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Chemical Recovery of Degraded Soil and Consequence in the Cost of Corn Production

Neuro Hilton Wolschick^{1*}

[https:// orcid.org/0000-0001-9680-692X](https://orcid.org/0000-0001-9680-692X)

Ildegardis Bertol¹

<https://orcid.org/0000-0003-4396-5382>

Bárbara Bagio¹

[https:// orcid.org/0000-0002-2454-8471](https://orcid.org/0000-0002-2454-8471)

Filipe Antonio Wroblewski¹

<https://orcid.org/0000-0001-9064-4835>

Loriane Bernardi¹

<https://orcid.org/0000-0002-8620-8253>

¹State University of Santa Catarina - CAV Agroveterinary Sciences Center - UDESC, Lages, Santa Catarina, Brazil.

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*Correspondence: neurohw@gmail.com; Tel.: +55-49-99903-2859

HIGHLIGHTS

- Soil response to acidity correction and chemical fertilization.
- Economic viability in the recovery of areas degraded by water erosion.
- Managed in a non-conservationist way, converted to conservationist.
- Maintenance of soil cover with plant use in the autumn/winter period.

Abstract: Improper management degrades the soil, decreases corn productivity and is reflected in the cost of production. The objective of this research was to evaluate the soil recovery in non-conservationist treatments after the change of management and cultivation to the conservation condition direct sowing, and compare these systems to consolidated direct seeding; This evaluation was based on the soil responsiveness to crop production and water erosion control, and based on the financial cost of soil recovery and corn production when soil management was converted from non-conservationist (tillage rotation - RT, minimum tillage - MT, conventional tillage – CT and bare soil - BS) to no-tillage (NT) condition, in a Humic Cambisol. The transition from managements to no-tillage occurred in 2015 year, after 27 years of conducting the preexisting managements. The chemical recovery was carried out with the application of limestone, phosphorus, and potassium. At the end of the research the yield of the corn crop, the cost of recovering the soil fertility and the cost of crop production were evaluated. Previous soil management influenced the cost of

soil chemical recovery. The cost of production showed a financial loss for the previous treatments CT and BS, on the average of the three corn crops.

Keywords: consortium; management; water erosion.

INTRODUCTION

Corn is the most expressive cereal grown in Brazil, with a production of 97 million tons in the 2016/17 crop, the highest in recent years, representing a 52% increase in relation to the previous harvest, which was strongly affected by the climate resulting from the phenomenon El Niño. In the state of Santa Catarina, production was 3.1 million tons in the referred harvest, with some regions reaching the productivity of 10-ton ha⁻¹, while the state average was 8.5-ton ha⁻¹ [1].

Water erosion is the main form of degradation of cultivated land, whereby the surface layer, the most fertile one, is the first to be eroded. Thus, water, sediments, and nutrients are transported away from the site of erosion origin. According to the Food and Agriculture Organization of the United Nations report [2], 33% of the world's agricultural lands have some degree of degradation, mainly due to water erosion.

No-tillage (NT) without previous tillage, when properly conducted, can improve soil conditions compared to the management in which plowing and harrowing are carried out, known as conventional tillage (CT). However, the absence of previous mechanical tillage in NT can result in compaction of the soil, with low infiltration of water and a high impediment to root growth. This occurs when NT management is improperly conducted, especially in clayey and low organic matter soils [3]. Changes in soil physical, chemical and biological properties, resulting from crops grown over long periods of time, are common in non-conservationist managements (CT) and may affect crop yield and production costs. Most of the studies that evaluated crop yields as a function of soil management were conducted for a short period of time and are recent, generally conducted in less than two decades [3-4]. In some cases, the results of these studies diverge among themselves on the effect of soil management on crop productivity, and these effects are dependent on many variables. Soil chemical attributes and yield of corn grains are influenced by soil management [5].

The evolution of the yield of grains grown in the form of NT over time already shows a trend stabilization phase [6]. Like this, after NT implantation productivity stabilization tends to happen, becoming similar to other soil management systems. The authors also verified that the execution of a soil chiseling operation periodically after implementation of NT without soil tillage, provides an increase in soybean yield in relation to the CT. However, stabilization of erosion at a low level due to conservationist practices (soil cover with residue and a consortium of vegetable species and terracing) in NT system was effective in recovering soil fertility and crop yield [7]. This shows that NT when properly implanted and correctly managed may result in conditions that favor the reduction of water erosion, although without eliminating it, and the recovery of soil productive capacity.

The objective of this research was to evaluate the soil recovery in non-conservationist treatments after the change of management and cultivation to the conservation condition direct sowing, and compare these systems to consolidated direct seeding; This evaluation was based on the soil responsiveness to crop production and water erosion control, and based on the financial cost of soil recovery and corn production when soil management was converted from non-conservationist to NT condition.

MATERIAL AND METHODS

The experiment has been conducted since 1988, in a natural rainfall condition, at the Campus of the Agroveterinary Sciences Center of Lages (SC), University of the State of Santa Catarina (CAV/UDESC) located between 27 ° 49 'S and 50 ° 20 'W, at 923 m altitude, in the region of the Plateau of Southern Santa Catarina. The climate is of the type Cfb (subtropical, humid, without dry season, with cool summers and frequent frost in the winter) according to the classification of Köppen, with an average annual temperature of 15.7° C, average annual precipitation of 1,533 mm and annual average erosivity of 5,033 MJ mm ha⁻¹ h⁻¹ [8]. The experimental area presents a mean slope of 0.102 mm⁻¹, in a Cambissolo Húmico aluminico léptico [9], which correspond to an Inceptisol according tthe Soil Survey Staff [10], with a substrate composed of siltstones and argillites, with erodibility of 0.0175 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹ [11].

The soil was initially covered by native grasses and in October 1988 the study on water erosion began. At the experiment implantation, the soil was corrected to raise the pH to 6.0 with 12 Mg ha⁻¹ of dolomitic

limestone, incorporated with two plows and two harrowing at 20 and 15 cm of layer, respectively, executed transversely to the slope. Immediately afterward, the experimental units were installed [12].

According to Schick [12], the study of water erosion was initiated in the experiment in 11/1988, with a fallow period between 11/1991 and 10/1992, in which no evaluations were carried out. After this period the experiment was reinstalled with a new tillage and application of limestone to raise the soil pH to 6.0 with the application of 3.5 Mg ha⁻¹ of dolomitic limestone, which was incorporated by the tillage with one plowing and two harrowing.

In March 2012, new liming was carried out in all treatments, which contained crops. The limestone doses were calculated according to the soil analysis of the 0 - 10 cm layer, to raise the pH in water to 6.0, being incorporated according to the management of each treatment; in the no-tillage system a semi-incorporation was carried out with a light harrowing [12].

Soil tillage treatments, up to April 2015, consisted of following management performed twice a year, as follows. I: treatments with crop: i) no-tillage without till - NT; ii) rotation of till in each crop (one plowing + two harrowing, one chiseling + one harrowing, and no-tillage no till); iii) - RT; one chiseling + one harrowing - MT; iv) one plowing + two harrowing - CT; and II: treatment without cultivation: v) one plow + two harrowing, where the soil remained uncultivated and uncovered - BS. Throughout the years, the plant species of corn, beans, and soybean were cultivated in the spring/summer period, and those of black oats, common vetch, and winter turnip forage in autumn/winter, in i; ii; iii; and iv treatments.

For change soil management, in 2015 year, the soil acidity correction was done by application of dolomitic limestone (PRNT 80%) to raise the pH to 6.0 and fertilization was carried out to correct the P levels with the use of triple superphosphate (41% P₂O₅) and K with potassium chloride (58% K₂O), the quantities applied in accordance with the recommendations of CQFS RS/SC [13], in treatments all. Lime and fertilizers were incorporated into the soil by doing the standard preparation of each treatment prior to the transition from management to no-tillage (Table 1).

The experiment was carried out in experimental units, or plots, of 3.5 x 22.1 m (77.35 m²), delimited by galvanized sheets on the sides and upper end and by a runoff-collector gutter, with two replications.

Table 1. Dolomitic limestone, triple superphosphate (SFT) and potassium chloride (KCl) applied in each plot to correct the acidity and soil P and K content, making them the same in all the experimental plots.

| Plot | Limestone | SFT (P ₂ O ₅) | KCL (K ₂ O) |
|----------|---------------------|--------------------------------------|------------------------|
| | Mg ha ⁻¹ | Kg ha ⁻¹ | |
| 1 (NT1) | 5.4 | 30 | 30 |
| 2 (NT2) | 1.6 | 60 | 30 |
| 3 (NT3) | 2.0 | 60 | 30 |
| 4 (NT5) | 8.4 | 150 | 60 |
| 5 (NT4) | 4.2 | 90 | 30 |
| 6 (NT2) | 2.0 | 30 | 30 |
| 7 (NT5) | 8.4 | 150 | 30 |
| 8 (NT1) | 5.4 | 30 | 30 |
| 9 (NT4) | 5.4 | 90 | 30 |
| 10 (NT3) | 1.6 | 60 | 30 |

During the autumn/winter of each year, the treatments were cultivated with a consortium of species destined to cover the soil. For this, black oats (*Avena strigosa*), forage turnip (*Raphanus sativus*) and common vetch (*Vicia sativa*) were used, at the seed densities of 30, 10 and 40 kg ha⁻¹, respectively, spread by manual broadcast. In the spring/summer crops, corn (*Zea mays*) was used, sown at the density of 60,000 ha⁻¹ seeds, with the aid of a manual seeder with a space between lines of 87.5 cm. In the harvest of 2015/16 sown on the hybrid Dekalb 390, sown on November 28, 2015, was used. In the 2016/17 crop, the hybrid AS 1666 PRO 3 UYH 00542 MAXIM, sown on November 11, 2016, was used, while the hybrid AG 9025 PRO, sown on November 7, 2017, was used in the 2017/18.

The fertilization was carried out according to the need of the crops, with the application of P as triple superphosphate (41% P₂O₅), at the dose of 350 kg ha⁻¹ and for K as potassium chloride (58% K₂O), at the

dose of 180 kg ha⁻¹ [13]. For corn, fertilization with N in the form of Urea (46% N) was carried out in two stages, the first one at the time of sowing and the second in the phase of four expanded leaves (V4) at doses of 35 and 195 kg ha⁻¹, respectively. Control of invasive plants was performed manually or chemically, depending on the degree of infestation.

At the end of each crop, when the cover crops reached full bloom, the aerial part of the plants was collected to quantify the production of dry mass.

In the corn crop the population were evaluated counted the plants at 10 meters in the two central rows. The biomass production and grain yield were evaluated, 10 plants were collected in the two central rows in each plot, with 10 meters being discarded at the end of those lines. Thus, dry mass, as well as grain yield, were determined. The ears and the straw samples were oven-dried at 60 °C until constant weight.

To calculate the costs of producing crops and recovering degraded soil chemically, a cost worksheet was created to record the values spent on acidity correction and soil fertility (Table 2).

Table 2. Spreadsheet of the cost of soil chemical recovery in the NT5 treatment example, in which the soil was kept in the uncropped and uncovered condition, prepared with one plowing + two harrowings twice a year, being the surface permanently kept free of vegetation, before the transition to NT.

| COMPONENT | Specification | Uni. | Quantity | Unit. value. (R\$) | Total value (R\$) |
|-------------------|--|------|----------|--------------------|-------------------|
| Limestone | 1 application | t | 8.4 | 131.09 | 1101.15 |
| Base fertilizer | SFT (41% P ₂ O ₅) | t | 0.15 | 1430.00 | 214.50 |
| Base fertilizer | KCL (58% K ₂ O) | t | 0.06 | 1464.50 | 87.87 |
| Limestone aplic. | Tractor+Limestone dist. | H | 0.6 | 102.54 | 61.52 |
| Fertilizer aplic. | Tractor+Fertilizer dist. | H | 0.3 | 94.40 | 28.32 |
| Harrowing | Tractor+disking | H | 1.2 | 63.43 | 79.53 |
| Subsoiling | Tractor+subsoiler | H | | 100.37 | 0.00 |
| Plowing | Tractor+Plow | H | 1 | 101.11 | 101.11 |
| TOTAL | | | | | 1674.00 |

Thus, for this treatment the cost of recovering the soil in one plot was calculated, that is, one of the repetitions of the treatment NT5. The same worksheet was used for the other treatments. Subsequently, the monetary value of this cost was reached and, as a consequence, was estimated, by temporal projection, the period of time necessary to obtain a financial return on the investment made with the recovery of the soil in this area. The same calculation procedure was carried out for the other plots of the experiment, according to the Center for Socioeconomic and Agricultural Planning. As for the production costs of the corn crop, we used the component spreadsheet, presented in Table 3. The price base of the inputs practiced in each crop was based on the price tables of agricultural commodities and the National Supply Company.

After verification of theoretical assumption, the data were submitted to the Shapiro-Wilk test. In cases where normality was found, the analysis of variance was done, followed by a comparison of the means by the Tukey test when necessary. In all the tests the minimum level of significance of 5% was adopted and the ASSISTAT program was used. In the cost data, a descriptive analysis was carried out.

Table 3. Spreadsheet of components of the cost of corn production for a plot of NT5 treatment of the 2015/16 crop, for the Cambissolo Húmico in Lages, SC.

| COMPONENT | Specification | Uni. | Quant. | Unit. value. (R\$) | Total value (R\$) |
|-----------------------|--|---------------------|----------|--------------------|-------------------|
| INPUT | | | | | 3330.90 |
| Winter seeds | aveia/nabo/ervi. | kg | 30 10 40 | 5; 12; 13. | 790.00 |
| Corn seeds | DEKALB 390 | sc | 1.16 | 900.00 | 1044.00 |
| Base fertilizer | SFT (41% P ₂ O ₅) | t | 0.35 | 1430.00 | 500.50 |
| Base fertilizer | KCL 58% (K ₂ O) | t | 0.18 | 1464.50 | 263.61 |
| Base fertilizer | UREA (46% N) | t | 0.03 | 1526.25 | 45.79 |
| Herb.dessec. | Roundup | L | 1.5 | 25.50 | 38.25 |
| Herb.Post emer. | Roundup | L | 1.5 | 25.50 | 38.25 |
| Cover fertilizer | Urea (46% N) | t | 0.2 | 1526.25 | 305.25 |
| SERVICE | | | | | 684.77 |
| Winter sowing | Tractor+seed dist. | H | 0.6 | 79.49 | 47.69 |
| Aplication/des. | Tractor+sprayer | H | 0.6 | 87.64 | 52.58 |
| Planti./fertilization | Tractor+planter | H | 1 | 124.52 | 124.52 |
| Herbicide aplic. | Tractor+sprayer | H | 0.6 | 87.64 | 52.58 |
| Cover fertilization. | Tractor+urea dist. | H | 0.6 | 79.49 | 47.69 |
| Mechan. harvest. | Medium harvester | h | 1 | 359.69 | 359.69 |
| REVENUE | | | | | 447.17 |
| Corn crop | Produtivity | Sc ha ⁻¹ | 125.6 | 43.37 | 5447.27 |
| PROFIT | | | | | 2116.37 |

RESULTS

The corn population did not differ between treatments in the three cultivations, reaching an average of 67126, 72241, and 68046 plants per hectare in the crops of 2015/16, 2016/17 and 2017/18 years, respectively (Table 4).

In the 2015/16 crop years, the NT5 presented lower weight of one thousand grains (P1000) when compared to the other treatments, whereas in the 2016/17 crop years, there was no statistical difference between the treatments (Table 4).

Corn grain production in the 2015/16 crop years was 28% higher in the NT1 and NT2 treatments than in the NT4 and NT5 treatments, in the average of the treatments (Table 4). In the following crops, however, there was no difference between treatments.

In the three years of evaluation, the NT5 treatment presented lower productivity than the average produced in the State of Santa Catarina, which was 8.5tha⁻¹ in the 2016/17 crop [1]. On average, this treatment produced 6.8tha⁻¹, showing the low response of the soil to acidity correction and chemical fertilization.

The implantation cost of the corn crop (Table 5) was R\$ 4015; 4100 and 3752 for the 2015/16, 2016/17 and 2017/18 crops years, respectively. The direct cost of production for the 2017/18 crop years was R\$ 4632, according to the survey done by the Socioeconomics and Agricultural Planning Center of Epagri [14]. This occurred because this agency included overhead costs such as technical assistance, production insurance, and trading expenses, which was not done in this study. The small difference in the value of the cost of the crops was due to the price of the inputs practiced in each crop, based on price lists of the agricultural commodities and of the Companhia Nacional de Abastecimento – CONAB [15].

Table 4. Population of plants, the weight of a thousand grains (P1000), grain mass and dry mass of the whole plant of corn, and dry mass of invasive plants in the treatments for the crops in the Cambissolo Húmico in Lages SC.

| Treatment | Population Plant ha ⁻¹ | P1000 G | Grain -----kg ha ⁻¹ ----- | Straw |
|------------------------|--------------------------------------|------------|---|----------|
| -----Crop 2015/16----- | | | | |
| NT1 | 68391 a | 321 a | 11649 a | 18397 a |
| NT2 | 67241 a | 325 a | 11236 a | 17316 ab |
| NT3 | 67529 a | 314 a | 10377 ab | 14737 ab |
| NT4 | 66092 a | 302 a | 8769 bc | 13990 ab |
| NT5 | 66379 a | 262 b | 7608 c | 11005 b |
| Average | 67126 | 304.83 | 9928 | 15089 |
| C.V. (%) | 1.99 | 3.15 | 4.18 | 11.7 |
| -----Crop 2016/17----- | | | | |
| NT1 | 69828 a | 315 a | 9090 a | 10840 a |
| NT2 | 74425 a | 334 a | 10009 a | 10008 a |
| NT3 | 73851 a | 318 a | 10002 a | 10757 a |
| NT4 | 72126 a | 301 a | 8370 a | 9191 a |
| NT5 | 70977 a | 297 a | 6839 a | 7463 a |
| Average | 72241 | 313 | 8862 | 9652 |
| C.V. (%) | 6.02 | 8.64 | 29.53 | 24.82 |
| -----Crop 2017/18----- | | | | |
| NT1 | 69828 a | 282 a | 8002 a | 9343 a |
| NT2 | 66954 a | 315 a | 8451 a | 8997 a |
| NT3 | 67529 a | 299 a | 9624 a | 11715 a |
| NT4 | 64943 a | 252 a | 5244 a | 6059 a |
| NT5 | 70977 a | 242 a | 5926 a | 6593 a |
| Average | 68046 | 278 | 7450 | 8541 |
| C.V. (%) | 8.85 | 7.84 | 17.24 | 17.01 |

(NT1) consolidated no-tillage, with previous management also under no-tillage, constituting the control; (NT2) no-tillage implanted after rotation of tillage; (NT3) no-tillage implanted after reduced tillage; (NT4) no-tillage implanted after conventional soil tillage; and (NT5) no-tillage implanted over open soil, without cultivation. Means followed by the same letter in the column in each layer do not differ among themselves by the Tukey test with 5% significance.

The gross margin varied numerically between treatments and crops, depending on the productivity of each treatment and the price practiced in the commercialization of the sack of corn (60 kg) in each harvest. These data were related to corn yield in each treatment. In the 2015/16 crop years, this value was R \$ 7176 in the average of treatments. In the NT1 treatment, the value was R\$ 8420 and in the NT5 R\$ 5499, that is, 35% lower, considering the commercial price of R\$ 43.37 for the 60 kg sack of corn. This same tendency was observed in the other crops.

The values of net revenue in the treatments and crops were higher in the historically conservationist systems (NT1, NT2, and NT3) than in those historically non-conservationist (NT4 and NT5) (Table 5). Monetary values show some negative numbers in the 2016/17 crops years, in the NT5 treatment, and in the 2017/18 crop years, in the NT4 and NT5 treatments, reflecting the low productivity and cost of production.

After three harvests, treatment NT5 was economically unfeasible, resulting in a monetary loss of R\$ 308, on the average of the three harvests (Table 6). The same trend occurred in the NT4 treatment, in which, in the 2017/18 harvest years, there was a monetary loss of R\$ 518 (Table 5).

Table 5. Implementation cost sheet and gross and net revenue observed in the 2015/16, 2016/17 and 2017/18 harvests, in the Cambissolo Húmico in Lages SC.

| Treat. | -----2015/16----- | | | -----2016/17----- | | | -----2017/18----- | | |
|---------|-------------------|------------|----------|-------------------|------------|----------|-------------------|------------|----------|
| | Cost | Gross Mar. | Net Mar. | Cost | Gross Mar. | Net Mar. | Cost | Gross Mar. | Net Mar. |
| | ------(R\$)----- | | | | | | | | |
| NT1 | 4015 | 8420 | 4404 | 4100 | 4600 | 500 | 3752 | 4934 | 1182 |
| NT2 | 4015 | 8121 | 4106 | 4100 | 5066 | 966 | 3752 | 5211 | 1459 |
| NT3 | 4015 | 7500 | 3485 | 4100 | 5062 | 962 | 3752 | 5935 | 2182 |
| NT4 | 4015 | 6338 | 2323 | 4100 | 4236 | 136 | 3752 | 3234 | -518 |
| NT5 | 4015 | 5499 | 1484 | 4100 | 3461 | -638 | 3752 | 3654 | -97 |
| Average | 4015 | 7176 | 3160 | 4100 | 4485 | 385 | 3752 | 4593 | 4015 |

Note: Dollar exchange rate source Central Bank US \$ 1.00 = R \$ 3.85, on 06/29/2018. (NT1) consolidated no-tillage, with previous management also under no-tillage, constituting the control; (NT2) no-tillage implanted after rotation of tillage; (NT3) no-tillage implanted after reduced tillage; (NT4) no-tillage implanted after conventional soil tillage, and (NT5) no-tillage implanted on open soil without cultivation.

Table 6. Spreadsheet of chemical recovery of soil and a net margin of the corn crop in the treatments, in the average of the harvests of 2015/16, 2016/17 and 2017/18, in the Cambissolo Húmico in Lages SC.

| Treat. | 2015 | | -----Net Margin----- | |
|---------|-------------------|-------------|----------------------|--------------|
| | Recuperation cost | Sum 3 crops | Total – Cost | Average/year |
| | ------(R\$)----- | | | |
| NT1 | 884 | 6087 | 5203 | 1734 |
| NT2 | 434 | 6531 | 6097 | 2032 |
| NT3 | 606 | 6630 | 6023 | 2007 |
| NT4 | 1094 | 1941 | 846 | 282 |
| NT5 | 1674 | 747 | -926 | -308 |
| Average | 938 | 4387 | 3449 | 1149 |

Note: Dollar exchange rate source Central Bank US \$ 1.00 = R \$ 3.85, on 06/29/2018. (NT1) consolidated no-tillage, with previous management also under no-tillage, constituting the control; (NT2) no-tillage implanted after rotation of tillage; (NT3) no-tillage implanted after reduced tillage; (NT4) no-tillage implanted after conventional soil tillage, and (NT5) no-tillage implanted on open soil without cultivation.

DISCUSSION

The weight of one thousand grains (P1000) was 17% lower in the NT5 treatment than on the average of the other treatments, in the harvest of 2015/16 years, with no difference in the subsequent crops. In absolute terms, however, in the last two crops, the values of the P1000 variable were 12% higher in the treatments with a history of soil cultivation (NT1, NT2, NT3 and NT4) than in the one with uncultivated history in which the soil was kept uncovered (NT5), on the average of the crops and the treatments. This shows the negative reflection of the soil use, which in this treatment was maintained without cultivation, without fertilization, and with intense revolving twice a year, which resulted in the degradation of the structure and the lowering of the C content, shown by Wolschick [16], in the same experiment. Also, there was a decrease in fertility and an increase in the acidity of the soil, and with this, a low root mass as verified also by Wolschick [17]. Considering only the 2017/18 harvest years, the P1000 difference, in absolute terms, was 16% higher in NT1 than in NT5. Another important difference occurred between treatments NT1 (old NT, considered soil conservationist) and NT4 (old CT, considered non-conservationist), for the P1000. This variable was only 7% higher in NT1 than in NT4, on the average of the three crop cycles, meaning that the fact that the soil was degraded by CT for many years was not enough to significantly influence the weight of 1000 grains of corn when management was converted to NT. Although the statistical difference occurred only in the first corn harvest, for the P1000,

this variable had a great influence on corn productivity. On average, the P1000 values obtained in the present study were higher than those of Wolschick [18], in the same consortium, but without chemical fertilization in corn.

The highest grain yield observed in the NT1 and NT2 treatments in the 2015/16 crop years represented a yield of 3254 kg ha⁻¹ higher in soil management systems with a conservationist history compared to those with non-conservationist history. In spite of the absence of statistical difference between treatments in the crops that followed, treatments NT1 and NT2 produced in absolute values 2093 and 3107 kg ha⁻¹ more than the NT4 and NT5, respectively in the 2016/17 and 2017/18 crops years, on average of treatments. This represents a significant gain for production and consequently monetary gain for the producer. Greater yields represent a greater financial return on production, considering that it is possible to associate maximum technical and economic efficiency with high yield ceiling, provided that the agronomic performance and the productive potential of the cultivar are optimized [19].

In general, the results of corn yield, 8.7 t ha⁻¹ on the average of the three crops and the treatments, were satisfactory for the Lages region, which were similar to those presented by Sangoi [19] for high productivity managements. Wolschick [20] evaluated the same consortium of this research, but without fertilization in the corn crop, and obtained productivity of 6 t ha⁻¹, showing the contribution of the turnip, vetch and oat consortium in corn yield in succession.

Regarding the cost of the recovery of the treatments presented (Table 6), it can be noticed that the more degraded the soil, the greater the monetary cost for its recovery, due to the use of correctives and fertilizers necessary to make production viable. When the cost of recovering the soil from each treatment of the net margin of the three harvests was amortized, there was a monetary loss for the NT5 treatment of R \$ 926 in the period of the research. On the average of the three harvests, this loss was R \$ 308. This reflected the effect of the previous use of the land used in this treatment. The land is in advanced degradation process, caused by water erosion, in which the soil was revolved twice per year, kept uncovered and uncultivated for 27 years.

Corroborating with the results of this study Bertol [21] observed higher values of soil recovery in conventional soil preparation systems, resulting from sediment and water losses, as well as the nutrients contained in them. The cost of total nutrient losses in the form of triple fertilizer superphosphate, K chloride, and urea and limestone due to water erosion was higher in the CT than in NT, indicating a 45% efficacy of NT in the reduction of this value in comparison with the CT.

Thus, the conversion of the CT to NT resulted in a decrease in the financial return on corn cultivation. This result reflected in productivity, as well as corn root development, which was influenced by soil physical characteristics. Thus, soil management treatments with a conservationist history have produced a greater mass of roots in winter crops than treatments with non-conservationist history.

CONCLUSION

The soil conventional tillage managed in this way for 27 years, when converted to the no-tillage form, produces fewer grains and corn plant mass in the first year after the management conversion than the consolidated no-tillage that had been managed for the same length of time. In subsequent years this management conversion is not reflected in corn productivity, considering the weight of a thousand grains and grain and residue mass in the aerial part of the plant.

The conversion of soil management from the conventional tillage to the no-tillage form is not sufficient to raise the net margin to the point of being equal to that of the consolidated no-tillage system; after three years of management conversion, the net margin in the consolidated no-tillage system remains 3.1 times higher than in the no-tillage resulting from the conversion of management, on the average of the time period.

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