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No-till surface runoff and soil losses in southern Brazil

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ABSTRACT

No-till is widely used to control soil erosion in agricultural areas in Brazil and is currently practiced on about 30 Mha. However, studies have shown that no-till is not as efficient in controlling surface runoff losses as it is in reducing soil loss. The objective of this study is to evaluate soil and surface runoff losses on small and large plots with differing slope lengths, cropping sequences and tillage systems in southern Brazil. Surface runoff and soil losses under natural rainfall erosion plots (3.5 × 11 m, 3.5 × 22 m, 50 × 100 m, and 100 × 100 m) were evaluated in two experiments in a well-drained Oxisol (>60% clay) with 9% and 7% slopes, respectively. The experiment extended over 14 years comparing 4 different soil management systems: (a) bare soil plots with slope length 22 m; (b) bare soil plots with slope length 11 m; (c) sequence of wheat (*Triticum aestivum*)/soybean [*Glycine max* (L.) Merr] with disk plow + lighter off-set disk-harrow (DP+LD); and (d) sequence of wheat/soybean under no-till (NT). In another experiment using large field plots, three soil tillage regimens (DP + LD; heavy off-set disk-harrow + lighter off-set disk-harrow (HD + LD), and NT) were compared over the course of a 5-yr. crop sequence of black oats (*Avena estrigosa*)/soybean-black oats/corn (*Zea mays* L.)-wheat/soybean- black oats/soybean -blue lupine (*Lupinus angustifolium*)/corn. Results for both experiments show that, when compared with conventional soil tillage (DP + LD or HD + LD), soil losses for NT were > 70% lower. However, the benefit of reduced surface runoff losses was less evident, suggesting the need to implement additional practices to control surface runoff to avoid transport of pollutants to waterways.

1. Introduction

Currently practiced on about 100 Mha worldwide (Derpsch et al., 2010), no-till (NT) is the predominant soil management practice used in Brazilian agriculture for controlling soil erosion, saving energy and improving soil quality. At present, about 30 Mha of Brazilian farmland is under no-till (FEBRAPDP, 2013).

No-till, the direct planting of crops with minimum soil disturbance, together with permanent soil cover and crop rotation are the three main principles of conservation agriculture (Friedrich et al., 2012). Despite the current debate about the limitations of conservation agriculture in sustainably addressing the challenge of feeding a growing world population, the beneficial environmental outcomes of continuous no-till are well recognized in the literature (Pittelkow et al., 2014), mainly when associated with cover crops (Palm et al., 2014). Compared with conventional tillage, these benefits include reduced soil erosion due to minimizing the time that soil is exposed to wind, rainfall and runoff, and reduced runoff due to increased water infiltration (Verhulst et al., 2010).

Raczkowski et al. (2009) compared no-till (NT) and conventional tillage (CT) systems in the southern USA Piedmont region and monitored for six years soil erosion and surface runoff in a corn–soybean rotation in a sandy clay loam and a clay loam soils. They concluded that the six-year surface runoff average for NT was 33% lower than for CT, and the six-year soil loss average was 74.7 Mg ha^{-1} and 2.6 Mg ha^{-1} for CT and NT, respectively. Williams et al. (2009) compared CT wheat-fallow two-year rotation and a no-till four-year rotation within a large field plot study in a coarse-silty soil in northern Oregon, and also concluded that no-till was more effective in reducing surface runoff and soil erosion and helped farmers protect soil and water resources. Numerous other studies have shown that no-till has the potential to substantially reduce surface runoff and soil erosion for different environments and management conditions (Govaerts et al., 2007; De Laune and Sij, 2012; Prasuhn, 2012; Kurothe et al., 2014).

Recently, however, problems of erosion have been observed in many areas under NT cultivation in southern Brazil because of the limited presence of crop residues, removal of structures for surface

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runoff control (terraces), down-slope cultivation and soil compaction (Didone et al., 2014).

Cover crop residues are important to increase water infiltration into soil and reduce surface runoff and erosion, and serve as a primary form of organic matter input that enhances soil biological activity, conserves moisture and moderates soil temperature (Derpsch et al., 2014). Despite these benefits, the high profitability of soybeans and favorable production prospects over the last decade in Brazil have led farmers to adopt a poorly diversified crop sequence (in which cover crops are rarely included in the system) that does not produce enough residue to allow for permanent cover throughout the cropping season.

In order to reduce operations time, the size of agricultural machinery has increased in the region. The large, heavy machines have increased soil compaction and changed traffic patterns leading to more down-slope operation and removal of physical structures such as terraces and surface runoff channels which could restrict machinery traffic (Didone et al., 2014).

Until the 1980s, soil was tilled in this region mainly by disk plow + lighter off-set disk-harrow (DP + LD) or heavy off-set disk-harrow + lighter off-set disk-harrow (HD + LD), which buried most crop residues. Reduced vegetation cover associated with low soil-surface roughness, caused by successive passes of a harrow, and the formation of a compacted layer caused by a disk plough or heavy disk-harrow, leads to a significantly reduced rate of water infiltration into soil matrix (Siqueira Leite et al., 2009; Panachuki et al., 2011). Erosive rainfall during soil tillage, together with a low level of crop residue, were found to be the main causes of high rates of erosion in agricultural areas of southern Brazil (Mondardo et al., 1979) up to that time.

In the 1980s, the Brazilian scientific community started to propose soil management systems that would reduce mechanized operations and retain soil cover during seedbed preparation and sowing of annual crops (Derpsch et al., 1986). Studies showed that NT was the most promising way to control soil loss (Vieira et al., 1978; Eltz et al., 1984; Dedecek et al., 1986; Hernani et al., 1997) and this system came to predominate throughout southern Brazil from the second half of the 1990s (Bollinger et al., 2007).

Confident that NT would be the answer to controlling soil and surface runoff losses, many farmers in the region removed existing terrace structures from their land. In addition, some agricultural operations (seeding, spraying and harvesting) were made down-slope, in the belief that this consumed less fuel than contour farming (Levien et al., 2011). However, these changes, combined with an inadequate amount of crop residues at the soil surface, gave rise to conditions where erosive processes could develop in areas under NT (Streck, 2012; Didone et al., 2014).

Studies of soil and surface runoff losses in Brazil and the US under natural and simulated rainfall conditions have shown that NT is very efficient at controlling soil loss. In general, soil loss under NT is reduced by 70% or more when compared with systems in which soil is moved more thoroughly (Laflen et al., 1978; Johnson and Moldenhauer, 1979; McGregor et al., 1975; De Maria, 1999; Raczkowski et al., 2009). However, other studies have shown that NT is less efficient at controlling surface runoff losses, especially in fine textured soils (Voorhees and Linstrom, 1983; Wendt and Burwell, 1985; Ghidey and Alberts, 1998; Roth et al., 1988; Raczkowski et al., 2009). In some cases where surface runoff losses are associated with stage of crop growth or with rainfall events, they may be as large or even greater for NT compared to conventional tillage (Ghidey and Alberts, 1998). Dedecek et al. (1986) showed that, for a well-drained Oxisol in central region of Brazil (Cerrado), surface runoff losses during two development stages of soybean crop were greater for NT than conventional tillage (DP + LD), both with down-slope cultivation.

Pesticide and soluble nutrients losses present in surface runoff have been another concern in NT (Fawcett et al., 1994; Isensee and Sadeghi, 1993). Considering the NT efficiency in controlling soil erosion, and the high nutrient concentration in the soil surface, P-losses occur preferentially in the dissolved-phase (Berg et al., 1988; Isensee and Sadeghi, 1993). Shipitalo et al. (2013) compared surface water quality between NT and chisel tillage (where nutrient

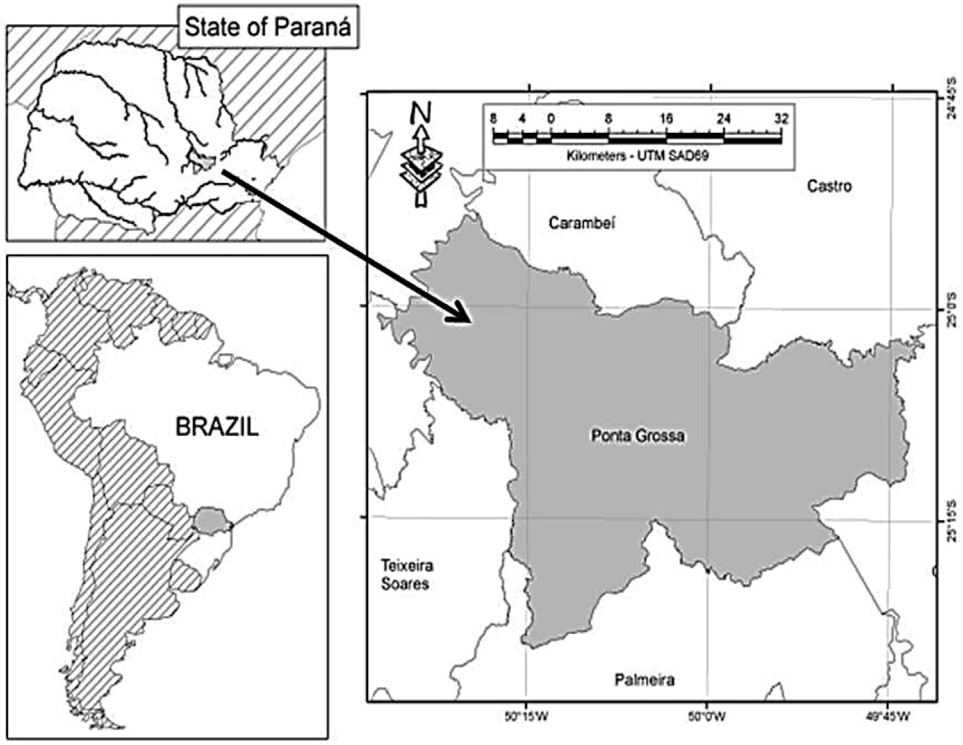

Fig. 1. Map with location of erosion plots.