sloping terrain and to induce the flow of water, as it happens in many slopes of Nova Alvorada and region, where the cultivation of grain crops is conducted.

To evaluate the effect of the treatments, these were organized as follows: 1) living cover with corn sowing + canola straw on the surface; 2) canola straw on the surface; 3) only discovered (Figure 1). In the treatment that received corn plants, the cultivar used was Syngenta Impacto, with a density of 12 plants per pot. In the treatments that received canola straw, was maintained the mass of 40 g of straw.plastic vessel<sup>-1</sup>, equivalent to approximately 7 t.ha<sup>-1</sup>.

The soil used in the present study is of high fertility, and the report of chemical analysis is presented in table 1. In the three models, maintenance fertilization was carried out for the corn crop with the fertilizer 5-20-20, recommending the exportation of the nutrients by the crop, according to fertilization and liming manual for the Rio Grande do Sul and Santa Catarina states (SBCS, 2016). To complement nitrogen fertilization, urea was used, at a dose equivalent to 150 kg N.ha<sup>-1</sup>.

**Table 1** - Report of a chemical analysis of soil.

pH in water	SMP index	Al	Ca	Mg	H + Al	CEC (pH 7,0)	Effective CEC	K	Cu	Zn	Mn
		..... cmol/dm <sup>3</sup> .....						..... mg/dm <sup>3</sup> .....			
5,78	6,18	0,00	15,86	4,21	3,55	24,36	20,81	289	6,19	> 10,0	41
		..... % (m/v) .....						..... mg/dm <sup>3</sup> .....			
EBS (%)	..... Saturation index (%) .....										
	Al	Ca	Mg	K	OM	Clay	P	S	B		
85,48	0	65,11	17,28	3,03	2,8	35	> 50	16,0	0,31		

\* CEC: Cations Exchange capacity; EBS: exchangeable base saturation; Al: exchangeable aluminum; Ca: exchangeable calcium; Mg: exchangeable magnesium; H + Al: active acidity; K: exchangeable potassium; Cu: exchangeable copper; Zn: exchangeable zinc; exchangeable manganese; MO: organic matter; S: exchangeable sulfur; P: labile phosphor; B: exchangeable boron.

In each of the models, two holes 1.2 cm in diameter were opened, one upper and one lower. The upper hole was positioned at the soil surface to collect the water drained surface, while the lower hole was positioned two fingers above the base, in order to collect the infiltrated water (Figure 2). To induce soil saturation, which naturally occurs during erosive rains, the lower hole was kept closed with a sealing tape, and it was opened 24 hours after the application of rain, to measure the infiltrated water.

In each of the holes made for the collection of water, transparent polyethylene tubes were attached to drainage of the water drained surface and water infiltrated in each of the models. The water was collected in plastic buckets for later gauging in graduated test tubes.



**Figure 1** - Top view of models with different treatments: a) only discovered soil; B) only covered with canola straw; C) soil covered by canola straw and corn plants.



**Figure 2** - Front view of the soil models, showing upper and lower holes for collecting the drained and infiltrated water, respectively.

### RAIN SIMULATION

In order to verify the effect of vegetation cover on soil and water loss through erosive rainfall, evaluations were carried out 15 days after maize sowing, when maize plants were in stage V3, according to Ciampitti et al. (2016). For this, erosive rains were simulated on each of the models, with a total volume of 5 liters of water distilled by rain, with the intensity of  $600 \text{ mL} \cdot \text{min}^{-1}$ . Each simulation was equivalent to a rain of 88 mm at an intensity of  $11 \text{ mm} \cdot \text{min}^{-1}$ . In order to obtain this effect, the use of 600 mL pissettes was done, which was manually pressed, simulating rainfall on the soil surface. Seven spots of rain were simulated, with an interval of 10 days between them, and after each rain simulation, the soil and water loss parameters were measured.

### EXPERIMENT CONDUCTION AND EVALUATIONS

The experiment was composed of three treatments and seven simulated spots of rain. The experiment was arranged in a completely randomized design, given the homogeneity of soil conditions, temperature, and luminosity incident on the models. The evaluated parameters were the water drained superficially in each model, the infiltrated water and the dry mass of suspended soil carried by the water drained superficially. After each simulated rainfall, the volume of water drained and infiltrated in each of the systems was measured in 500 mL graduated beakers.

For the determination of the dry mass of the soil particles carried in each of said systems, the samples were kept in test tubes for sedimentation for a period of 48 hours. Subsequent to the sedimentation of the solid particles, the water was drained. After flow, the solid particles were collected in microwave drying flasks, according to the methodology described by Tavares et al. (2008).

The data were submitted to analysis of variance and means test (Scott Knott, 5%), using the statistical program SISVAR 5.6 (FERREIRA, 2000).

### RESULTS AND DISCUSSION

The averages for the parameters evaluated throughout the study are presented in table 2. For simulated rainfall of 5000 mL, equivalent to 88 mm, with an intensity of  $11 \text{ mm} \cdot \text{min}^{-1}$ , approximately 30% of the volume of water applied was superficially drained, with no difference between treatments. Regarding the loss of water by runoff, in the present study, there was no difference between the control treatment without cover and the treatments with superficial straw or straw and corn crop. This is due to the fact that the environment provided by pots of 16 liters of soil and a slope of 7% was not efficient in simulating a real

condition of an erosive process in the field. This study reinforces the hypothesis of soil erosion equations, in which the soil slope and the space that the water travels horizontally since it reaches the surface of the ground, known as ramp length, are preponderant factors for erosive processes. In other words, without the existence of a considerable ramp length, it was not possible to verify the effect of straw and crop in mitigating the water runoff. In a study conducted in the field, several authors describe the vegetation cover as an important mitigating agent of erosive processes (SANTOS et al., 2000; ANDREOLA et al., 2000; SOUSA et al., 2012).

**Table 2** - Volumes of water drained and infiltrated in the models of soil conducted under different treatments.

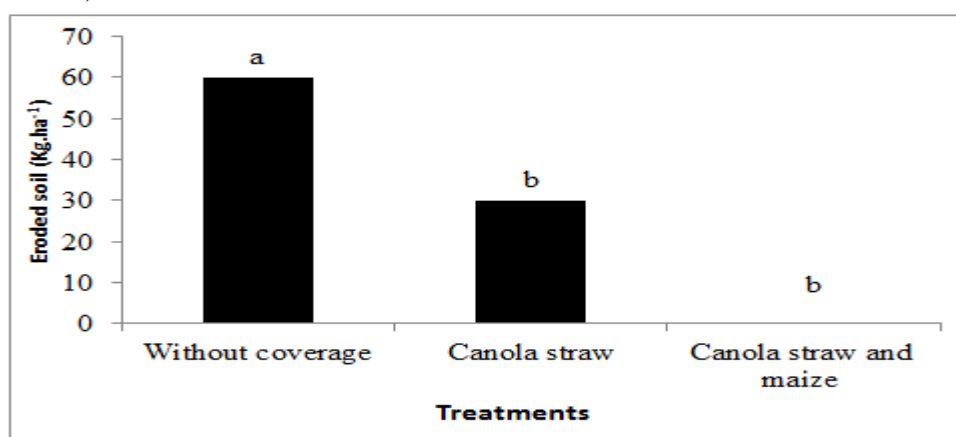
Treatment	Water drained superficially (mL)	Infiltrated water (mL)	Eroded soil (mg)
Without coverage	1405,0 *	2679,3 a	333,3 a
Canola straw	1525,0	2839,7 a	166,7 b
Canola straw and maize	1330,0	2326,3 b	0,0 b
CV (%)	33,25	5,85	89,33

\* Means accompanied by an asterisk in the column did not differ statistically according to the Scott Knott test, at 5% probability of error. Means with different letters in the column differ statistically from one another according to the Scott Knott test, at 5% probability of error.

Table 2 also shows the data regarding the amount of soil lost in each of the systems. In the treatment without cover, the greatest loss of soil was observed, with a mean of 333.3 mg of soil eroded by rainfall. In the treatment covered by canola straw, the soil loss was 166.7 mg of soil per rainfall, which did not differ from treatment covered by canola straw and maize crop, in which soil loss was zero. Due to the high coefficient of variation for the eroded soil parameter (89.3%), there was no difference between treatments of canola straw and canola straw + corn.

24 hours after the simulation of each rain, the bottom holes of each model of soil were uncovered to collect the water infiltrated in each culture system. It was possible to verify differences in the infiltration of water, and the treatment straw on the surface and cultivation of corn had less infiltration of water than the others. This is due to the consumption of water by the maize crop since this was the only treatment with a live plant. At the end of the study, which lasted for 75 days, the plants were at the stage of the tassel emission, having covered the entire vegetative period throughout the study, which caused considerable water consumption and interfered with the results of infiltrated water, being the canola straw treatment + Less infiltration of water. There were no differences in the infiltration of water between the canola straw treatments and the uncovered treatment.

Based on the results obtained in the soil models, soil loss per hectare was estimated in each of the cropping systems (Table 3).



**Figure 3** - Estimation of soil loss per hectare, in each of the treatments. Means with different letters differ

statistically from one another according to the Scott Knott test, at 5% probability of error.

Although there was no significant difference between treatments straw and straw + maize cultivation, due to the simple presence of 7 t.ha<sup>-1</sup> of canola straw, without the maize crop, the equivalent of approximately 30 kg.ha<sup>-1</sup> of soil would be lost, whereas in the presence of canola straw associated with maize cultivation, soil loss would be zero (Figure 3). Under uncovered soil conditions the losses would be equivalent to 60 kg of soil.ha<sup>-1</sup>, representing significant losses in the cropping system (Figure 3). Under field conditions, soil losses through erosive rains are much more dramatic than those observed in the present study. According to Amado et al. (2002), soil losses of up to 37 tons of soil.ha<sup>-1</sup> were verified under field conditions by erosive rainfall occurring in the year of occurrence of the El Niño climatic phenomenon.

These soil losses occurring in the field represent significant economic losses to farmers since part of their investments are taken out of the crop together with the colloidal particles of eroded soil. Sousa et al. (2012) observed a decrease in eroded nutrient concentrations when the percentage coverage by sugar cane straw was greater than 50% (0.7 kg straw). This reduction in coverage of 100% was quite significant (1.4 kg straw.m<sup>2</sup>).

Soil losses can also induce manhole clogging, road degradation, fish mortality due to the accumulation of fertilizers and organic materials in water sources and contamination of food webs due to the transfer of waste from soil to water.

Thus, in the present study, it was possible to verify that the maintenance of straw on the surface, especially when associated with crops such as corn, is a practice of soil conservation. It preserves the structure of the cultivated soils, since it provides greater protection of the soil against the impact of the rain drop, reduces the velocity of the laminar flow of the water on the surface of the soil and thus induces greater preservation of the soil aggregates, drastically reducing its withdrawal by erosive processes. In addition to preserving the farmers' investments in farming, these conservation principles advocated by the no-tillage system are also of great environmental importance, since avoiding the loss of soil due to surface runoff also prevents the contamination of dams, streams, and rivers against contamination by nutrients and pesticides adsorbed to colloidal soil particles.

Due to the restrictions in greenhouse conditions, it is impossible to faithfully represent all the factors that induce erosive processes in field cultivation systems. An important restriction of the present study is the impossibility of representing the effect of the flood, which consists of the erosive force gain that the rainwater acquires under crops, especially under conditions of great slope and great distances covered by water without finding any obstacle. In this sense, the results obtained in the present study are underestimated due to the conditions that occur in the field, but they serve to demonstrate the erosive effects of rain to farmers, technicians, and students, especially with regard to soil losses. In this way, the soil models consist of important tools for the dissemination of the importance of the vegetation cover for the mitigation of soil erosion.

## CONCLUSIONS

With the use of the soil model, it was possible to demonstrate that the coverage with canola straw or canola straw associated with maize crop is efficient to mitigate the loss of soil compared to the uncovered soil.

With the use of the soil model, no differences were observed between the cultivation systems for surface water losses.

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