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Perception and level of soil and water conservation practices adoption by farmers in a watershed[1]

Percepção e nível de adoção de práticas de conservação de solo e água por agricultores em uma bacia hidrográfica

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ABSTRACT - In Brazil, to conserve soil and water, the adoption of a complete array of conservation agriculture technologies in conjunction with contour farming and agricultural terraces is necessary. However, there is little knowledge about the awareness and adoption level of conservationist practices by farmers. In this context, the objective of the study, which took place in a watershed containing agricultural areas dominated by annual crops, was to verify farmers' perception and adoption level of soil and water conservation practices and the relationship between their adoption level of conservation practices and their socioeconomic characteristics. For this purpose, a survey was carried out with farmers in the Rio Vermelho watershed in southern Brazil. It was found that the majority of farmers have adequate awareness about the use of soil and water conservation practices. Maintaining productivity was identified as the main reason to conserve soil and water, while reducing production costs and controlling erosion stood out as secondary reasons. Agricultural terraces and no-tillage were the most adopted practices by farmers. No-tillage was implemented by approximately 78.3% of landowners and 50% of tenants. However, only 26.8% of farmers adopted conservation agriculture. Overall, most farmers adopt conservationist practices, but in a partial manner, which may not be sufficient to ensure soil and water conservation. Awareness of soil and water conservation needs to be further improved.

Keywords: No-tillage. Agricultural terraces. Crop rotation. Conservation agriculture. Soil degradation.

RESUMO - No Brasil para conservar o solo e a água faz-se necessário a adoção do pacote tecnológico da agricultura conservacionista, em conjunto com o plantio em nível e o uso dos terraços agrícolas. Porém pouco se sabe sobre a percepção e o nível de adoção dessas práticas pelos agricultores. Neste contexto, o objetivo do estudo foi verificar a percepção e o nível de adoção de práticas de conservação do solo e da água por agricultores, em áreas agrícolas com culturas anuais, o objetivo do estudo foi verificar a percepção e o nível de adoção de práticas de conservação do solo e da água por agricultores, em áreas agrícolas com culturas anuais, em uma bacia hidrográfica; além de analisar a relação entre a adoção destas práticas e as características socioeconômicas destes agricultores . Para tanto, foi realizada uma pesquisa do tipo survey junto a agricultores da bacia hidrográfica do Rio Vermelho, no sul do Brasil. Com base nos resultados, verificou-se que a grande maioria dos agricultores tem percepção adequada acerca do uso das práticas de conservação do solo e da água. A manutenção da produtividade foi apontada como principal motivo para se conservar o solo e a água, enquanto que a redução de custo de produção e o controle da erosão aparecem como motivos secundários. O uso dos terraços agrícolas e o plantio direto foram as práticas mais adotadas pelos agricultores, e a rotação de culturas foi a menos adotada. Cerca de 78,3% dos proprietários de terra e 50% dos arrendatários adotaram o plantio direto. Porém, apenas 26,8% dos agricultores adotaram a agricultura conservacionista. No geral, verificou-se que a maioria dos agricultores adota medidas conservacionistas, mas de forma parcial, que podem não ser suficientes para garantir a conservação do solo e a da água. A conscientização sobre a conservação do solo e da água precisa ser melhorada.

Palavras-chave: Plantio direto. Terraços agrícolas. Rotação de culturas. Agricultura conservacionista. Degradação do solo.

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INTRODUCTION

In Brazil, since the 19th century, research has been conducted on soil and water management and conservation agricultural practices (TELLES; DECHEN; GUIMARÃES, 2013), leading to the accumulation of a wide range of information on the importance, benefits, and advantages of soil and water conservation. No-tillage (NT) stands out as one of the main agricultural practices in soil and water management and conservation in Brazil, as it is used in more than 60% of total annual crop area (FUENTES-LLANILLO *et al*., 2021). However, as an isolated practice, NT does not guarantee soil and water conservation (MINELLA *et al*., 2018; PITTELKOW *et al*., 2015).

Between the 1970s and 1980s, the principles of the no-tillage system (NTS) were developed and established in Brazil. The NTS is a pattern of soil management that covers, from a systemic approach, three fundamental principles: absence or soil disturbance only in the sowing row (i.e., NT), crop rotation (CR) with species diversification, and permanent soil cover, with crop residues, cover crops or both (MUZILLI, 1983). The NTS pillars were appropriated and used to define and conceptualize conservation agriculture (CA) as well and are considered to be synonymous when referring to annual crops (KASSAM *et al*., 2009).

For farmers in agricultural production, CA provides several benefits (GILLER *et al*., 2015; KNOWLER; BRADSHAW, 2007; LAL, 2015), which are important for soil and water conservation. However, to avoid erosive processes and water loss in agricultural areas, other conservation practices, such as contour farming (CF) and agricultural terraces (AT), should be combined with CA practices (RICCI *et al*., 2022; TELLES *et al*., 2019). The CF and AT are conservation practices used for water management in agriculture (FREITAS *et al*., 2021; TAROLLI; PRETI; ROMANO, 2014) and maintenance of crop productivity (DENG *et al*., 2021a; ROCKSTRÖM *et al*., 2010). These conservation practices are physical structures used to reduce slope length, runoff energy, and water loss through runoff and increase water infiltration capacity (LONDERO *et al*., 2021), particularly in watersheds, where the initial processes of runoff, water erosion, and sediment production are detected and are responsible for the water flows for the drainage network.

Given their agronomic and economic benefits, the use of CA practices has expanded (LALANI; DORWARD; HOLLOWAY, 2017), proof that it is advantageous for farmers to adopt soil and water conservation techniques. However, soil erosion and degradation are still frequently observed in agricultural land (MINELLA *et al*., 2018), which can be explained by the inadequate or partial adoption of CA practices (TELLES *et al*., 2019). There is little knowledge about the awareness, motivation, and level of adoption of soil and water conservation practices by farmers in Brazil. In Paraná state, for example, weathered basalt soils usually can sustain highly intensive agriculture. However, a decrease in the use of conservation practices has been noted over the last few years (TELLES *et al*., 2022). In this context, it is important to characterize the motivations of farmers for adopting practices of soil and water conservation.

The study is based on the hypothesis that the adoption of conservation practices differs between producers according to their land tenure condition, i.e., landowners and tenants profiles based on their socioeconomic characteristics, such as schooling, age, technical assistance, and short-term income demand. The aim of this study is to verify the perception and level of soil and water conservation practices adopted by farmers with annual crops in a specific watershed and verify the relationship between the adoption of conservation practices and the socioeconomic characteristics of farmers.

MATERIAL AND METHODS

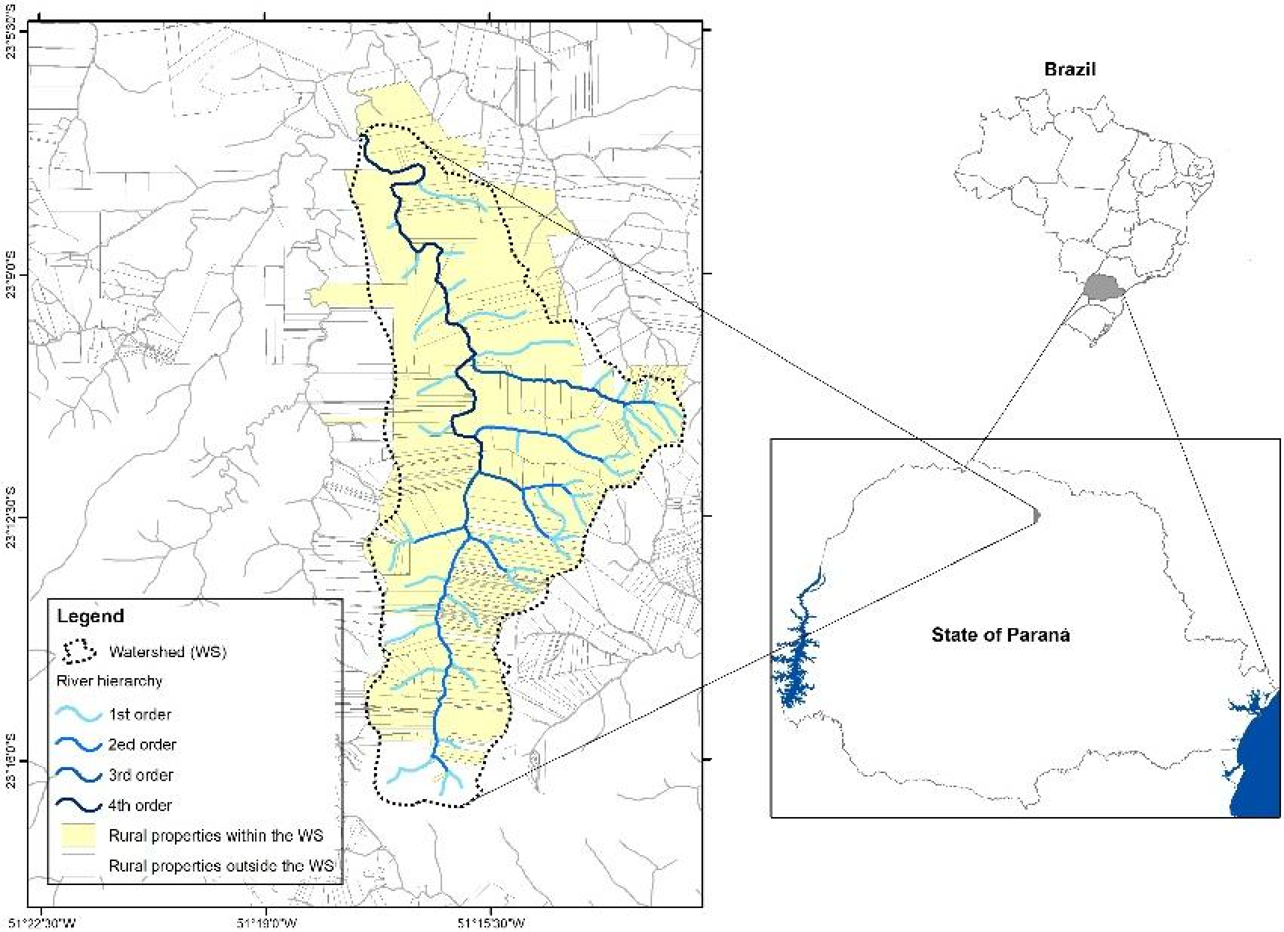
Study area

The study was carried out in the Rio Vermelho watershed (23° 14’ 20.5008” S and 51° 16’ 51.1716” W) in the municipality of Cambé, which is located in the north of state of Paraná, southern Brazil (Figure 1). This region has modern and intensified agriculture, with grain crops (soybeans and maize) in the majority of the farmlands.

The municipality of Cambé has an agricultural area of 38,751 hectares, comprising 563 farming businesses (IBGE, 2019), which cover 1,071 farm holdings registered in the Rural Environmental Registry (SISTEMA NACIONAL DE CADASTRO AMBIENTAL RURAL, 2021). The Rio Vermelho watershed is situated in an area with 209 of these farm holdings, which are potential sources for sediment that flows into the Rio Vermelho River, a fourth-order watercourse.

The predominant soil class in the Rio Vermelho watershed is Latossolo Vermelho, according to the Brazilian System of Soil Classification (SANTOS *et al*., 2018) or Rhodic Ferralsol, according to the International System of Soil Classification (IUSS WORKING GROUP WRB, 2015), or Rhodic Eutrudox, according to the USDA Soil Classification System (SOIL SURVEY STAFF, 2014). The landscape of the watershed is predominantly slightly undulated (3–8%) to undulated (8–20%), and the climate is Cfa (subtropical climate) by the Köppen classification, with a mean annual temperature of 18 °C in winter and 22 °C in summer and average annual precipitation between 1,600 and 1,800 mm (ALVARES *et al*., 2014).

Figure 1 - Rural properties and rivers of the Rio Vermelho watershed in Cambé, Paraná, Brazil



Data collection and sampling procedure

Sampling can reproduce accurate results using a fraction of the entire population (COCHRAN, 1977). The representative sample could vary and is linked to cultural factors; nonetheless, approximately 20 to 50 interviews are recommended for qualitative theoretical studies (CRESWELL; POTH, 2017; MARSHALL; ROSSMAN, 2014). From the 209 farms registered in the Rural Environmental Registry composing the Rio Vermelho watershed, through the methodological procedures, a sample size of at least 38 farms was indicated for a confidence level of 95% (p = 0.5). This survey was applied to 41 farms in the Rio Vermelho watershed, conducted during the 2019-2020 crop year, where the predominant production system is annual crops, mainly with soybean and maize in double crops under no-tillage.

For the interview, a convenience sampling technique, which is a non-probabilistic procedure, was used, for which the population members meet selected practical criteria, with the homogeneity of the population as an associated hypothesis (BENEDETTI; PIERSIMONI; POSTIGLIONE, 2015).

Data analysis

Data were analyzed using the Statistical Package for the Social Science (SPSS) version 25 and R software version 3.4.3. Ratio analysis, descriptive statistics, and principal component analysis (PCA) were performed. PCA was performed based on the correlation matrix of the data and the Euclidean similarity (ABDI; BEATON, 2019). The number of principal components (PC) was obtained as defined by the Kaiser criterion, in which PC with eigenvalues greater than one were chosen. The significance level was set at $p < 0.05$.

RESULTS AND DISCUSSION

Farmers' socioeconomic characteristics

The results in Table 1 show that in the study sample, 43.9% of the farmers are landowners, and 56.1% are tenants. The average age of the farm managers is 51 years old; 54 years is the average age for landowners, and 49 years is the average age for tenants. It was observed that agriculture is their main economic activity, and 85.4% do not have any income source other than that from agricultural activities. Among the farmers, 77.8% of landowners and 91.3% of tenants have income exclusively from agricultural activity. Generally, only 42.9% of the farmers reside on the property (Table 1); this figure is higher for landowners, at 50%, than for tenants, for which the rate is 39.1%. The results regarding the income sources are similar to those verified for Brazil according to data from the National Agricultural Census (IBGE, 2019), which states that approximately 85% of the income of Brazilian farmers comes from agricultural-related activities.

It was verified that 97.6% of farmers received technical assistance, mainly provided by agricultural cooperatives, of which they are members, which are indicated as their main source of technical information. Access to technical assistance is essential for farmers to learn how to adopt soil conservation practices appropriately (DELAROCHE, 2020).

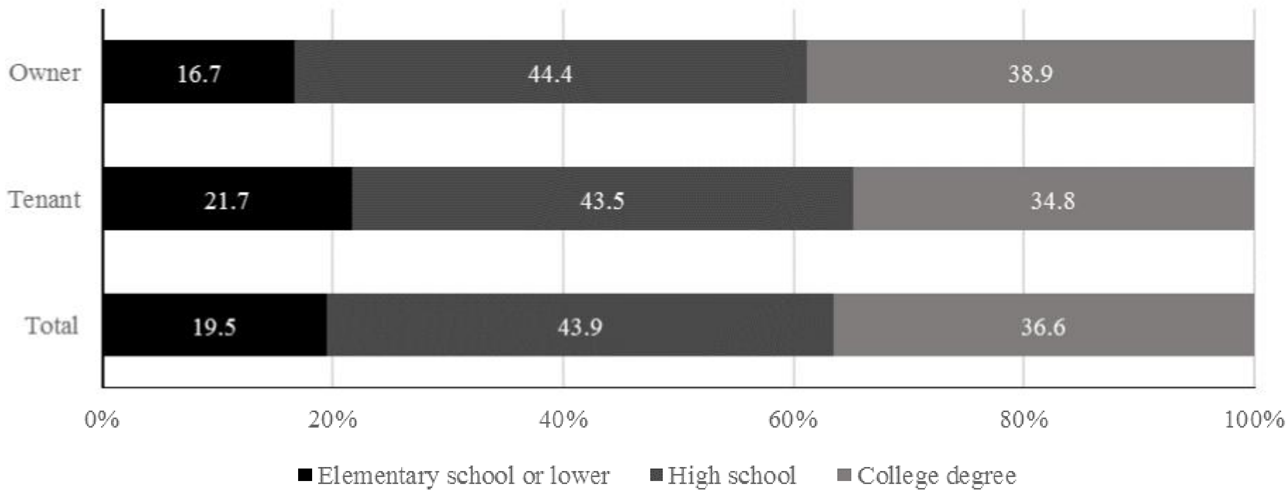
Regarding the level of education, 19.5% of the farmers had received an elementary school education or less, 43.9% had received a high school education and 36.6% had received a college education (Figure 2). It was observed that landowners have a slightly higher schooling level than tenants. The level of education is an important indicator for the adoption of soil and water conservation practices since decision-making for CA adoption, in addition to experience, requires a certain degree of knowledge. The transformations and innovations in the agricultural production process, evidenced by modernization and technification, require more skilled farmers who are able to deal with technological changes in the field (VILPOUX; GONZAGA; PEREIRA, 2021).

Farm sizes and land prices were also verified in the study (Table 2). The average farm size is 72.2 hectares, varying between small farms (up to 5 hectares) and large farms (more than 200 hectares). Landowners, on average, represent an area 2.3 times larger than tenants. Larger areas of landowners may be related to lower production costs due to economies of scale in crop production. It is worth mentioning here that tenants, in addition to a smaller scale of production (ARTUZO *et al*., 2018), also have the disadvantage of being subjected to land leasing rates.

Table 1 - Farmers' socioeconomic characteristics, by land tenure groups, from Rio Vermelho watershed, Cambé, Paraná, Brazil

Socieconomic characteristic	Group of land tenure		
	Landowner	Tenant	Landowner and tenant
Quantity of farmers (%)	43.9	56.1	-
Average age (years)	54	49	51
Only agricultural income (%)	77.8	91.3	85.4
Lives on the farm (%)	50.0	39.1	42.9
Receives technical assistance (%)	94.0	100	97.6

Figure 2 - Schooling of the farmers by land tenure category (%), from the Rio Vermelho watershed, Cambé, Paraná, Brazil



The average land price is US$15,073.8 ha^{-1} (Table 2), according to farmers' responses. It was found that the land prices of farmers who adopt a greater number of soil and water conservation practices, such as CA, CF, and AT, are higher than those who do not adopt or only partially adopt these conservation practices. This highlights that the adoption of soil and water conservation practices has an influence on agricultural land values (TELLES; REYDON; MAIA, 2018).

In brief, the analyses of the socioeconomic characteristics of the farmers in this watershed of the study indicate that there are differences between landowners and tenants in terms of farm size, income source, schooling, and place of residence.

Farmers' awareness of soil and water conservation practices

The results regarding the awareness of farmers in the selected watershed regarding soil and water conservation practices showed that, for most of them, the adoption of conservation practices is important for maintaining production (Table 3). This result is, in relative terms, similar for both landowners and tenants, with 84.2% and 78.3% of the total, respectively. For 10.5% of the landowners, the adoption of conservation practices is important for reducing production costs and, for 5.3% of this group, for avoiding erosion. The adoption of conservation practices is important for preventing erosion to 17.4% of tenants and the reduction in production costs to 4.3% of them.

The point of view of the landowners or tenants determines whether CR is regarded as important for production maintenance (Table 3). Approximately 58% of the landowners and 87% of the tenants understand that production maintenance is the most important reason for adopting CR. AT is used primarily to avoid erosion by 42.1% of the landowners, while for 34.8% of the tenants, it is important for reducing production costs.

An awareness regarding the importance of soil and water management and conservation practices, as well as their benefits, may be influenced by education level (Figure 2). Education level is a characteristic noted in other regions, such as Africa (MOGES; TAYE, 2017) and the United States of America (ADUSUMILLI; WANG, 2018), as a determining factor for CA adoption. The higher the level of education is, the greater the knowledge and perception about the importance of soil and water conservation. According to Piñero *et al*. (2020), farmers with a higher level of education have a knowledge base for decision-making and are the ones who appropriately adopt conservation practices.

Therefore, the maintenance of soil productivity and reduction in environmental damage are linked to farmers' education levels and knowledge, which influence their adoption of conservation practices that avoid erosion and degradation of agricultural soils, reduce production costs and maintain crop production. Adopting conservation practices improves soil organic matter in weathered basalt soils (MELLO *et al*., 2021), which can improve soil quality and resistance to water erosion.

Adoption of soil and water conservation practices by farmers

Even though farmers demonstrated awareness of the benefits of conservation practices such as production maintenance, reduction in production cost, and prevention of erosion and soil degradation, it has been verified that the farmers in this watershed have rarely been engaged in embracing CA, as only 26.8% of the farmers have adopted it. Surprisingly, landowners have lower adoption rates (22.2%) than tenants (30.4%). The level of CA adoption observed is in line with the worldwide level of CA adoption, which is 12.5% (KASSAM; FRIEDRICH; DERPSCH, 2019).

The results also revealed that, although the tenants adopt more CA practices, the landowners are the ones who adopt the largest number of conservationist practices, even though in isolated form (Table 4). The nonadoption or partial adoption of CA by farmers was observed in the study by Pittelkow *et al*. (2015), which highlights the false perception regarding sustainable intensification in agriculture, based on, for instance, the isolated adoption of NT. In Brazil´s scenario, in addition to CA adoption, for the sustainable intensification of production, CF and AT adoption would still be necessary (TELLES *et al*., 2019).

Table 2 - Descriptive statistics of the farms in the Rio Vermelho watershed, Cambé, Paraná, Brazil

	Summary statistics			
	Mean	Median	Standard deviation	Amplitude
Land value (US$/ha)	15,073.8	15,092.2	3,894.6	29,052.4
Total area (ha)	72.2	26.6	132.1	774.2
Landowners' area (ha)	106.4	44.4	181.8	770.3
Tenant area (ha)	45.4	25.0	66.9	263.2

Note: Land values were converted to US dollars based on the exchange rate on June 30, 2020

Several other studies suggest that landowners are more likely to adopt soil and water conservation practices than tenants (ADUSUMILLI; WANG, 2018; SINGH *et al*., 2018). Specifically, CA occurs in locations with annual crop production, such as in the south of the United States of America (ADUSUMILLI; WANG, 2019), in the Czech Republic (SKLENICKA *et al*., 2015), and in Austria (LEONHARDT; PENKER; SALHOFER, 2019). However, the question is whether the practices they have adopted are those necessary for sustainable intensification of agricultural production.

CR is the single conservation practice with the lowest level of adoption among farmers, adopted by 30.4% of landowners and 33.3% of tenants. Even with awareness of CR´s importance in maintaining the level of agricultural production yields, farmers demonstrate substantial resistance in adopting this practice. The main reason for the low adoption of CR is the uncertainty in obtaining profits from cultivating alternative crops to DC (with soybean [*Glycine max*] cultivation during spring/summer followed by maize [*Zea mays*]). To adopt CR, farmers demand higher profitability compared to double crops (DC); in other words, the profitability of areas with CR should be higher compared to areas without CR (ADUSUMILLI *et al*., 2020; WANG *et al*., 2019). This is one of the

Table 3 - Farmers awareness of soil conservation practices, by land tenure group, in the Rio Vermelho watershed, Cambé, Paraná, Brazil

Category	Land tenure	Main reason for importance	%
Importance of soil conservation practices	Landowner	Production maintenance	84.2
		Reduction in production cost	10.5
		Avoid erosion	5.3
	Tenant	Production maintenance	78.3
		Reduction in production cost	4.3
		Avoid erosion	17.4
Importance of crop rotation	Landowner	Production maintenance	57.9
		Reduction in production cost	15.8
		Avoid erosion	26.3
	Tenant	Production maintenance	87.0
		Reduction in production cost	8.7
		Avoid erosion	4.3
Importance of agriculture terraces	Landowner	Helps soil conservation	31.6
		Reduction in production cost	26.3
		Avoid erosion	42.1
	Tenant	Helps soil conservation	34.8
		Reduction in production cost	34.8
		Avoid erosion	30.4

Table 4 - Cropping systems, soil tillage and soil conservation practices adopted by farmers, by type of land tenure, from Rio Vermelho watershed, Cambé, Paraná, Brazil

Soil management	Group of land tenure		
	Landowner	Tenant	Landowner and tenant
Double crop (%)	69.6	66.7	68.3
Crop rotation (%)	30.4	33.3	31.7
Minimum tillage (%)	21.7	50.0	34.2
No-tillage (%)	78.3	50.0	65.9
Conservation agriculture (%)	22.2	30.4	26.8
Agricultural terraces (%)	100.0	100.0	100.0
Contour farming (%)	100.0	94.4	97.6

factors that lead producers in this watershed to not implement CR, with DC remaining the predominant cropping system (more than 68% of the farms). This is possibly due in part to a limited view about the profitability of the agricultural production system, which is sometimes restricted to a short-term analysis. The improvements for agricultural systems, including their economic benefits, with the adoption of CR come only in the medium and long term. This is one of the main bottlenecks for the sustainable intensification of agricultural production and needs to be approached in public and private actions, especially by technical assistance.

It is also noteworthy that while some of the farmers declare that they adopt CR, it is observed that this is not the case because they actually seem to adopt DC. This may be due to a conceptual confusion by some of the farmers about CR and DC (TELLES *et al*., 2022), as it involves, to a certain degree, a subjective evaluation. In this case, for a proper CR, there must be at least three or more alternate species planted in the same area, in nonconsecutive crops, and not just two alternate species in the same area, continuously, over time, as is the predominant case in DC. The continuous use of DC has caused concern regarding soil and water conservation because the straw left by maize as a second crop does not provide sufficient coverage for the soil, making these areas susceptible to erosive processes (LONDERO *et al*., 2021).

In regard to the results concerning soil management practices, NT is adopted by 78.3% of the landowners in the selected watershed and approximately 50% of the tenants. In Brazil, NT is adopted in 60% of the area with annual crops (FUENTES-LLANILLO *et al*., 2021); therefore, NT adoption by farmers in the selected watershed is within the national average. NT is a practice that improves soil physical quality and agricultural production (BLANCO-CANQUI; RUIS, 2018), and farmers having an adequate understanding of this practice. In the selected watershed, when NT is not adopted, farmers use minimum tillage (MT) – 34.2% of the total – which involves soil tillage operations. The results reveal that 7.3% of them use a plow and 34.2% use a chisel plow for soil preparation, mischaracterizing the CA practice. That is, NT and MT are mutually exclusive practices since the adoption of one negates the adoption of the other. Such a situation of nonadoption of CA practices is observed in Brazil (MINELLA *et al*., 2018; TELLES *et al*., 2019), and noncompliance generates favorable conditions for soil losses (DEUSCHLE *et al*., 2019) and water loss in drought periods (LAL *et al*., 2012).

Water management and conservation practices, such as AT and CF, are extensively adopted by farmers in the selected watershed, with AT being adopted by all landowners and tenants, and CF is adopted by all except 5.6% of the tenants. ATs are physical structures allocated on the land to decrease slope length, reduce the runoff surface speed, and increase water infiltration into the soil (DENG *et al*., 2021a; FREITAS *et al*., 2021), thereby preventing water erosion. The presence of AT in all the properties is a differential in the watershed being study. According to Silva and De Maria (2011), farmers have been removing AT from their farms because they believe that NT alone is enough to contain losses from soil erosion, which is not true. Only with the concomitant adoption of soil management practices, such as CA, and water management practices, such as AT, is there an effective reduction in soil and water losses in agricultural areas with intensive grain cultivation (LONDERO *et al*., 2018; MERTEN *et al*., 2015).

CF was another water conservation practice analyzed. Farmers execute most of their agricultural operations using CF (Table 5). All tenants, for example, perform sowing and harvesting operations using CF, while landowners perform 94.4% of sowing and 83.3% of harvesting using CF. For spraying operations, 100% of the landowners and 52.2% of the tenants perform these operations with CF. Operations involving soil mobilization and soil revolving are still carried out by farmers, with plowing performed by 16.7% of landowners and scarifying performed by 38.9% of landowners and 30.4% of tenants. CF contributes to the maintenance and increase in agricultural production (DENG *et al*., 2021b) and soil moisture retention capacity (RECHA; MUKOPI; OTIENO, 2015) and helps in reducing water runoff and sediment production (JIA *et al*., 2020; LONDERO *et al*., 2021), thereby controlling water erosion. It is worth emphasizing that the maintenance of productivity was considered by farmers as the main reason for them to conserve soil and water.

The consequences of the low adoption of CA are evident by the reports of soil loss due to erosion, which was present in 29.7% of the farms. Furthermore, 19.8% of the farmers reported difficulty in controlling erosion (Figure 3). The erosion observed by the farmers may be indicative of the partial adoption of soil and water conservation practices. Through the nonadoption or partial adoption of conservation practices, there are problems of erosion and soil degradation in Brazil (MINELLA *et al*., 2018). It is emphasized that the adoption of only one practice, for example, NT, is not enough to ensure soil and water conservation (PITTELKOW *et al*., 2015; TELLES *et al*., 2019).

In the evaluation of the relationship between the adoption of conservation practices and land tenure, based on PCA, two principal components were identified, which, combined, explained more than 55% of the data variability (Figure 4). PC 1 explains 33% of the variation

Table 5 - Tillage operations adopted in contour farming (%) by farmers, by land tenure, from Rio Vermelho watershed, Cambé, Paraná, Brazil

Soil tillage operations	Group of land tenure		
	Landowner	Tenant	Landowner and tenant
Spraying (%)	100.0	52.2	51.2
Harvesting (%)	83.3	100.0	92.7
Sowing (%)	94.4	100.0	97.6
Plow tillage (%)	16.7	0.0	7.3
Chiseling (%)	38.9	30.4	34.2

Figure 3 - Proportion of farmers who reported water erosion and difficulty in controlling water erosion, by land tenure groups, from Rio Vermelho watershed, Cambé, Paraná, Brazil

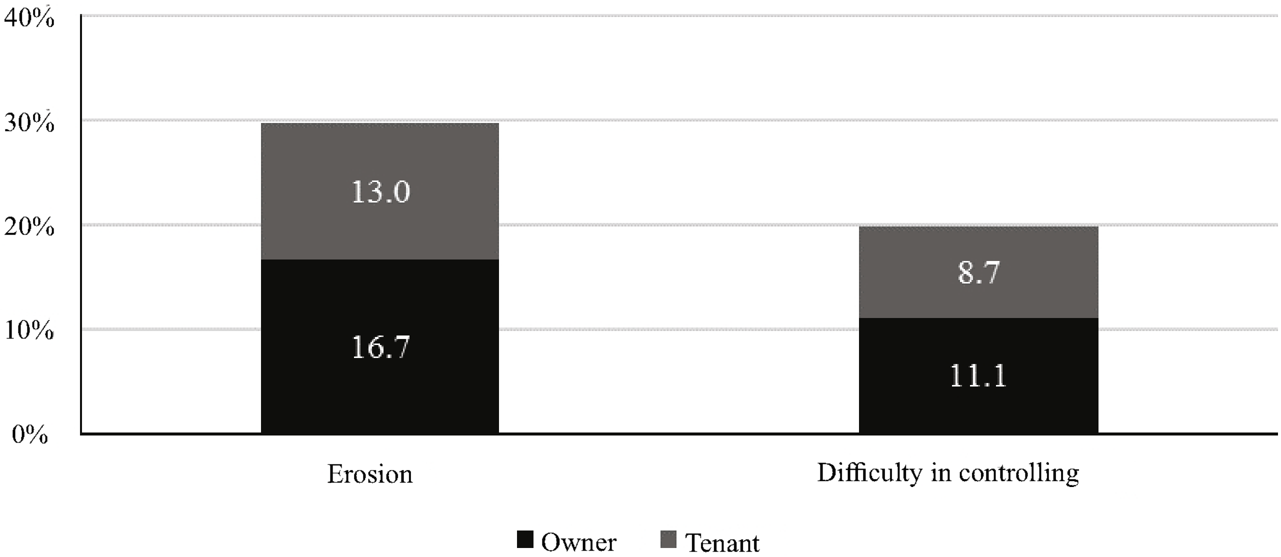
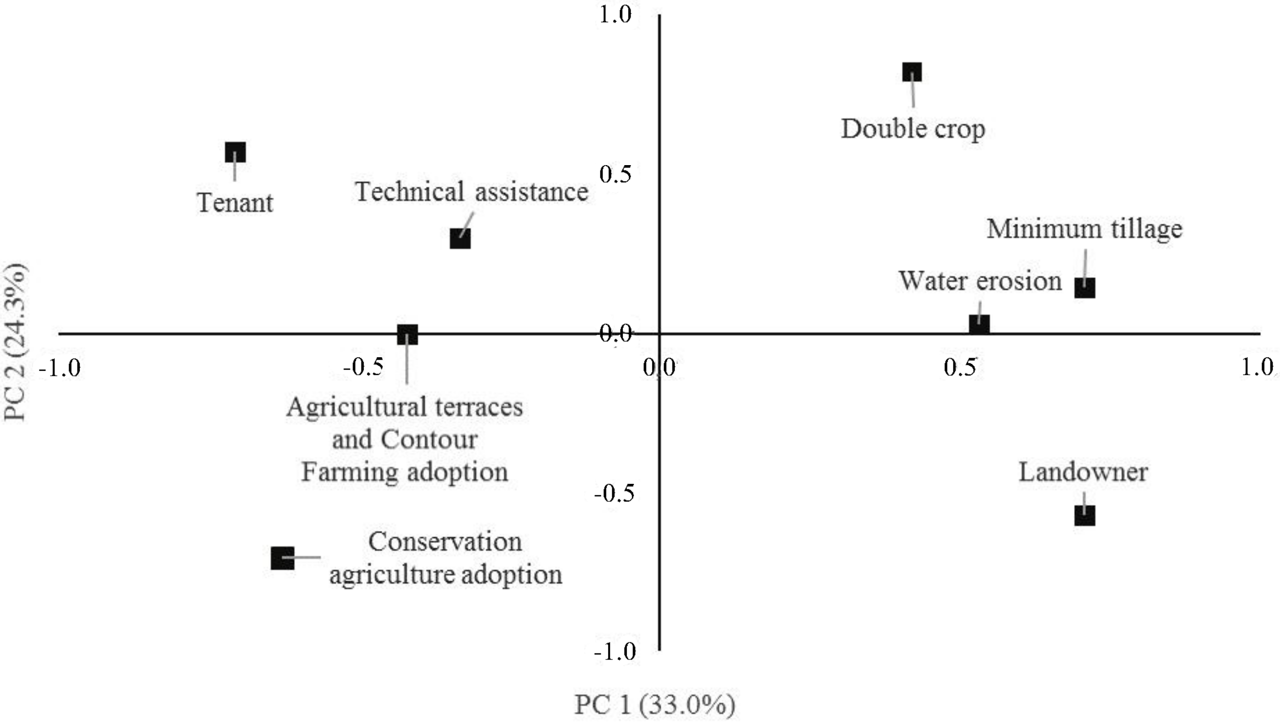


Figure 4 - Principal component analysis showing the relationship between water erosion and soil and water conservation practices, according to the responses of farmers from the Rio Vermelho watershed, Cambé, Paraná, Brazil



in the data, while PC 2 explains 24.3%. PC 1 is explained by landowners, tenants, and MT adoption. DC and CA adoption explain PC 2. The PCA results showed that tenants and landowners were negatively correlated (PC 1). Landowners correlate positively with MT, while tenants correlate negatively with MT (PC 1). Tenants correlate positively with CA adoption (PC 1). DC correlates negatively with CA adoption (PC 2). The PCA results confirm the study results, in which it is verified that the tenants are the ones who most adopt AC.

Despite their knowledge about the importance of soil and water conservation practices, farmers have a Farmers have a low adoption to CA, with a rate of only 26.8% and most of the farmers have only partially adopted conservation practices. Therefore, for soil and water conservation, it is necessary to combine the practices of CA with CF and AT to intensify agricultural production and generate benefits, i.e., maintaining production and reducing soil erosion and degradation.

CONCLUSIONS

1. Conservation agriculture is minimally adopted among farmers in the selected watershed. No-tillage has the highest level of adoption, and crop rotation has the lowest level of adoption. Agricultural terraces and contour farming are adopted by most farmers. Thus it can be concluded that the farmers in this watershed are characterized by partial adoption of soil and water conservation practices, mainly because they do not adopt conservation agriculture;
2. Farmers' awareness of the importance of soil and water conservation is mainly limited to the role of conservation in maintaining productivity. Additionally, although less important, farmers highlight the reduction in production costs and control of erosion and soil degradation as important factors for preserving soil and water;
3. Among the socioeconomic characteristics evaluated, land tenure is highlighted, and important differences between landowners and tenants emerged, such as (i) farm size, with landowners having larger farms; (ii) income source, with tenants mostly having agriculture as their only source of income; (iii) education, with landowners having more years of study than tenants; and (iv) place of residence, with most tenants identifying are nonrural residents;
4. Furthermore, the adoption of soil and water conservation practices is also related to farmers' socioeconomic characteristics. There are important differences between landowners and tenants in the adoption of soil and water conservation practices. Landowners adopt mostly no-tillage and double crops, but a few adopt CA. Moreover, the tenants have neglected no-tillage, but a considerable portion adopt crop rotation and conservation agriculture. Practices such as contour farming and agricultural terraces are adopted by almost all farmers, whether landowners or tenants. Overall, the majority of both landowners and tenants partially adopt soil and water conservation practices, which may be insufficient to control soil erosion and may represent obstacles to sustainable intensification of agricultural production.

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REFERENCES

ABDI, H.; BEATON, D. **Principal component and correspondence analyses using R**. New York: Springer International Publishing, 2019. 110 p.

ADUSUMILLI, N. *et al*. Estimating risk premiums for adopting no-till and cover crops management practices in soybean production system using stochastic efficiency approach. **Agricultural Systems**, v. 178, 102744, 2020. DOI: https://doi.org/10.1016/j.agsy.2019.102744.

ADUSUMILLI, N.; WANG, H. Analysis of soil management and water conservation practices adoption among crop and pasture farmers in humid-south of the United States. **International Soil and Water Conservation Research**, v. 6, n. 2, p. 79-86, 2018. DOI: https://doi.org/10.1016/j.iswcr.2017.12.005.

ADUSUMILLI, N.; WANG, H. Conservation adoption among owners and tenant farmers in the Southern United States. **Agriculture**, v. 9, n. 3, p. 53, 2019. DOI: https://doi.org/10.3390/agriculture9030053.

ALVARES, C. A. *et al*. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728, 2014. DOI: https://doi.org/10.1127/0941-2948/2013/0507.

ARTUZO, F. D. *et al*. Gestão de custos na produção de milho e soja. **Revista Brasileira de Gestão de Negócios**, v. 20, n. 2, p. 273-294, 2018. DOI: https://doi.org/10.7819/rbgn.v20i2.3192.

BENEDETTI, R.; PIERSIMONI, F.; POSTIGLIONE, P. **Sampling spatial units for agricultural surveys**. Berlin: Springer, 2015. 325 p.

BLANCO-CANQUI, H.; RUIS, S. J. No-tillage and soil physical environment. **Geoderma**, v. 326, p. 164-200, 2018. DOI: http://doi.org/10.1016/j.geoderma.2018.03.011.

COCHRAN, W. G. **Sampling techniques**. 3rd ed. New York: John Wiley and Sons, 1977. 448 p.

CRESWELL, J. W; POTH, J. W. **Qualitative inquiry and research design**: choosing among five approaches. 4th ed. California: SAGE Publications, 2017. 488 p.

DELAROCHE, M. Adoption of conservation practices: what have we learned from two decades of social-psychological approaches? **Current Opinion in Environmental Sustainability**, v. 45, p. 25-35, 2020. DOI: https://doi.org/10.1016/j.cosust.2020.08.004.

DENG, C. *et al*. Advantages and disadvantages of terracing: a comprehensive review. **International Soil and Water Conservation Research**, v. 9, n. 3, p. 344-359, 2021a. DOI: https://doi.org/10.1016/j.iswcr.2021.03.002.

DENG, X. *et al*. Does farmland abandonment harm agricultural productivity in hilly and mountainous areas? Evidence from China. **Journal of Land Use Science**, v. 1, n. 4, p. 433-449, 2021b. DOI: https://doi.org/10.1080/1747423X.2021.1954707.

DEUSCHLE, D. *et al*. Erosion and hydrological response in no-tillage subjected to crop rotation intensification in southern Brazil. **Geoderma**, v. 340, p. 157-163, 2019. DOI: https://doi.org/10.1016/j.geoderma.2019.01.010.

FREITAS, L. R. *et al*. Terracing increases soil available water to plants in no-tillage. **Revista Brasileira de Ciência do Solo**, v. 45, e0210046, 2021. DOI: https://doi.org/10.36783/18069657rbcs20210046.

FUENTES-LLANILLO, R. *et al*. Expansion of no-tillage practice in conservation agriculture in Brazil. **Soil and Tillage Research**, v. 208, 104877, 2021. DOI: https://doi.org/10.1016/j.still.2020.104877.

GILLER, K. E. *et al*. Beyond conservation agriculture. **Frontiers in Plant Science**, v. 6, p. 870, 2015. DOI: https://doi.org/10.3389/fpls.2015.00870.

IBGE. **Censo agropecuário 2017**: resultados definitivos. Rio de Janeiro: IBGE, 2019. 105 p.

IUSS WORKING GROUP WRB. World reference base for soil resources 2014, update 2015. **International soil classification system for naming soils and creating legends for soil maps**. Rome: Food and Agriculture Organization of The United Nations, 2015. 192 p. (World Soil Resources Reports, n. 106).

JIA, L. *et al*. Quantifying the effects of contour tillage in controlling water erosion in China: a meta-analysis. **Catena**, v. 195, 104829, 2020. DOI: https://doi.org/10.1016/j.catena.2020.104829.

KASSAM, A. *et al*. The spread of conservation agriculture: justification, sustainability and uptake. **International Journal of Agricultural Sustainability**, v. 7, n. 4, p. 292-320, 2009. DOI: https://doi.org/10.3763/ijas.2009.0477.

KASSAM, A.; FRIEDRICH, T.; DERPSCH, R. Global spread of conservation agriculture. **International Journal of Environmental Studies**, v. 76, n. 1, p. 29-51, 2019. DOI: https://doi.org/10.1080/00207233.2018.1494927.

KNOWLER, D.; BRADSHAW, B. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. **Food Policy**, v. 32, n. 1, p. 25-48, 2007. DOI: https://doi.org/10.1016/j.foodpol.2006.01.003.

LAL, R. Climate change and soil degradation mitigation by sustainable management of soils and other natural resources. **Agricultural Research**, v. 1, n. 3, p. 199-212, 2012. DOI: https://doi.org/10.1007/s40003-012-0031-9.

LAL, R. Sequestering carbon and increasing productivity by conservation agriculture. **Journal of Soil and Water Conservation**, v. 70, n. 3, p. 55A-62A, 2015. DOI: https://doi.org/10.2489/jswc.70.3.55A.

LALANI, B.; DORWARD, P.; HOLLOWAY, G. Farm-level economic analysis: is conservation agriculture helping the poor? **Ecological Economics**, v. 141, p. 144-153, 2017. DOI: https://doi.org/10.1016/j.ecolecon.2017.05.033.

LEONHARDT, H.; PENKER, M.; SALHOFER, K. Do farmers care about rented land? A multi-method study on land tenure and soil conservation. **Land Use Policy**, v. 82, p. 228-239, 2019. DOI: https://doi.org/10.1016/j.landusepol.2018.12.006.

LONDERO, A. L. *et al*. Impact of broad-based terraces on water and sediment losses in no-till (paired zero-order) catchments in southern Brazil. **Journal of Soils and Sediments**, v. 18, n. 3, p. 1159-1175, 2018. DOI: https://doi.org/10.1007/s11368-017-1894-y.

LONDERO, A. L. *et al*. Quantifying the impact of no-till on sediment yield in southern Brazil at the hillslope and catchment scales. **Hydrological Processes**, v. 35, n. 7, e14286, 2021. DOI: https://doi.org/10.1002/hyp.14286.

MARSHALL, C.; ROSSMAN, G. B. **Designing qualitative research**. 6 th ed. London: SAGE Publications, 2014. 352 p.

MELLO, I. *et al*. Benefits of conservation agriculture in watershed management: participatory governance to improve the quality of no-till systems in the Paraná 3 Watershed, Brazil. **Agronomy**, v. 11, p. 2455, 2021. DOI: https://doi.org/10.3390/agronomy11122455.

MERTEN, G. H. *et al*. No-till surface runoff and soil losses in southern Brazil. **Soil and Tillage Research**, v. 152, p. 85-93, 2015. DOI: https://doi.org/10.1016/j.still.2015.03.014.

MINELLA, J. P. G. *et al*. Long-term sediment yield from a small catchment in southern Brazil affected by land use and soil management changes. **Hydrological Processes**, v. 32, n. 2, p. 200-211, 2018. DOI: https://doi.org/10.1002/hyp.11404.

MOGES, D. M.; TAYE, A. A. Determinants of farmers' perception to invest in soil and water conservation technologies in the North-Western Highlands of Ethiopia. **International Soil and Water Conservation Research**, v. 5, n. 1, p. 56-61, 2017. DOI: https://doi.org/10.1016/j.iswcr.2017.02.003.

MUZILLI, O. Influência do sistema de plantio direto, comparado ao convencional, sobre a fertilidade da camada arável do solo. **Revista Brasileira da Ciência do Solo**, v. 7, p. 95-102, 1983.

PIÑERO, V. *et al*. A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. **Nature Sustainability**, v. 3, p. 809-820, 2020. DOI: https://doi.org/10.1038/s41893-020-00617-y.

PITTELKOW, C. M. *et al*. Productivity limits and potentials of the principles of conservation agriculture. **Nature**, v. 517,

n. 7534, p. 365-368, 2015. DOI: https://doi.org/10.1038/nature13809.

RECHA, C. W.; MUKOPI, M. N.; OTIENO, J. O. Socio-economic determinants of adoption of rainwater harvesting and conservation techniques in semi-arid Tharaka Sub-County, Kenya. **Land Degradation & Development**, v. 26, n. 7, p. 765-773, 2015. DOI: https://doi.org/10.1002/ldr.2326.

RICCI, G. F. *et al*. Efficiency and feasibility of Best Management Practices to reduce nutrient loads in an agricultural river basin. **Agricultural Water Management**, v. 259, 107241, 2022. DOI: https://doi.org/10.1016/j.agwat.2021.107241.

ROCKSTRÖM, J. *et al*. Managing water in rainfed agriculture: the need for a paradigm shift. **Agricultural Water Management**, v. 97, n. 4, p. 543-550, 2010. DOI: https://doi.org/10.1016/j.agwat.2009.09.009.

SANTOS, H. G. *et al*. **Brazilian soil classification system**. 5 th ed. Brasília: Embrapa, 2018.

SILVA, R. L.; DE MARIA, I. C. Erosão em sistema plantio direto: influência do comprimento de rampa e da direção de semeadura. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, p. 554-561, 2011. DOI: https://doi.org/10.1590/S1415-43662011000600003.

SINGH, A. *et al*. The influence of demonstration sites and field days on adoption of conservation practices. **Journal of Soil and Water Conservation**, v. 73, n. 3, p. 276-283, 2018. DOI: https://doi.org/10.2489/jswc.73.3.276.

SISTEMA NACIONAL DE CADASTRO AMBIENTAL RURAL (BRASIL). **Número do cadastro ambiental rural**. 2021. Disponível em: https://www.car.gov.br/publico/imoveis/index. Acesso em: 11 out. 2021.

SKLENICKA, P. *et al*. Owner or tenant: who adopts better soil conservation practices? **Land Use Policy**, v. 47, p. 253-261, 2015. DOI: https://doi.org/10.1016/j.landusepol.2015.04.017.

SOIL SURVEY STAFF. **Keys to Soil Taxonomy**. 12 th ed. Washington, DC: USDA-Natural Resources Conservation Service, 2014. 360 p.

TAROLLI, P.; PRETI, F.; ROMANO, N. Terraced landscapes: from an old best practice to a potential hazard for soil degradation due to land abandonment. **Anthropocene**, v. 6, p. 10-25, 2014. DOI: https://doi.org/10.1016/j.ancene.2014.03.002.

TELLES, T. S. *et al*. Conservation agriculture practices adopted in southern Brazil. **International Journal of Agricultural Sustainability**, v. 17, n. 5, p. 338-346, 2019. DOI: https://doi.org/10.1080/14735903.2019.1655863.

TELLES, T. S. *et al*. Soil management practices adopted by farmers and how they perceive conservation agriculture. **Revista Brasileira de Ciência do Solo**, v. 46, e0210151, 2022. DOI: https://doi.org/10.36783/18069657rbcs20210151.

TELLES, T. S.; DECHEN, S. C. F.; GUIMARÃES, M. F. Institutional landmarks in Brazilian research on soil erosion: a historical overview. **Revista Brasileira de Ciência do Solo**, v. 37, p. 1431-1440, 2013. DOI: https://doi.org/10.1590/S0100-06832013000600001.

TELLES, T. S.; REYDON, B. P.; MAIA, A. G. Effects of no-tillage on agricultural land values in Brazil. **Land Use Policy**, v. 76, p. 124-129, 2018. DOI: https://doi.org/10.1016/j.landusepol.2018.04.053.

VILPOUX, O. F.; GONZAGA, J. F.; PEREIRA, M. W. G. Agrarian reform in the Brazilian Midwest: difficulties of modernization via conventional or organic production systems. **Land Use Policy**, v. 103, 105327, 2021. DOI: https://doi.org/10.1016/j.landusepol.2021.105327.

WANG, T. *et al*. Soil conservation practice adoption in the Northern Great Plains: Economic versus stewardship motivations. **Journal of Agricultural and Resource Economics**, v. 44, n. 2, p. 404-421, 2019. DOI: https://doi.org/10.22004/ag.econ.287989