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# Quality No-tillage System: The Importance of the Use of Cover Species in Reducing Compaction and Soil and Water Losses Due to Erosion

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**Abstract**

Water and soil losses due to surface runoff depend on rainfall intensity and periods, vegetation cover, slope, and ramp length, in addition to conservation practices. The implementation of a quality planting system for the effective control of erosion while avoiding the disintegration of the soil structure by the direct impact of dropping is of paramount importance. Nevertheless, the current no-tillage system has led to the emergence of compacted layers in the soil, which reduce water infiltration, favoring surface runoff. Thus, it is necessary to optimize the use of soil cover species, aiming at reducing compaction and, subsequently, losses of water and soil that flow superficially. The purpose of this study is to highlight the importance of using a quality management system to reduce soil and water losses due to erosion caused by compaction. Furthermore, it is hoped that the study may contribute to the guidance of the best use and management of the soil for farmers.

**Keywords:** erosion, infiltration, straw

## 1. Introduction

Soil erosion is considered one of the biggest environmental problems on a global scale. In addition to promoting soil and nutrient losses, it is associated with flooding, sedimentation and pollution of water bodies (Wang et al., 2016). The erosive process is affected by several factors, including soil cover and management practices (Panagos et al., 2015).

Soils historically submitted to successive crops, in the states of Paraná and São Paulo, present damage caused by erosion. These figures are estimated at $212 million and $242 million per year, respectively (Telles, Guimarães, & Dechen, 2011).

Despite being recognized as low-erodibility soils, cultivated Latosols presented soil losses of up to 67.24 Mg $ha^{-1}$ $year^{-1}$ under conditions of absence of vegetation cover, five times above the maximum tolerance limit of 12.7 Mg $ha^{-1}$ $year^{-1}$ (Carvalho et al., 2007).

Water erosion may reflect the inappropriate use and management of the soil, which promotes porosity reduction and alteration of the water infiltration/drainage balance. The passage of agricultural machines, for example, promotes compaction of the soil and favors the formation of concentrated erosion in Latosols (Thomaz, 2013).

Mechanized operations performed on Distroferric Red Latosol have promoted deformations in the cultivated soils and resulted in reduced connectivity between the pores (Silva et al., 2015).

Thus, mulching, as a practice that reduces the damage caused by the erosive action of raindrops, besides providing increased soil moisture, reduced runoff, water erosion, and soil temperature control (Jordán, Zavala, & Gil, 2010; Montenegro et al., 2013) plays an important role in soil coverage by reducing the impact of raindrops

(Martins et al., 2003; Cândido et al., 2014). Additionally, the increase of soil organic matter and the root system contribute to the improvement of soil physical attributes related to water infiltration and aggregation, subsequently contributing to the reduction of soil erodibility (Wohlenberg et al., 2004; Conte et al., 2011).

**2. Soil Management**

Management practices influence the chemical and physical properties of the soil (Otsubo et al., 2008). In the conventional soil management system (CM), for example, there is intense soil disturbance in the surface layer, which favors the decomposition of the organic matter. Minimum tillage (MT) consists of disturbing the soil as little as possible, keeping the plant residue on its surface, and has the advantage of improving or maintaining the physical attributes of the soil (Gonçalves, & Benedetti, 2005).

The rotation of crops with cover crops is considered a good alternative to restoring soil quality in areas degraded by intensive cultivation (Santos et al., 2014; Zotarelli et al., 2012).

Nevertheless, in these areas, there are records of increased soil compaction in the layer located between 0.07 m and 0.15 m (Suzuki et al., 2008; Drescher et al., 2011), resulting from management oversights, such as lack of diversification, excessive liming, use of seeders devoid of ridging ploughs, with fertilizer deposition on the surface or topsoil, intensive grazing, and increased frequency of agricultural machinery traffic (Denardin, Kochlann, & Faganello, 2011).

As a strategy to restructure or delay the increase in soil compaction, implements are often used for scarification purposes (Jin et al., 2007). The use of this practice, however, should be limited, as it requires high energy consumption, investment in equipment and changes in the cultivation system (Chamen et al., 2015). In addition, the benefits of soil scarification on crop yields do not always materialize (Gubiani et al., 2013, Nunes et al., 2014).

Studies have shown that soil tillage reduces soil organic matter content and, consequently, porosity and water storage in Red Latosol under native cerrado region (Figueredo, Ramos, & Tostes, 2008).

Thus, conservation management provides greater efficiency in the control of water erosion, due to the lower water losses caused by surface runoff (Zhou, Al-Kaise, & Maçariqueiro, 2009).

Therefore, the cultivation of green manures is the ideal practice to be adopted, as it promotes the protection of the soil surface against the impact of rainwater, thanks to the presence of plants or plant residues on the area (Bonini, & Alves, 2012). As with corn, which being a grassy plant, has a higher C/N ratio than legumes, and its straw has a slower rate of decomposition, being able to remain on the soil surface for a longer period, protecting it, for example, from water erosion, which could minimize its productive capacity (Sandini et al., 2011).

*2.1 Water and Soil Losses*

Areas with conventional soil preparation and devoid of vegetation cover on the surface are more susceptible to water erosion, as this system favors the formation of surface sealing, characterized by a thin layer of soil that becomes compacted by the direct impact of raindrops on or soil (Panachuki et al., 2011).

To increase the generation of information on soil and water losses in agricultural systems under different soil management systems and vegetation covers, the application of simulated rainfall has been widely used (Ries et al., 2009). The use of portable rainfall simulators makes it possible to study the dynamics of the erosive process altered by soil management, as it is easily repeatable and fast to obtain soil erosion rates (Alves Sobrinho, Gómez-Macpherson, & Gómez, 2008).

Its evaluation results from several factors that influence the erosion process, namely: rainfall erosivity (R); soil erodibility (K); soil use and management (C); conservation practices (P); and topography (LS), the latter being represented by the effects of tilt length (L) and slope (S) (Durães, & Mello, 2014).

Local impacts such as soil erosion and compaction, once installed, give rise to associated impacts in downstream areas, such as pollution and silting of water bodies (Lal, 2014).

In isolation, the presence of plant residues as soil cover is the most important factor in the dissipation of rainfall impact energy (Panachuki et al., 2011). In areas under pasture with a high cover percentage, with the increase in the surface roughness of the soil (Nacinovic, Mahler, & Avelar, 2014), favors greater water infiltration and, subsequently, less surface runoff (Amaral et al., 2008).

Nevertheless, it is favored in systems considered conservationist, such as no till and pasture under adequate management, with little or no soil rotation and maintaining the vegetation cover on the surface, with the formation of larger and more stable aggregates (Souza et al., 2005), providing increased soil resistance to erosion (Engel et al., 2009).

Although visual evaluations have recently been highlighted in the literature to establish levels of degradation (Melloni et al., 2008; Niero et al., 2010), pasture degradation can be better portrayed by changes in quality indicators (Pessoa et al., 2012). According to Costa et al. (2012), physical indicators such as high values of resistance to penetration, are efficient in discriminating areas with lower growth and production of roots, which reduce the absorption capacity of the root system and affect aerial biomass production.

### *2.2 Cover Plants vs. Nutrient Cycling*

The cultivation of cover crops in the no-tillage farming (NTF) system can favor the accumulation of organic matter (OM) in soils and increase the efficiency of nutrient cycling, being crucial for the sustainability of production systems and, in the case of phosphorus (P), about 77% and 79% of the total nutrients in the leaves and dead roots, respectively, are available for the growth of the cultivated plants after cultivation of the cover crop (Borkert et al., 2003).

In general, green fertilizers, or cover crops used to form NTF straw, play a key role in the cycling of nutrients, both those added by mineral fertilizers and not utilized by commercial crops and those originating from the mineralization of soil organic matter (Torres, Pereira, & Fabian, 2008).

Among the species used in straw production, Fabaceae plants are notable for fixing atmospheric $N_2$ and for their low C/N ratio, which, along with the presence of soluble compounds and low amount of lignin and polyphenols in their tissues (Cobo et al., 2012) favors rapid decomposition and mineralization, with significant nitrogen (N) contribution to the soil-plant system, but with the reduction of the soil cover, which essential for NTF (Ferreira et al., 2011; Partelli et al., 2011).

On the other hand, Poaceae plants contribute with relatively high amounts of dry matter, characterized by the high C/N ratio, which can increase the persistence of the soil cover, but with frequent problems due to N immobilization (Perin et al., 2004).

With emphasis on N dynamics and straw maintenance in NTF, Giacomini et al. (2004) argued that the ideal situation would be a straw with C/N ratio of intermediate plant residue (17.5 to 30) to achieve a balance between soil cover maintenance (given the persistence of plant remains) and the availability of N for subsequent crops. According to the authors, this would be possible with the consortium between Poaceae and Fabaceae.

Thus, crop rotation with cover crops can be considered as an alternative to restore soil quality in areas degraded by intensive cultivation. This is because rotation can promote nutrient cycling and improve soil structure, as well as improve its physical attributes (Zotarelli et al., 2012; Santos et al., 2014).

### *2.3 Cover Plants vs. Crop Decompaction*

The history of soil use by humans has been shown to be intensive and disorderly, leading to degradation (Bonini et al., 2016). Due to the concern of equating the problems related to water and soil loss and its relationship with the adopted management, it is necessary to emphasize studies aiming at more information about the physical quality of the soil with the use of cover species.

Thus, Crotalaria juncea plants have roots capable of growing in layers of compacted soil and develop greater number of thin lateral roots in this layer, thereby contributing to the formation of biopores and improving soil physical conditions (Foloni, Lima, & Büll, 2006).

Abreu, Reichert, and Reinert (2004), demonstrated the negative effects caused by compaction in the water properties of a sandy loamy Acrisol. Nevertheless, with Crotalaria cultivation, there was an increase in hydraulic conductivity, infiltration and water storage in the soil.

This fact can be evidenced as both the *Crotalaria juncea* and *Crotalaria spectabilis*, which are annual legumes, with a semi-ligneous stem, branched in the upper part, have deep roots that are capable of breaking compacted layers (Rosolem, Foloni, & Tiritan, 2002).

The pigeon pea (Cajanus cajan) is another species that has an aggressive root system, which can promote the recycling of nutrients through its absorption of the deeper layers of the soil can be used in areas with compaction problems in the no-tillage system (Teixeira et al., 2005).

The velvet bean (*Mucuna pruriens*) is a species widely used in agriculture in the practices of green fertilization, contributing to the improvement of the chemical and physical properties of the soil (Barthès et al., 2004).

Thus, the physical and chemical quality of the soil can be improved with the increase of the organic matter contents and availability of nutrients for the plants. In studies conducted by Bonini and Alves (2011), it was found that the use of green manures (Crotalaria, velvet bean, jack bean (*Canavalia ensiformis*) and their combination with limestone and gypsum) had a positive impact on improving the physical quality of a degraded red Latosol in recovery. Furthermore, the use of cover crops under direct seeding improves the physical properties of the soil, such as porosity, density and resistance to penetration, as verified in a succession of crops with corn and soybean (Alves & Suzuki, 2004).

### *2.4 Physical Attributes vs. Physical Soil Quality*

The effect of management on soil physical properties is dependent on its texture and mineralogy, which influence the resistance and resilience of the soil to certain agricultural practices (Seybold, Herrick, & Brejda, 1999). Alves and Suzuki (2004), when evaluating a degraded area in recovery with the use of green manures, sewage sludge and pasture, observed that the use of cover crops combined with succession of crops (corn and soybean) under NTF improved soil physical properties, such as porosity, soil density, and resistance to penetration. Studies have shown that increasing soil organic matter content has improved soil physical properties, such as reduced soil density and increased soil water infiltration (Alves, Suzuki, & Suzuki, 2007).

Nevertheless, these models are of complex application and emphasize the quality of the soil aimed at the vegetal production, its application being intended mainly for research.

Where the impacts of the use and management on soil physical quality have been quantified using different physical properties related to the shape and structural stability of the soil. They include soil compaction, soil density, soil resistance to root penetration, structure, total porosity, pore size and continuity, nutrient adsorption and absorption, water infiltration and redistribution, gas exchange, and root system development (Bonini & Alves, 2011, 2012).

In the evaluation of environmental impacts, quality indexes are used, namely: water infiltration, soil density, organic matter content ensuring a more efficient and sustainable management of the soil (Dexter, 2004a, 2004b, 2004c).

The attributes most widely used as indicators of soil physical quality are those that consider the effective depth of rooting, total porosity and pore size distribution, particle size distribution, soil density, soil resistance to root penetration, optimal hydric interval, compression index, and stability of the aggregates (Richart et al., 2005).

In addition, soil compaction is an important cause of productivity losses due to physical changes in the root environment. These changes encompass the reduction of oxygen and water availability and the increase in soil resistance to root growth (Debiasi et al., 2010).

The understanding of the soil compaction process and the search for alternatives to mitigate its effects have given rise to studies on a global scale, as compaction is considered one of the main threats to the maintenance of soil quality in agricultural areas (Keller et al., 2013). In the southern region of Brazil, over 80% of the grain production area is cultivated with soybean (*Glycine max* L.), corn (*Zea mays* L.) and wheat (*Triticum aestivum* L.) in no-tillage farming (Cooperativa dos Agricultores de Plantio Direto, 2012). In these areas, the increase in soil compaction has caused a restriction to the root growth of the plants and, subsequently, the concentration of roots in the topsoil. This may result in decreased water and nutrient uptake, even in short periods of water deficit, as well as in the reduction of shoot growth and crop productivity (Klein, Baseggio, & Madalosso, 2009).

Therefore, due to the concern with the parameters to be studied, which are aimed at water and soil loss, it is of paramount importance to study the structural quality of the soil under different uses and management.

## 3. Conclusion

Studies related to cultivation with cover species have presented positive results in relation to soil physical structure, in addition to minimizing the water and soil losses and contributing to soil quality management. Another characteristic of cover crop is that, in some species, the root system can develop at greater depths, thereby increasing total soil porosity after its decomposition and favoring the development of subsequent crops. Therefore, studies are necessary in this field of research, to favor productivity and minimize environmental damage caused by anthropic activities.

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