31. No tillage and cover crops in the Pampas, Argentina

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1. Related practices and hot-spot

No-till, cover cropping; Black soils

2. Description of the case study

This study case is based in the Pampas in Argentina, a vast plain of around 60 million hectares, considered as one of the most important grain producing regions in the world. Three meta-analysis were used for this chapter that integrate results from numerous experiments of no-till (Steinbach and Alvarez, 2006; Alvarez and Steinbach, 2009) and cover crops management (Alvarez *et al.*, 2017), together with some other research in the Pampas.

A meta-analysis was done to integrate results from numerous experiments of short, medium, and long-term periods under no-till management in Steinbach and Alvarez (2006). This review used data from experiments done under experimental designs, using machinery and practices commonly used by farmers, and SOC mass could be calculated to the depth (equal to or deeper than tillage depth). On an equivalent mass basis, 42 paired data sets were used for SOC comparisons of no-till vs. plow till (moldboard plow or disk plow). Another review compiled results produced in 35 field experiments along the Pampas to determine the effect of no-till systems on some soil physical properties, water content, nitrogen availability or crops yield (Alvarez and Steinbach, 2009).

Results of 67 local field experiments with winter cover crop effects on soils and crops were analyzed in Alvarez *et al.* (2017). The majority of the tested graminaceous cover crops were rye (*Secale cereale*), oat (*Avena sativa*), triticosecale (*x Triticosecale*), ryegrass (*Lolium multiflorum*), barley (*Hordeum vulgare*) and rescue grass (*Bromus unioloides*). Legumes cover crops were hairy vetch (*Vicia villosa*) and common vetch (*Vicia sativa*).

3. Context of the case study

The Pampas Region is an extensive prairie that occupy some 22 percent of Argentina. Mean annual temperature ranges from 19 °C in the north to 12 °C in the south, and mean annual rainfall varies from 500 mm in the west to 1100 mm in the east. Soils of the region were developed over eolian-loessic type sediments and the predominant order is Mollisols. Cultivation in the Pampas began by the last quarter of the 19th century and is occupying 50 percent of the surface at present. Low-input agriculture, in combination with livestock production, was performed till 1970; afterwards soybean crop was introduced. This crop replaced pastures and at present it accounts for 60 percent of the seeded area of grain crops. A widespread adoption of no-till occurred since 1990 and nowadays almost 95 percent of agriculture is under no-till in the Pampas. The public sector (researchers and extension units) as well as the associated manufacturing industries (farm machinery, seeds, and agrochemicals) played a key role in establishing a new agricultural production strategy based no-till farming. The no-till association (AAPRESID) as a consolidated network, brought together all relevant stakeholders to share technical and economic information and to promote the benefits of the no-till and cover crops technology. However, there is currently an ongoing debate regarding the possible negative impacts of no-till in marginal areas not suited for cultivation. The northern part of Argentina has experienced a major shift in farming systems from (more sustainable) livestock production to relatively intensive (and less sustainable) cropping systems.

Cover crops are a valuable management option for reducing soil erosion and nitrogen losses from agroecosystems. They improve soil quality but the impacts on crop yield depend on the type of cover crop, the commercial crop considered and the climate. In the Argentine Pampas the introduction of cover crops in rotations is being extensively studied by official institutions. Winter cover crops are being adopted by farmers gradually and many experiments were performed by official institutions to evaluate their suitability as a common production practice. Here we reviewed the effect of no-till and cover crops as agricultural practices implemented in rainfed agriculture at commercial scale in the Pampas for SOC sequestration.

4. Possibility of scaling up

Almost 95 percent of agriculture is under no-till in the Pampas, there is no data on how much of agriculture uses cover crops. Although, no-till and cover crops management is expanding to other regions and to different crops (i.e. horticulture: Bondía *et al.,* 2014; Caracotche, Bondia and Vanzolini, 2014; D´Amico, Varela and Bellaccomo, 2016).

5. Impact on soil organic carbon stocks

The no-till review showed that carbon increases between 3 percent and 15 percent in the topsoil (0-20 cm) in the long term (Steinbach and Alvarez, 2006). Average over the experiments a 2.76 t/ha SOC increase was observed in no-till systems compared with tilled systems (Table 125). The largest increases corresponded to soils from the semiarid portion of the region, and the SOC under tillage explained most of the SOC variation under no-till ($R^2 = 0.94$). The conversion of the whole Pampas cropping area to no-till would increase SOC by 74 MtC, about twice the annual C emissions from fossil fuel consumption of Argentina (40 MtC/yr; CIA World Factbook, 2004). The review of field experiments with winter cover crop reflect that SOC content of the 0–20 cm layer rose ca. 4 percent in fine-textured soils and 9 percent in coarser ones (Alvarez *et al.*, 2017).

Table 125. Evolution of SOC stocks at 0-20 cm depth in no-till systems of the Pampas

Climate zone	Soil type	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	Duration (Year)	More information: number of studies included for the given soil type/climate
Warm Temperate Dry	Entic Haplustoll	39.2	0.33	6.3	3 cropland experiments
Warm Temperate Moist	Haplustol	34.8	3.15	4	2 cropland experiments
Warm Temperate Moist	Luvic Phaozem	78.2	2.14	5	1 cropland experiment
Warm Temperate Moist	Pretrocalcic Argiudoll	67.8	0.48	6	1 cropland experiment
Warm Temperate Moist	Pretrocalcic Paleudoll	51.7	0.71	7	2 cropland experiments
Warm Temperate Moist	Typic Argiudoll	46.7	0.48	8.2	36 cropland experiments
Warm Temperate Moist	Typic Hapludoll	35.6	1.86	5	1 cropland experiment
Warm Temperate Moist	Typic Haplustoll	50.5	1.50	7.7	3 cropland experiments

Source: Data from Steinbach and Alvarez (2006)

6. Other benefits of the practice

6.1. Improvement of soil properties

No-till has been an effective solution to the problem of soil erosion in the Pampas and is meant to keep soil in its place and keep the top layer, which is the most fertile fraction. Soil physical properties improved after cover crops. Bulk density was minimally affected, structural stability and water infiltration increased, while soil penetration resistance decreased. Nitrate-N decreased after cover crops by 30 percent regardless of the cover crop species was or was not legume (Alvarez *et al.*, 2017).

6.2 Minimization of threats to soil functions

Table 126. Soil threats

Soil threats	
Soil erosion	No till and cover crops increase surface plant residues, which prevent from wind erosion and water runoff (Buschiazzo, Zobeck and Abascal, 2007).
Nutrient imbalance and cycles	Legume cover crops increase soil nitrogen, incorporation of N via atmospheric fixation; while grass species tend to reduce available nitrogen, and used for the retention of nutrients (catch crop).
Soil salinization and alkalinization	Cover crops are used to keep salty water tables at low levels by increasing water consumption.
Soil contamination / pollution	Cover crops are used for reduction of weeds by competition, reducing the use of herbicides.
Soil biodiversity loss	No-till increase the biodiversity of soils (Gomez *et al.*, 2007).
Soil compaction	The incorporation of organic matter (green manure) or high root biomass from cover crops are used for the decompaction of the soil.
Soil water management	No-till increase soil available water (Dardanelli, 1998). Cover crops are used to consume water to reduce flooding or providing soil cover to reduce evaporation.

6.3 Increases in production (e.g. food/fuel/feed/timber)

Soybean yield was not affected by tillage system, but wheat and corn yields were lower under no-till than under plow tillage without nitrogen fertilization (Alvarez and Steinbach, 2009). Corn yield increased by 7 percent after legume species cover crop as compared to a fallow (Alvarez *et al.*, 2017).

6.4 Mitigation of and adaptation to climate change

No-till system reduces fuel consumption as compared to plow tillage, in line with international efforts to reduce fossil fuel consumption, this represents a C saving of 24 to 61 kgC/ha/yr (West and Marland, 2002). Cover crops increase C inputs to the soil.

6.5 Socio-economic benefits

No-till and cover crops may have positive socio-economic benefits. The use of legume cover crops reduces the nitrogen fertilizer costs in cereals, increasing the profit up to 10-15 percent (Capurro *et al.*, 2011). Grass cover crops reduce the need for herbicides and other pesticides, reducing cost but also by helping safeguard personal health. No-till also prevent soil erosion so reducing the risk of floods while protect water quality for farms and cities.

7. Potential drawbacks to the practice

7.1 Tradeoffs with other threats to soil functions

Table 127. Soil threats

Soil threats	
Nutrient imbalance and cycles	Nutrients become highly stratified near the soil surface under no-till (Diaz-Zorita, Barraco and Alvarez, 2004). This might produce a shallow root system. The level of nitrate in soils is significantly lower (-21 kg N/ha) under no-till, reaching to differences as high as 60-80 kg N/ha when comparing with conventional tillage (Alvarez and Steinbach, 2009). No-till generates the necessity of increase nitrogen fertilizers utilization in graminaceus crops.

Soil threats	
Soil contamination / pollution	No-till increased the use of herbicides and their persistence in soils. Cover crops are used also to compete with weeds and to reduce the use of herbicides under no-till, nevertheless the use of cover crops under no-till is still limited.
Soil acidification	Increases of acidity in surface layers of soils under no-till have been widely reported and are usually associated with the acidifying effect of nitrification of ammoniacal fertilizers and the decomposition of crop residues.
Soil compaction	Wheel traffic of heavy machinery over moist soils, especially at harvest can cause substantial compaction to a depth of 20-30 cm and sometimes deeper (Botta *et al.*, 2018).
Soil water management	Cumulative water content to 2m depth decreased by around 20 percent with cover crops (Alvarez *et al.*, 2017).

7.2 Increases in greenhouse gas emissions

Emissions of N_2O were greater under no-till with a mean increase of 1 kg N/ha/yr in denitrification rate for humid pampean scenarios (Steinbach and Alvarez, 2006). Results from Alvarez *et al.* (2013) showed that corn crops under no-till produce higher N_2O emissions than soybean crops due to N fertilization. The increased emissions of N_2O might overcome the mitigation potential of no-till due to C sequestration in about 35 years, and therefore no-till might contribute to global warming. So far, no research has been done in the Pampas about the effect of cover crops on greenhouse gas emissions. However, grass cover crops tend to reduce available nitrogen and increase soil physical properties, and this could reduce denitrification processes under no-till.

7.3 Conflict with other practice(s)

No-till conflict with conventional tillage practice, which it is used by farmers for soil aeration and decompaction. No-till increase bulk density by 4 percent in comparison to conventional tillage, and cone penetration increased by 50 percent in many soils (Alvarez and Steinbach, 2009). The increase of bulk density is greater in soils of initial low bulk density.

7.4 Decreases in production (Food/fuel/feed/timber/fibre

When comparing yields of summer crops after fallow or cover crops, soybean yield was little affected (~2 percent) by the cover crop (usually grass cover crop), while corn yield tended to decrease when the cover crop was a non-legume (- 8 percent) or significantly increased after legume species (+7 percent).

8. Recommendations before implementing the practice

- Residues of no-till cereal crops are best handled by chopping and spreading very evenly at harvesting.
- It is recommended to have variability in the quantity of aboveground crop residues and roots in soil profile. Increasing in cropping frequency and crop diversity, such as double crops rotation, can produce more roots and reduce possibilities of soil compaction.
- Use cover crops with no-till in order to reduce the need of herbicides and nitrogen fertilizers.

9. Potential barriers for adoption

Table 128. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	Yes	In water-limited areas the adoption of these practices may be hampered because of competition problems for water and nutrient between the ground covers and the main crop (Cooper *et al.*, 2016).
Cultural	Yes	The adoption of no-till was possible due to the rapid adoption of transgenic crops - soybean, maize, and cotton (Pengue, 2005). Herbicide-resistant crops were needed to change from plowing to chemical weed control.
Social	Yes	No-till adoption in Argentina significantly increased the use of pesticides, this brought rejection in much of society, and increased social conflicts against the no-till model of production. (García-López and Arizpe, 2010).
Economic	Yes/No	No-till requires a significant investment in new machinery for their effective implementation (Trigo *et al.*, 2009), which could make the technology not directly applicable to small farming and familiar subsistence agriculture.

Barrier	YES/NO	
		However, planting, spraying and harvesting operations are contracted in most Argentinean farms, achieving huge efficiencies in the use of machinery and making operations cheaper for farmers. Cover crops includes the direct cost for sowing, normally uses low technology (broadcast seeding) and can be done by hand for small areas or mechanically for relatively large areas. Species and cultivar used for cover crops are of low economic value and frequently self-produced seeds. These costs might be overcome by its benefits, as the reduced herbicides and/or tillage cost for weed control.
Knowledge	Yes	No-till substantially change crop management (weeds pest control, fertilization). New knowledge needs to be created locally to adopt this practice.

Photos

Photo 61. Corn under no-till system and cover crops seeded with airplane before corn harvest in March 2020

Photo 62. Cover crop Vicia villosa for weed control and nitrogen fixation previous to sow maize in spring 2019

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