

Division - Soil Use and Management | Commission - Soil and Water Management and Conservation

# Long-term wheat-soybean successions affecting the cover and soil management factor in USLE, under subtropical climate

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**ABSTRACT:** Vegetation cover and soil management influence the magnitude of soil losses. In the Universal Soil Loss Equation (USLE), cover and management are represented by the C factor, as it is the easiest factor to manage to reduce loss of soil and water in agricultural areas. This study aimed to determine the C factor of a succession of wheat (*Triticum aestivum* L.) followed by soybean (*Glycine max*) under conventional tillage, reduced tillage, and no-tillage. For this, data of soil losses obtained in the field, under natural rainfall conditions, in a long-term experiment that lasted for 13 years were used. The cycle of both crops was divided into five stages with different time intervals between winter and summer, which resulted in ten periods per year constituting the succession. The C factor values varied widely among the treatments and the stages during the crop cycle, and they were influenced mainly by the rainfall distribution of the region, growth of the vegetation and soil disturbance level. By the end of the 13 years of experimentation, the C factor of the wheat-soybean succession under conventional tillage was 0.1576, 0.0407 under reduced tillage, and 0.0368 under no-tillage.

**Keywords:** C factor, erosion, soil losses, soil tillage, crop systems.

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## INTRODUCTION

The prevention of soil losses by water erosion is essential for the conservation and management of natural resources (Sadeghi et al., 2007). Soil erosion affects soil quality and the productivity of crops, reduces infiltration and soil water storage capability, increases losses of nutrients, organic matter, and harms soil biota with considerable impacts on the soil environment (Pimentel, 2006; Nyakatawa et al., 2007; Panagos et al., 2015).

A proper assessment of the main erosive factors in an area of interest provides the first step for choosing strategies to control soil erosion (Auerswald et al., 2014). Soil erosion models have been developed in the last few decades with the aim of enhancing the knowledge of these processes, their mitigation, and the level of resilience to them (Tanyas et al., 2015). The most widely used prediction model of water erosion is the Universal Soil Loss Equation – USLE (Wischmeier and Smith, 1978; Auerswald et al., 2014). The USLE is considered the most reliable tool for estimating water erosion and consists of the following factors: rainfall erosivity (R), soil erodibility (K), slope length (L), slope angle (S), cover and soil management (C), and erosion control practices (P) (Wischmeier and Smith, 1978; Preiti et al., 2017). The long-term, average annual of soil loss is calculated by the product of R, K, L, and S, and modified by P and C (Giordani and Zanchi, 1995; Bagarello and Ferro, 2006). Among these factors, the cover and management (represented by the C factor) are considered the most important ones, since technicians and farmers can use the equation to assess potential management options to reducing or keeping soil losses within tolerable limits.

The C factor represents the efficacy of the soil and crop management systems in preventing soil losses (Gabriels et al., 2003). According to Guo et al. (2015), in the USLE, this factor indicates the combined effect of crops, soil cover, and tillage system, as well as the corresponding alterations in annual rainfall erosivity. The soil cover and management in the USLE are usually determined based on experimental data obtained in the field (Özhan et al., 2005). This factor is defined by the ratio of the soil losses from a plot with a specific crop and its management, to the loss from a plot conventional tilled and remain fallow during the entire crop growing period. Two reasons that explain the importance of the C factor are: (1) it represents superficial conditions that are often easily managed to control erosion, and (2) its values vary from practically 0 to slightly above 1, showing the significance of the cropping and management effects on soil loss (Toy et al., 1999). The annual C factor is obtained by the weighted mean of the Soil Loss Ratio (SLR) to the rainfall erosivity during all growth periods (Fraction Erosivity Index –  $FEI_{30}$ ) of the crops (Guo et al., 2015). The C factor reflects the complex interactions from many possible combinations of crops under different tillage systems (De Maria and Lombardi Neto, 1997). The variables that influence the C factor, besides the R factor, are the stages during the crop cycle, covering of the soil by the canopy of the vegetation; covering of the soil by crop residues, management of crop residues, type of soil tillage, type of crop rotation, and the residual effect from the prior crop or land use (Wischmeier and Smith, 1978).

The field experiments performed to determine the values of the C factor for rotations and successions of specific crops are the best approach to estimate soil loss, but they require a considerable amount of time and relevant data are rarely available (Preiti et al., 2017). Recognizing a lack of long-term field data, we aim to offer with this study, a contribution to this subject by determining the C factor for one of the most common agricultural systems in South Brazil.

In Brazil, efforts in determining the C factor for different cropping and management systems include those of De Maria and Lombardi Neto (1997) for corn; Bertol et al. (2001) for wheat and soybean; Silva and Schulz (2001) for mulch of yard debris; Bertol et al. (2002) for oat and corn; Amaral (2006) for wheat and soybean; Prochnow et al. (2005) for coffee planted in five different spacings; Albuquerque et al. (2005) for native semiarid

vegetation; Martins et al. (2010) for eucalyptus production forest and native forest (Atlantic Forest); Eduardo (2012) for corn in contour line and slope line; and Santos et al. (2014) for 'Caatinga', thinned 'Caatinga', and grass (after deforestation and burning) in Brazilian semiarid region. Other researches around the world determined C factor in Italy (Novara et al., 2011; Preiti et al., 2017); Panagos et al. (2015) proposed a methodology for estimating the C factor in the European Union; Gabriels et al. (2003) determined for 40 crop rotation systems on arable farms in Belgium; Pham et al. (2018) quantified in Vietnam the C factor using Geographical Information System (GIS). Brazilian literature on the C factor is still scarce (Amaral, 2006; Silva, 2016; Cassol et al., 2018).

In the face of this absence of C factor data, it is necessary to obtain results for USLE use and to create a database that is useful for soil conservation planning and other studies involving modeling. The objective of this study was to determine the C factor (cover and management) for a wheat-soybean succession in conventional tillage, reduced tillage, and no-tillage, using soil loss data measured in a long-term experiment in South Brazil.

## MATERIALS AND METHODS

### Description of the study area

The experiment was conducted in the field under natural rainfall conditions, at the Experimental Station of the Federal University of Rio Grande do Sul, in the municipality of Eldorado do Sul (30° 05' South, 51° 39' West and 42 m a.s.l.) in Rio Grande do Sul State, Brazil. According to the Köppen classification system, the climate of this region is Cfa, humid subtropical, with a mean annual temperature of 18.8 °C, with the lowest temperature being reached in July and the highest in January. Precipitation is distributed evenly throughout the year, with four well defined seasons and mean annual rainfall of 1,455 mm (Bergamaschi et al., 2013). The surface layer (0.00–0.25 m) has sandy clay loam texture with 613 g kg<sup>-1</sup> of sand, 216 g kg<sup>-1</sup> of silt, and 171 g kg<sup>-1</sup> of clay, in addition to 1.51 % of organic matter. The soil of the experimental area was characterized as Ultisol (Soil Survey Staff, 2014), which corresponds to an *Argissolo Vermelho-Amarelo distrófico típico*, according to Brazilian Soil Classification System (Santos et al., 2013).

### Experimental plot

The data on soil losses were assessed over 13 years of field experimentation from winter 1976 to summer 1989. As this type of experiment requires a lot of area and laborious efforts in sampling and long-term plot maintenance, only one replicate was implanted in the field for each treatment. This study was conducted in four experimental plots, without replication using data from multiple years to obtain long-term average treatment effects. The plots were installed with dimensions of 22.0 × 3.5 m, comprising an area of 77 m<sup>2</sup> and were delimited by galvanized steel sheets (height 0.20 m) driven into the soil to a depth of 0.10 m. At the lower end of the plot, there were runoff collection systems consisting of gutters, PVC pipes, and two collection tanks connected through GEIB divisors for collection of the water volume.

### Sampling soil loss

After each erosive rainfall event or group of erosive rainfalls, the surface runoff was collected from the tanks. Sampling was conducted whenever possible after each erosive rainfall. However, on many occasions, sampling was carried out by accumulating soil loss caused by more than one erosive rainfall or non-erosive rainfall. The sediments inside the tanks were removed, sampled, and taken to the Erosion Laboratory for quantification.

## Determining the C factor

### Treatments assessed

1. Wheat-soybean succession in no-tillage (NT): the sowing of soybean (*Glycine max* (L.) Merrill) was performed immediately after the wheat was harvested, sown directly on the residues crop with rows oriented up and down slope. The wheat (*Triticum aestivum* L.) was shown in rows spaced at 0.17 m, with 60 seeds per linear meter (352 seeds m<sup>-2</sup>). The soybean was sown with spacing of 0.50 m and with 30 seeds per linear meter (60 seeds m<sup>-2</sup>).
2. Wheat-soybean succession in reduced tillage (RT): the tillage of the soil was performed with a chisel plow equipped with five shanks, 0.40 m interval between shanks down to 0.25 m depth, in the sowing of both wheat and soybean crops. The sowing, spacing, number of seeds per linear, and harvest were the same as those of the NT treatment, differing only in soil tillage. After the crops were harvested, the straw cover was kept on the plot, with the chiseling being performed in the up and down slope direction.
3. Wheat-soybean succession in conventional tillage (CT): with the incorporation of the stubble of the crops. The sowing of both wheat and soybean were performed immediately after the conventional tillage with a disc plow (mounted, with three-disc, 28 inches) operating at a depth of 0.20 m, oriented downhill, followed by two harrowing (a tandem implement with 20 discs, 18 inches) also oriented downhill.

In addition to these cropping treatments, there was another plot with conventional tillage - oriented downhill and kept bare, which represented the standard plot (SP) of the USLE (Wischmeier and Smith, 1978). In 1980/1981 and 1985/1986 all plots were amended with 4 ton ha<sup>-1</sup> of lime to increase soil pH. This application was made in the superficial layer, being incorporated in those treatments with soil disturbance.

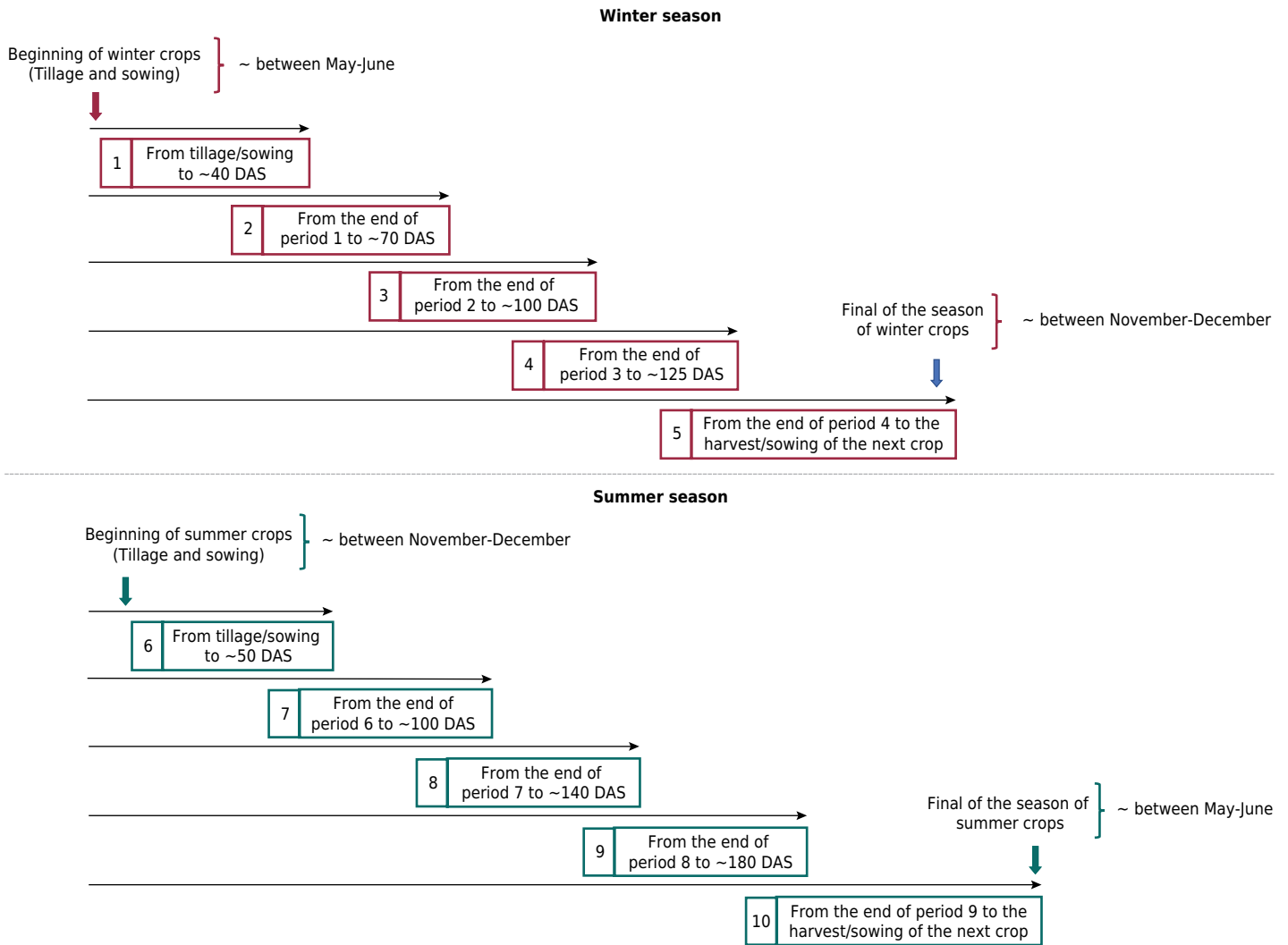
### Crop cycle periods

The cycle of winter crop (wheat) followed by summer crop (soybean) was divided into five periods (Figure 1). The first five periods of the crop year, corresponding to the winter crop cycle, were the following: period 1 - from preparing and sowing to approximately 40 days after sowing (DAS); period 2 - from the end of period 1 to ~70 DAS; period 3 - from the end of period 2 to ~100 DAS; period 4 - from the end of period 3 to ~125 DAS; period 5 - from the end of period 4 to the harvest/sowing of the next crop. The summer crop periods were the following: period 6 - from soil preparation and summer crop sowing to ~50 DAS; period 7 - from the end of period 6 to ~100 DAS; period 8 - from the end of period 7 to ~140 DAS; period 9 - from the end of period 8 ~180 DAS; period 10 - from the end of period 9 to the harvest/sowing of the next crop.

The Soil Loss Ratio (SLR) was calculated as the ratio of soil loss under a certain cover and management, to the soil losses of the standard plot of the USLE. The Fraction Erosivity Index (FEI<sub>30</sub>) is expressed in decimal, therefore, varies from zero to one, meaning the percentage of the erosivity index that caused erosion used in the calculation of the respective SLR. To determine the FEI<sub>30</sub>, analyses were performed regarding the erosivity indexes of each of the crop cycle periods. These fractions were obtained by the ratio of the erosivity of the rainfall events during each growth period to the annual rainfall erosivity. As in the FEI<sub>30</sub>, the SLR was determined for each crop cycle period, calculating the C factor according to equation 1.

$$\text{Annual C factor} = \sum^{i=10} \text{SLR} \times \text{FEI}_{30} \quad \text{Eq. 1}$$

in which *i* stands for crop period, amounting to 10 annual periods. After obtaining each annual C factor, the mean of the 13 crop years of assessment was considered for the value of the C factor - USLE.



**Figure 1.** Timeline of the crop periods over the experiment. Periods between 1 and 5 corresponding to winter crops; periods between 6 and 10 corresponding to summer crops. Note that the initial and final periods was not exactly the same over the 13 years of experimentation, but it was in a narrow variation of months. DAS: days after sowing.

## RESULTS

Annual soil losses from different tillage systems for wheat-soybean succession are shown in table 1. Soil losses varied widely during the 13 years and among different tillage treatments. For the CT treatment, soil losses varied between 0.1 and 121.2 Mg ha<sup>-1</sup> (1988/1989 and 1984/1985); for RT, 0.1 and 28.9 Mg ha<sup>-1</sup> (1988/1989 and 1980/1981); and for NT, 0.1 and 33.9 Mg ha<sup>-1</sup> (1988/1989 and 1980/1981). These large variations are mainly due to the differences in rainfall, with the year of 1988/1989 having the least erosivity (Table 1).

Analyzing data in table 1, it can be observed that in years 1980/1981 and 1985/1986 there was a great soil loss in NT. This was probably because the liming applied every five years was mechanically incorporated. The NT plot having a greater amount of organic material, it may have conditions more susceptible to soil loss, showing a loss of 33.9 Mg ha<sup>-1</sup> in the year 1980/1981, slightly higher than soil loss from the RT plot (i.e., 28.9 Mg ha<sup>-1</sup>). In 1985/1986 occurred the same behavior with this treatment, with high soil losses in regarding to other years.

With the separation of the annual crop growth cycle into 10 periods, we were able to examine how different crop growth stages affect soil erosion (Table 2). In all the treatments

studied, period 1 of the winter crops and period 6 of the summer crops demonstrated the most soil losses (Table 2).

In figure 2, the results of the SLR and  $FEI_{30}$  for the ten periods are presented. The SLR followed the same behavior of the soil loss, with greater values in initial periods and diminishing over time with the growth of crops. It is notable that the summer periods (6 to 10) are the most critical regarding SLR and  $FEI_{30}$ , with higher values of these variables. Given this, they need greater care with respect to soil losses due to the concomitance and the resulting clash of the seasons of tillage and seeding of the crops in the region, during which the soil is more exposed to erosive processes. The

**Table 1.** Soil losses in treatments evaluated in 13 years of carrying out the experiment, from 1976/1977 to 1988/1989 in Eldorado do Sul, Rio Grande do Sul, Brazil

Crop year	Annual Erosivity	SP	CT	RT	NT
	MJ mm ha <sup>-1</sup> h <sup>-1</sup>	Mg ha <sup>-1</sup>			
1976/1977	10,123.9	288.9	5.9	2.8	4.9
1977/1978	3,730.0	81.4	29.9	3.7	0.4
1978/1979	3,717.1	215.5	3.6	0.6	0.2
1979/1980	9,788.8	377.9	87.4	24.0	23.8
1980/1981	4,551.3	301.4	38.7	28.9	33.9
1981/1982	4,050.4	183.4	10.0	2.8	1.6
1982/1983	6,355.9	445.5	20.5	9.6	5.8
1983/1984	7,082.8	521.8	62.0	5.0	1.8
1984/1985	4,802.0	502.3	121.2	15.1	0.8
1985/1986	3,380.9	189.9	31.2	17.1	16.2
1986/1987	6,834.0	283.6	7.8	2.3	0.2
1987/1988	5,339.8	293.2	8.3	0.6	0.1
1988/1989	3,138.5	50.5	0.1	0.1	0.1
Mean	5,607.3	287.3	32.8	8.7	6.9

SP: standard plot of USLE; CT: wheat-soybean succession in conventional tillage; RT: wheat-soybean succession in reduced tillage; NT: wheat-soybean succession in no-tillage.

**Table 2.** Mean of the periods for erosivity ( $EI_{30}$ ) and soil losses in the different soil management systems during 13-years of assessment. Sub total correspond the accumulated of the winter crops and summer crops

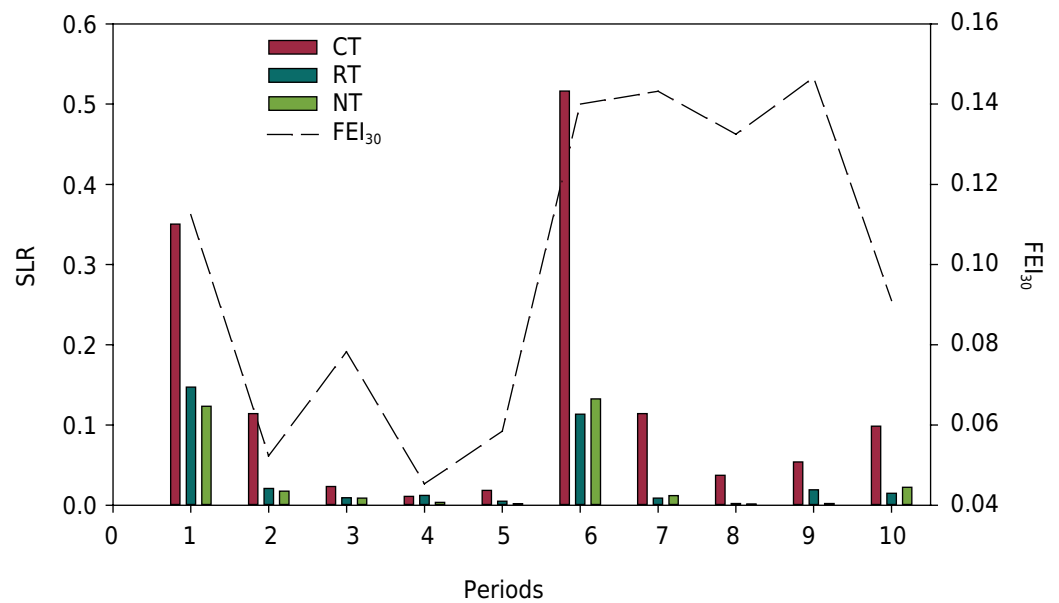
Period	$EI_{30}$	SP	CT	RT	NT
	MJ mm ha <sup>-1</sup> h <sup>-1</sup>	Mg ha <sup>-1</sup>			
1	550.6	33.0	10.7	4.6	4.1
2	308.5	28.2	2.8	0.6	0.7
3	448.9	35.6	1.0	0.2	0.1
4	234.5	14.5	0.1	0.0	0.0
5	299.0	13.3	0.1	0.0	0.0
Sub-total winter	1,841.5	124.6	14.7	5.4	5.0
6	829.2	20.1	6.8	1.5	1.0
7	854.0	38.6	2.7	0.3	0.5
8	822.7	34.5	0.3	0.1	0.1
9	749.1	40.1	6.7	1.2	0.1
10	510.9	29.5	1.6	0.3	0.2
Sub-total summer	3,765.8	162.7	18.2	3.2	1.9
Total annual	5,607.3	287.3	32.8	8.7	6.9

SP: standard plot of USLE; CT: wheat-soybean succession in conventional tillage; RT: wheat-soybean succession in reduced tillage; NT: wheat-soybean succession in no-tillage.

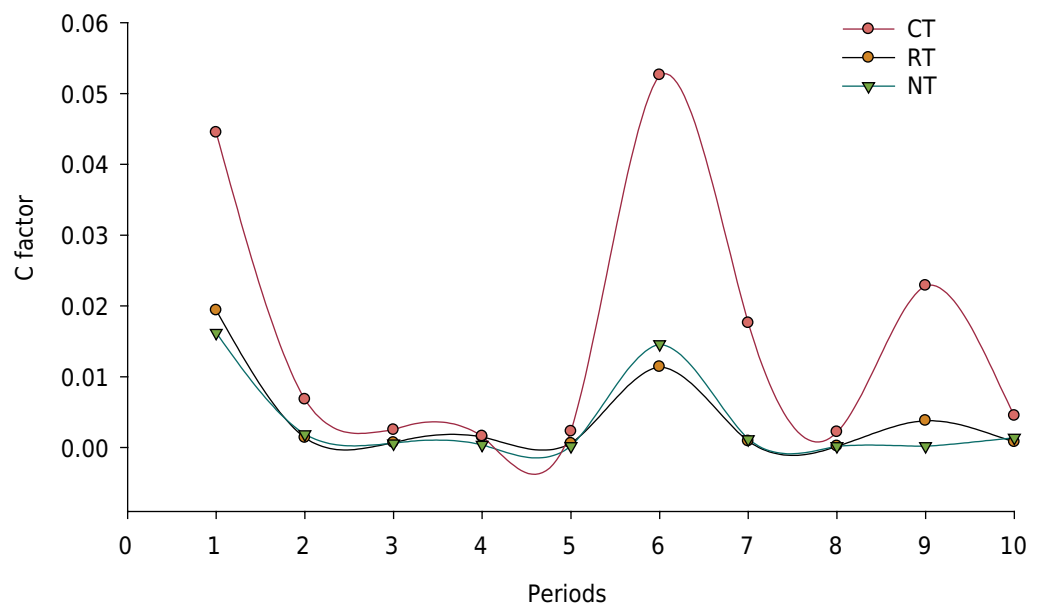
FEI<sub>30</sub> peaks shown in figure 2 for the winter periods (1 to 5), although shorter-lasting than summer periods, have a greater potential of causing erosion because of the high volume of surface runoff.

### Cover and management (C factor - USLE)

The C factor values for crop succession are shown separately, according to the periods (Figure 3) and to the crop year (Table 3). Figure 3 shows the values of the average C factor of each period during the succession of wheat-soybean crops in CT, RT, and NT, measured for 13 years of field experimentation. The C values followed the same tendency as the soil losses and SLR in every treatment, presenting higher values in the beginning, in periods 1 and 6, and a decrease of these values as the crops grew.



**Figure 2.** Soil Loss Ratio (SLR) and Fraction Erosivity Index (FEI<sub>30</sub>) in the different periods and management systems for wheat-soybean succession.



**Figure 3.** Average of 13 years of C factor of the different wheat-soybean management systems over the 10 periods.

**Table 3.** Annual mean C factor during the 13-year evaluation of the experiment

Crop year	CT	RT	NT
1976/77	0.1047	0.0532	0.0467
1977/78	0.5234	0.0807	0.0924
1978/79	0.0154	0.0022	0.0008
1979/80	0.2624	0.0724	0.0672
1980/81	0.1709	0.1033	0.1188
1981/82	0.1236	0.0267	0.0208
1982/83	0.0498	0.0298	0.0311
1983/84	0.1337	0.0070	0.0066
1984/85	0.4276	0.0494	0.0025
1985/86	0.1498	0.0734	0.0762
1986/87	0.0655	0.0199	0.0009
1987/88	0.0204	0.0025	0.0019
1988/89	0.0011	0.0089	0.0126
Mean	0.1576	0.0407	0.0368

CT: wheat-soybean succession in conventional tillage; RT: wheat-soybean succession in reduced tillage; NT: wheat-soybean succession in no-tillage.

## DISCUSSION

### Soil losses and erosivity

Mean soil losses in the wheat-soybean tillage, measured during the 13 years of the experiment represented the efficiency of the conservation systems in controlling water erosion, reducing soil losses 3.8 times for RT and 4.7 times for NT in relation to CT. This demonstrates how important it is to maintain crop residues on the soil during the entire year and to reduce the use of implements that cause excessive soil disturbance. Direct contact of the crop residue with the soil surface dissipates the kinetic energy of rainfall, and it reduces the flow energy of surface runoff by an increasing hydraulic roughness and infiltration, resulting in a reduced runoff (Cogo, 1981; Lopes et al., 1987; Bertol, 1995).

Comparing the losses of the SP (Standard Plot) treatment to those of the CT, there is a reduction of 88 % just due to the protection given by the vegetation cover, which prevents the direct impact of rainfall on the soil, since the tillage method for both of these two treatments was the same. Combination of crop rotation and reduced or no tillage that leave residues on the soil can reduce mean soil losses from 33 to 41 times, for wheat-soybean successions in RT and in NT, respectively, in comparison to the SP - USLE. This shows the importance of keeping the soil covered in this region, as losses of this magnitude can be prevented simply by the presence of vegetation.

The tolerable limit of soil losses for the *Argissolos* is around  $9.0 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ , based on the estimated formation of 0.71 mm of soil annually (Bertol and Almeida, 2000). Regarding this soil, considering its depth and relation to texture, it is notable that conservation systems (wheat-soybean NT =  $6.9 \text{ Mg ha}^{-1}$  and wheat-soybean RT =  $8.7 \text{ Mg ha}^{-1}$ ) showed losses below this limit (Table 1). On the other hand, the wheat-soybean CT ( $32.8 \text{ Mg ha}^{-1}$ ) showed soil losses almost four times above the tolerable limit for this type of soil. According to the criteria defined for the application of the USLE, the levels of soil loss by erosion should not influence the productivity of crops, when simple production technology is used. In this case, one can apply the USLE with the manipulation of the C and P factors, determining alternatives of use and managing, and alternating agricultural practices to reduce soil losses in other treatments.



The first period of winter, despite its lower erosivity, had more soil losses when compared to the first period of summer. This is probably because in winter the predominant type of rain in the region is frontal rainfall (Moreno, 1961), which lasts longer (Forgiarini et al., 2014). In addition to this, the lower temperature in winter results in low evaporation loss. The amount of evapotranspiration in the region is 16 mm in June (referring to the first winter period) and 88 mm in November (referring to the first summer period) (Mota and Goedert, 1966). These factors contribute to the maintenance of soil moisture for several days, increasing susceptibility to erosion at each new rainfall event.

As the crop period advanced, the soil loss declined. This is because of the soil cover provided by the plant canopy, even with the greater erosivity that occurs in these periods (Table 2). Period 9 of the summer crop had high soil loss, in the CT and RT treatments. This occurred due to the high erosivity in this same period, of 1,203.6, 1,798.8, and 1,995.0 MJ mm ha<sup>-1</sup> h<sup>-1</sup> in 1982/1983, 1983/1984 and 1984/1985, respectively. It is also possible that the canopy cover was reduced due to leaves lost during plant senescence. On the other hand, periods 3, 4, and 5 showed less soil loss due to the crops being already well grown, concomitant with the presence of less erosivity in these periods. The behavior of soil loss in the SP influenced the behavior SLRs, subsequently affected directly the C factor, which is in agreement with the findings of Amaral (2006).

### Cover and management (C factor - USLE)

The C factor values are expected to diminish as crops grow, increasing cover and improving the soil structure (Bertol et al., 2002). This happens in relation to conventional soil tillage methods, in which initial cover is scarce. In succession systems that keep a high level of residues and low soil disturbance, low C factors can occur from the very beginning of the cycle.

Regarding the succession of wheat-soybean crops under CT, the average value for the C factor was 0.1576, having oscillated between 0.0011 (in the crop year of 1988/1989) and 0.5234 (in the crop year of 1977/1978). For the wheat-soybean succession under RT, the C factor value was 0.0407, with a range between 0.0022 (in 1978/1979) and 0.1033 (in 1980/1981) (Table 3). For the wheat-soybean succession under NT, the C factor value was 0.0368, with an oscillation between 0.0008 (in 1978/1979) and 0.1188 (in 1980/1981). This high variability among the crop years is due to the natural variation in soil losses, which in turn is due to the variation in quantity and distribution of rainfall erosivity. These results demonstrate efficiency of, respectively, 84, 95, and 96 % in comparison to the standard plot.

The results followed the same tendency as the soil losses, with higher C factor values for CT, followed by RT and NT. Considering the behavior of the distribution of local rainfall erosivity, especially during the cultivation of summer crops, and the distribution of the C factor throughout the stages (Figure 2), Amaral (2006) reports that there is a necessity for keeping the soil protected with crop residues, to control soil losses and, thus, reduce the value of the C factor, therefore reducing soil losses and possible environmental damages, outside the location where the water erosion was originated. To estimate soil losses with the Universal Soil Loss Equation, such as systems of vegetation management and cover that are similar those assessed in this study, average C factor values are used.

Some authors worked on determining the C factor for wheat-soybean management systems. Amaral (2006) determined C factor for a field experiment under natural rainfall (from November 2002 to October 2005, in Lages, Santa Catarina), with respect to wheat-soybean successions under conventional tillage, reduced tillage, and no-tillage. The author found values of 0.198, 0.099, and 0.042, respectively. These results are 20, 59, and 12 % higher than those found in this study. Except for reduced tillage, our results were somewhat close to those found by Amaral (2006). Also, in a field experiment under

natural rainfall, Bertol et al. (2001) found C factor values (from summer 1992/1993 to winter 1998, in Lages) for the same succession of crops and soil tillage, which were of 0.3595, 0.2661, and 0.1043. The difference in C factor in these results may be attributed to the location of the experiments, where rainfall distribution had the main impact on them. Another possible cause could be the method employed, where the authors summed the C factor of wheat and C factor of soybean, based on the erosivity of the crop cycle. In this study, it was related to annual erosivity.

According to Bertol et al. (2001), in both treatments with crops and in those without crops (standard plot), erosion depends heavily on previous soil moisture, in addition to soil surface conditions (cover with weed and crop residues and superficial roughness) during rainfall. All these values of soil loss in treatments with crops and in the standard plot influence directly the values of the C factor.

Brazilian literature about the C factor is still scarce (Amaral, 2006; Cassol et al., 2018). Nonetheless, there is still a great need for obtaining data that may supply a model for a conservational planning and for other studies involving modeling in the subject of erosion and conservation. This study found that the treatments with less disturbance presented smaller soil losses and, consequently, smaller mean values of the C factor. The difficulty of obtaining the C factor is in determining the SLR for countless possible combinations of crops, rotations and other management practices where soil losses must be measured (Hudson, 1973). In recent years, Geographical Information System (GIS) and Remote Sensing (RS) have become useful tools for natural resources management and disaster research. This research requires much spatial data, which GIS is capable of handling easily and efficiently (Pham et al., 2018).

## CONCLUSIONS

The higher values of SLR and  $FEI_{30}$  are found in the initial growth periods of the winter and summer crops, under the conditions of the region of Eldorado do Sul, Rio Grande do Sul, Brazil.



The C factor for the wheat-soybean succession in conventional tillage is 0.1576, in reduced tillage 0.0407, and in no-tillage 0.0368. These are the values to be used in the Universal Soil Loss Equation (USLE).




Conservation agriculture, such as reduced tillage and no-tillage are soil management capable of reducing soil losses by water erosion below the tolerable limit for this type of soil.



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## AUTHOR CONTRIBUTIONS



**Conceptualization:**  Tiago Stumpf da Silva (equal) and  Elemar Antonino Cassol (equal).




**Methodology:**  Elemar Antonino Cassol (equal),  Renato Levien (equal), and  Flávio Luiz Foletto Eltz (equal).



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