6. No-till

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1. Description of the practice

The need for tillage has been questioned since the dustbowls in the mid-west United States of America in the 1930s. In the decades that followed no-till and other forms of soil cover were developed as practices for soil erosion protection. No-till is a system where a crop is planted directly into a seedbed that has not been tilled since harvest of the previous crop. It is also called zero tillage and it is used in conservation agriculture. The no-till operation consists of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed (Parr *et al.*, 1990). No-tillage systems eliminate all mechanical seedbed preparation before seeding except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact. The entire soil surface is covered by crop residue, mulch or sod. The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with cover crops and crop rotation.

2. Range of applicability

No-till can be applied in all row crops and in all countries. The greatest adoption is in South America where continuous no-till is being used on nearly 100 percent of the cropland in Argentina and Paraguay and approximately 70 percent of the arable land in Brazil (Kassam *et al.*, 2015). It is currently used in agriculture under dry conditions (300 mm/yr in the Plurinational State of Bolivia) to very humid (2000 mm/yr in Brazil).

A review of tillage studies in Nigeria (Opara-Nadi, 1990) shows that no-tillage with residue mulch is appropriate for Luvisols in the humid tropics. No-tillage is used in mechanized wheat farming in the northern United Republic of Tanzania and for some perennial crops (Antapa and Angen, 1990; de Leijster *et al.*, 2019). Several studies have reported the success of no-tillage systems in many parts of the United States of America (Smika and Unger, 1986; Unger, Langdale, and Papendick, 1988; Parr *et al.*, 1990). Though the use of no-till is increasing, adoption has been slow in many parts of the world.

3. Impact on soil organic carbon stocks

In Table 22 is a summary of information from studies on the effect of no-till on soil organic carbon (SOC) sequestration. Conversion to no-till is usually associated with increased SOC stocks in comparison to conventional tillage. However, in most studies SOC content is significantly greater only in the surface soil layers. A number of studies have shown that this effect is sometimes partly or completely offset by greater SOC content near the bottom of the plow layer under conventional tillage. For that reason, SOC stock changes have to be measured to at least 30 cm depth. Moreover, SOC stocks need to be expressed in an equivalent soil mass. Calculating stocks based on fixed depth layers, and without consideration of the equivalent soil mass, results in an overestimation of the increase ins SOC under no-till. Increases in SOC storage induced by no-till conversion seem to be largely related to increases of crop C inputs. Overall, this difference in favor of no-till increased significantly with the duration of the experiment, so long-term experiments are necessary for evaluation of SOC changes. Most of the studies of no-till effects on SOC are from North America and Europe; Oceania, Central and South America are less represented, and information from the other continents (Asia and Africa) is scarce or lacking.

Table 22. Reviews of no-till effects on soil carbon

Location	Climate zone	Soil type	Baseline C stock (tC/ha)	Additional C storage ± SE (tC/ha/yr)	Duration (Years)	Depth (cm)	Methodology; Main crops	Reference
Global studies								
Europe, North and South America	Various	Various	95.4	0.30[1]	> 5 (mean: 16)	≥30 cm (0-30 to 0-100)	MA; Various crops (mainly maize, wheat, soybean). Baseline is the average value of full inversion tillage	Angers and Eriksen-Hamel (2008)
Africa, Europe, Oceania, North and South America			NA	ns	>4 (4-41)	≥40 cm (0-40 to 0-120)	MA	Luo, Wang and Sun (2010)
Americas and Europe			62.6	0.23 ± 0.08	>5 (mean: 15)	0-30	MA; Various crops Baseline is the average of inversion tillage treatment	Virto *et al.* (2012)
Boreo-temperate regions from Europe, Oceania, North and South America			NA	0.13 ± 0.09	>5 (mean: 17.6)	0-30 and 0-60	MA; mainly annual crops	Meurer *et al.* (2018)
Regional meta-analysis or reviews								
Mediterranean croplands (Mediterranean basin, California, Chile, South Africa, Australia)	Warm Temperate Dry	Various	NA	0.48	>3 (mean: 11.7)	0-33.8	MA; Cereals, horticulture, woody crops	Aguilera *et al.* (2013)
National studies								
Brazil	Tropical moist	Sand and clay soils	NA	0.41 ± 0.06	Various	0-20 and 0-30	R; Soybean and maize	La Scala Júnior, De Figueiredo and Panosso (2012)

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[1] Total C stocks difference between full inversion tillage (FIT) and no-till (NT) = +4.9 tC/ha (95.4 tC/ha under FIT and 100.3 tC/ha under NT divided by the average duration, i.e. 16 years).

Location	Climate zone	Soil type	Baseline C stock (tC/ha)	Additional C storage ± SE (tC/ha/yr)	Duration (Years)	Depth (cm)	Methodology; Main crops	Reference
United States of America	Various	Various	NA	0.04 ± 0.6 ns	13.5	0-60	R; Various crops	Blanco-Canqui and Lal (2008)
China	Various	Various	NA	0.14 ± 0.12	>3 (mean: 6.5)	0-30	MA; Various crops (mainly maize, wheat, rice, soybean)	Du *et al.* (2017)
Local studies								
Pampean region, Argentina	Warm Temperate Moist	Typic Argiudoll	46.7	0.48± 0.11	1 to 20 (mean: 8.2)	0-20	MA; Annual crops (Corn, wheat, soybean)	Steinbach and Alvarez (2006)
	Warm Temperate Dry	Entic Haplustoll	39.0	0.32± 0.18	5 to 8 (mean: 6)	0-20	MA; Annual crops (Wheat, sunflower)	
Northern France	Warm Temperate Moist	Haplic Luvisol	44.2	0.02	41	0-28	Annual crops in rotation	Dimassi *et al.* (2014)
Eastern Cape, South-Africa	Semi-arid	Haplic Cambisol	29.8	1.71	3	0-20	Maize, soybean, wheat	Mtyobile, Muzangwa and Mnkeni (2019)
Buffelsvlei, South-Africa	Cold Arid	Chromic Lixisol	19.7	0; ns	8	0-30	Conservation Agriculture; Millet, sunflower, maize	Swanepoel *et al.* (2018)[2]
Tripura, India	Tropical Moist	Typic Kandiudults	19.1	0.18	4	0-30	Conservation Agriculture; Rice, rapeseed, cowpea	Yadav *et al.* (2019)

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2 Also see case study No.5, Volume 4

MA: Meta-analysis; R: Review; NA: not applicable; ns: not significant

4. Other benefits of the practice

4.1. Improvement of soil properties

No-till can often increase soil carbon, soil quality and function, and reduce CO_2 emissions when compared to conventional tilling practices (Karlen *et al.*, 1994; Kladivko, 2001; Bolliger *et al.*, 2006). Soil microbial biomass increases (+37 percent), including both fungal (+31 percent) and bacterial biomass (+11 percent), in top 20-cm soils under no-till agro-ecosystems, but not in sandy soils (Chen *et al.,* 2020). No-till increased wet aggregate stability by 1 to 97 percent, water infiltration by 17 to 86 percent, and available water by 44 percent (Blanco-Canqui and Ruis 2018). However, no-till benefits largely depend on crop rotations (Mtyobile *et al.,* 2019). In some studies, however, no changes in SOC, aggregate stability or water infiltration have been found (Alvarez *et al.,* 2009; Swanepoel *et al.,* 2018).

4.2. Minimization of threats to soil functions

Table 23. Soil threats

Soil threats	
Soil erosion	Surface crop residue prevent from wind erosion by reducing wind speed in the soil surface and water erosion by absorbing the energy of raindrop impact (Langdale *et al.*, 1979).
Soil biodiversity loss	No-till increase soil biodiversity (Soane *et al.,* 2012).
Soil water management	Surface crop residue decreases soil temperature and soil water evaporation (Dardanelli, 1998).

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

In Europe, reduction of 5 percent in yield have been reported for no-till crops, and yields tend to approach or exceed those after ploughing as the rainfall decreases from northern to southwestern Europe (Soane *et al.* 2012). In Argentina, a review by Alvarez and Steinbach (2009) indicates soybean yield was not significantly different between plow tillage and no-till.

In unfertilized situations wheat and corn yields were in average 9–12 percent significantly lower under no-till. Yield was not affected by tillage management when nitrogen was not a limiting resource (Alvarez and Steinbach, 2009). A global meta-analysis showed that overall no-till reduces yields, but this response is variable (Pittelkow *et al.*, 2014). When combined with residue retention and crop rotation no-till can produce equivalent or greater yields than conventional tillage. Moreover, in dry areas no-till significantly increases rainfed crop yields.

4.4. Mitigation of and adaptation to climate change

No-till farming reduces the rapid oxidation of organic matter to CO_2 which is induced by tillage (Alvarez et al., 1995). Limited C inputs, ranging between 0.1 and 1 g C/kg soil/yr, are likely to be the major bottleneck for C increase (Virto *et al.*, 2012: Powlson *et al.*, 2014; VandenBygaart, 2016). The presence of a mulch at the soil surface decreases soil water evaporation (Chakraborty *et al.*, 2008; Verhulst *et al.*, 2011; Balwinder et al., 2011), and hence no-till may become an important climate-change adaptation strategy for ever-drier regions of the world (Pittelkow *et al.*, 2014).

4.5. Socio-economic benefits

No-till facilitates seeding of crops in soils where seed bed preparations is not easy. Moreover, surveys among European farmers indicated that reduced working time and lower costs were the dominant reasons for adopting no-till. The reductions of labour and mechanization costs with no-till represent 46 euros per hectare, while an increase of herbicide costs of 5 euros per hectare (Soane *et al.* 2012). Australian no-till farmers recognized the soil benefits of no-till, but it was not an important factor in explaining the no-till adoption. Shorter-term crop production benefits, such as weed management and the ability to sow crops earlier on less rainfall, were influential (D'Emden, Llewellyn and Burton, 2008). In India, the main driver of adoption was found to be a significant, immediate and recurring "cost saving effect", reduced tractor time and fuel for land preparation and wheat establishment led to around 15 percent saving in operating costs (Erenstein *et al.,* 2012). Profit increase of 800–2200 Rs/ha/yr was attributed to cost savings under no-till in India (Sidhu, Vatta, and Dhaliwal, 2010).

5. Potential drawbacks to the practice

5.1. Tradeoffs with other threats to soil functions

Table 24. Soil threats

Soil threats	
Nutrient imbalance and cycles	Available P and K tend to become highly stratified near the soil surface. Soil temperature is lower under no-till slowing down nutrient release from organic matter (N and S).
Soil salinization and alkalinization	Crop production in marginal soils can increase soil salinization risks.

Soil threats	
Soil contamination /pollution	No-till might increase herbicide persistence in soil (Mickelson *et al.*, 2001).
Soil acidification	Concentration of SOC in the first upper layer decreases the pH (Limousin and Tessier, 2007). Increases of acidity in surface layers of soils under no-till have been associated with the acidifying effect of nitrification of ammoniacal fertilizers and the decomposition of crop residues (Soane *et al.*, 2012).
Soil compaction	No-till without proper management tend to increase soil compaction (Blanco-Canqui and Lal, 2008). 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).

5.2. Increases in greenhouse gas emissions

No-till generally increased N_2O emissions in poorly aerated soils but was neutral in soils with good and medium aeration (Rochette, 2008). A meta-analysis comparing soil N_2O emissions from no-till and conventional tillage showed that emissions were significantly higher under no-till in the tropical climate (74.1 percent) and warm temperate climate (17.0 percent), but not in the cool temperate climate (Mei *et al.*, 2018).

This trace gas has a large impact on mitigation potential because 1 kg N_2O–N produces the warming effect of 120 kg CO_2–C (Houghton *et al.*, 2001) and this might reduce the mitigation potential of no-till (Smith *et al.*, 2000; Guenet *et al.*, 2021). However, increased cropping frequency and crop diversity, such as double crops rotation, significantly reduce CH_4 uptake by 18.4 percent, N_2O emission by 21.0 percent, and overall global warming potential by 20.8 percent compared to the single crop monoculture system as revealed by a recent review (Feng *et al.*, 2018).

5.3. Conflict with other practice(s)

No-till has a major influence in the vertical distribution of weed seedbank (Swanton *et al.*, 2000). Weed species which germination is stimulated by exposure to light become more prevalent under no-till. The performance of herbicides, particularly for soil active herbicides, is reduced under no-till. In summary, no till has effect on the weed ecology and care need to be taken with weed control practice (Chauhan, Gill and Preston, 2006).

5.4. Decreases in production (e.g. food/fuel/feed/timber/fibre)

In cold climates, the presence of crop residues on the surface generally results in wetter and cooler conditions, thus favoring disease and pests, and pathogens also multiply with an additional source of energy (Reicosky, 2008).

5.5. Other conflicts

The large adoption of no-till is in regions characterized by large-scale mechanized monocropping of corn, soybeans, wheat, and other row crops. The adoption of NT farming is practically negligible by poor small land holders of sub-Saharan Africa (SSA), South and Southeast Asia, Central America, the Caribbean, and the Pacific Islands. These are also the regions where the potential benefits of NT farming are probably the highest (Lal, 2007).

6. Recommendations before implementing the practice

A list of top critical factors for no-tillage adoption has been prepared by Derpsch (2008):

- Improve your knowledge about the system, especially in weed control and plan for the change to permanent no-tillage at least 1 year in advance.
- Analyze your soil (aim for a balanced nutrient and pH status).
- Avoid soils with poor drainage or invest in an adequate drainage system before starting no-tillage. No-tillage does not work on poorly drained soils.
- Level the soil surface. An uneven soil surface is a very unfavorable condition for seeding at an even depth.
- Eliminate soil compaction issues before starting no-till. When plow pan compaction is present it needs to be removed before going into a no-till system. Use a chisel or subsoiler.
- A special no-till seeding machine is needed. Buy or find one to rent.
- Start on 10 percent of your farm
- Use crop rotation and green manure cover crops to produce the largest possible amount of mulch cover. This is the best way to avoid soil compaction and to reduce N_2O emissions.
- Be prepared to learn constantly and watch for new developments.

7. Potential barriers for adoption

Table 25. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	Yes	In cold climate sites, problems have been found when cereal crops were drilled in the presence of crop residues on the surface. Crops which require much traffic of heavy harvesting machinery, may cause difficulties for no-till establishment of the following crop. Soils with imperfect drainage and weak structure are unfavorable for no-till (Soane *et al.*, 2012). In dry climate, there are also risks of residue fire.
Cultural	Yes	Farmers have been plowing for weed control and seedbed preparation for many millennia (Lal, Reicosky, and Hanson, 2007).
Social	Yes	Social conflicts are associated with an increase of the use of pesticides under no-till (Levidow, 2007).
Economic	Yes	No-till requires a significant investment in new machinery for their effective implementation (Trigo *et al.*, 2009). A profitability analysis in the U.S. suggests that about 10 years after implementation are needed to recuperate the initial expense of no-till implementation, with the probability of higher relative profit increasing with longevity (Cusser *et al.*, 2019).
Institutional	Yes	In Argentina, 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. During the 1990's and along with farmer associations with similar objectives in Brazil, Mexico, Paraguay, and Uruguay, these organization later coalesced into the American Confederation of No-Till Farmers Associations (CAAPAS, www.caapas.org).
Knowledge	Yes	No-till substantially change crop management (weeds pest control, fertilization). New knowledge needs to be created locally to adopt this practice.

Photos of the practice

Photo 7. Corn under no-till, after wheat. Spring 2019, Santa Fe, Argentina

Photo 8. Seeding pastures under no-till in a cattle farm. Autumn 2019, Santa Fe, Argentina

Table 26. Related cases studies available in volumes 3 and 5

Title	Region	Duration of study (Years)	Volume	Case-study No.
Short-time effects of no-tillage in olive orchards in Lebanon	NENA	5	3	1
16 years of no tillage and residue cover on continuous maize in a Black soil of China	Asia	16	3	10
Rice straw mulching, charcoal, and no-tillage on maize in Lopburi, Thailand	Asia	4	3	11
Mediterranean olive orchard subjected to sustainable management in Matera, Basilicata, Italy	Europe	20	3	16
Application of mulching in subtropical orchards in Granada, Spain	Europe	5	3	20
Reduced tillage frequency and no-till to allow ground covers and seeding cover crops in rainfed almond fields, Spain	Europe	10	3	21
No tillage and cover crops in the Pampas, Argentina	Latin America and the Caribbean	2 to 8	3	31
Increasing Yield and Carbon Sequestration in a Signalgrass Pasture by Liming and Fertilization in Sao Carlos (SP, Brazil)	Latin America and the Caribbean	6	3	32
Crop-pasture rotation on Black Soils of Uruguay and Argentine	Latin America and the Caribbean	10 to 48	3	39
Zone Tillage of a Clay Loam in Southwestern Ontario, Canada	North America	13	3	44
Long-term no-tillage maize in Kentucky, United States of America	North America	48 and 79	3	45
Deficit irrigation scenarios using sprinkle irrigation system in western Kansas, United States of America	North America	5 and 8	3	46

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