

The effect of conservation tillage on crop yield production (The Review)

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Abstract: Conservation tillage (CA) systems are gaining increased attention as a way to reduce the water footprint of crops by improving soil water infiltration, increasing soil moisture and reducing runoff and water contamination. The concept of water footprint is defined as the total volume of freshwater used, directly or indirectly, to produce a product or process including the total amount of water required in agriculture for growing crops. About 141 million and 645 thousand hectares of land in the world have been destroyed by erosion because of inappropriate tillage operations. The total amount of 26 billion tons of soil eroded is estimated and about 2 billion tons comes out from Iran. Parallel to the erosion, loss of soil organic matter that occurs on to several factors, farming has become more challenging. Many strategies exist to combat soil degradation through erosion and compaction on agricultural fields. One of these strategies is conservation agriculture (CA). Reduced or no-tillage techniques, together with crop residue management and crop rotation are the pillars of CA. The term reduced tillage covers a range of tillage practices but it never involves inverting the soil. In this way, soil disturbance is minimized and crop residues are left on the soil. Studies in many European countries have shown that CA can indeed be very effective in combating soil erosion. However, soil and water conservation do not appear as main drivers in farmers' decisions to shift or not to CA. Economic factors tend to be more important, but there are a lot of uncertainties on this domain. Studies show that production costs are mostly reduced, mainly by reduced fuel costs. Although many European studies have investigated the effect of reduced soil tillage on crop yields, a lot of uncertainties still exist.

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1. Introduction

Soil and water conservation techniques (SWCTs) have long existed as a means to combat the detrimental effects of soil loss through interrill and rill erosion (Morgan, 2005; Montgomery, 2007; Cerdà et al., 2009). The aim of SWCTs is to reduce both on-site runoff (R) and soil loss (SL) as well as the off-site consequences of erosion such as sedimentation in reservoirs, deterioration of water quality and flooding (e.g. Verstraeten and Poesen, 1999; Owens et al., 2005; Vanmaercke et al., 2011a). Recent research also focuses on the role of SWCTs in the conservation of various ecosystem functions of the soil and its role in bio-geochemical cycles, including carbon sequestration (e.g. Conley, 2000). Whereas the role of SWCTs in reducing soil loss is well recognized (e.g. Morgan, 2005; Boardman and Poesen, 2006), there is still a need to integrate SWCTs effectively into good agricultural and sustainable land management practices.

2. In arable crops growing soil tillage is usually marked as one of the greatest energy and labour consumer. The primary tillage operations require 75% F the total energy spent before the seed-time (Pelizzi et al., 1988). Although numerous investigations have

proved efficiency of non-conventional soil tillage systems in a manner of saving significant amount of energy and labour, 93.7% of arable growing land in Slavonia and Baranja are still being ploughed (Zimmer et al., 2002).

Substitution of conventional tillage system by various types of conservation tillage in USA recently reached level of 41% total arable land (45.64×10^6 hectares). Within mentioned land area no-till reached even 23% or 24.96×10^6 hectares. During recent years Europe also noticed trend of non-conventional tillage followers are increased.

Therefore, nowadays conservation tillage occupies 1.3% of total agriculture land in Portugal, very significant amount of 14% in Spain, 17% in France, 20% in Germany till fascinating 30% of total agricultural land in United Kingdom. Two basic reasons that initiated mentioned changes could be explained by ecological and economic factors. Conventional tillage is on the one side the most expensive, complicated, organizationally slow system and is significantly great energy and labor consumer, while on the other side it is also ecologically unfavorable way of soil tillage (Zugec et al., 2000).

2. Reasons to Use Conservation tillage

2.1. Benefits

• Yields are as good, if not better, than reduced or intensive tillage systems when attention is paid to management details.

• Optimize soil moisture. Improved infiltration and increased organic matter are especially important on droughty soils and may help the crop through a persistent dry period. Tillage reduces available moisture by about ½" per trip.

• Saves time. On a 404.7 hectares farm, an additional 100 hours are needed for every pass (example based on 18' disk, 160 Hp FWD tractor). Many growers take advantage of the time savings by exploring other "opportunities."

• Reduces fuel consumption. In fact, no-till can reduce fuel use by 8.4 gallons/ hectares compared to intensive tillage.

• Reduces machinery wear. Less machinery means fewer pieces need to be replaced. Economists report this amounts to a \$12.355/ hectares reduction in costs.

2.2. Environment

• Reduces soil erosion. This is an obvious benefit of conservation tillage. In fact, a 90% erosion reduction can be expected when using a no-till instead of intensive tillage system.

• Increases organic matter. Each tillage trip oxidizes some organic matter. Research shows continuous no-till can increase organic matter in the top 2 inches of soil about 0.1% each year.

• Improves water quality. When combined with crop nutrient management, weed and pest management (IPM) and conservation buffers, conservation tillage plays an important role in improving both runoff to streams, rivers and lakes as well as water that finds its way into aquifers.

• Wildlife. Conservation tillage improves habitat. The crop's residue provides food and shelter. And, if combined with other needed habitat (grassy cover and woody areas), wildlife may increase significantly.

3. Conservation Tillage System Management

Managing a conservation tillage system is an important part of the overall farm management strategy. It includes planning crop rotation; analyzing soil conditions; keeping tabs on soil temperature and moisture; adjusting nutrient and weed management approaches; and selecting the equipment and attachments to match your favorite farming system.

3.1. Crop Rotation

The previous crop will, in many ways, dictate the amount of tillage (if any) that can be done and still leave around one-third of the soil's surface covered by crop residue. Corn, wheat and sorghum produce high levels of residue after harvest. Thus, you can either

plant directly into these residues (no-till/strip-till) or use one or two low-disturbance tillage passes (mulch-till) and still leave approximately one-third of the soil covered. Soybeans and cotton produce much less crop residue. Thus, just one tillable pass may not leave enough cover after planting.

3.2. Soil Conditions

While compaction, drainage and low fertility levels are important to correct in any tillage system, they are especially important to correct prior to the adoption of a conservation tillage system. Improved soil structure and higher organic matter levels may reduce the necessity to repeat these corrective measures.

3.3. Equipment Selection and Adjustment

To assure good seed-to-soil contact when planting, equipment must be selected and adjusted to match your system, soils, yields and size. For instance, your combine needs to have a chaff spreader so the crop's residue is evenly spread across the full width of the combine. If your equipment is extremely old, you'll need to modify and strengthen it to handle high residue and more strenuous field conditions. In some regions residue managers, coulters and other planter attachments may be needed. Special equipment-like strip-till equipment-may be needed for sensitive crops (corn and cotton) in climates where moisture keeps soil cool at planting time. Row width will also need to be analyzed.

3.4. Weed Control

Weed control strategies may need to be modified. While weed pressure often seems to increase the first few years, over time weed pressure may decrease. A different array of weeds may prefer different tillage systems. For instance, weed species commonly found in intensive tillage systems often differ from those commonly found in a no-till system.

4. Bottom Line

If farmers properly manage these factors (crop rotation, soil conditions, equipment selection and adjustments, plant nutrients and weed control) conservation tillage will help to improve the bottom line. It's also a critical step in maintaining (and even improving) soil productivity. Best of all, conservation tillage helps to keep topsoil, nutrients (particularly phosphorus) and crop protection products on farmers fields and out of creeks, streams and lakes. In fact, scientific evidence indicates approximately 80% of environmental issues that result from cropland can be corrected by integrating conservation tillage, conservation buffers, nutrient management, weeds and integrated pest management (IPM) systems into farm management approach.

5. Tillage System Comparisons

Typical advantages and disadvantages of tillage systems are shown in Table 1. The most important advantage of conservation tillage is significantly less soil erosion. Fuel and labor requirements are also reduced with conservation tillage, Tables 2 and 3. This information is useful in determining the suitability of tillage systems or combinations of systems for various situations. However, base selection on specific soils and cropping circumstances as well as individual management ability.

Of the systems compared in the tables, the moldboard plow system has the greatest fuel and labor requirements for tilling and planting corn and soybeans. Compared to the commonly used disk system, no-till saves about 1-1/2 gal/ac in fuel and 20 minutes of labor/ac.

Labor savings allow a larger area to be farmed without additional equipment or help. Even if increased acreage is not anticipated, more timely planting may result in greater yields. In addition, costs for tractors, tillage equipment and maintenance will be less with fewer tillage operations.

Regardless of the tillage system selected, spread residue uniformly behind the combine using either a

straw chopper or straw spreader. A chaff spreader may be desirable, especially when harvesting small grains or soybeans with larger combines. Uniform distribution of residue and chaff reduces equipment clogging and provides more uniform soil conditions for planting, easier weed control and better erosion control.

Recent advancements in herbicides make weed control with no-till easier than it used to be. Early preplant applications, longer-lasting residual herbicides, and a wide variety of post emerge products are helping assure weed control success with no-till.

Conservation tillage systems represent alternatives at a time when economics require flexibility in crop production. The growing concerns about agricultural sustainability and the environment require reduction of soil erosion. Conservation tillage effectively and economically reduces soil erosion and the resulting sedimentation, a major water pollutant.

Carefully evaluate the need for each tillage operation and pesticide application. Systems with more than two tillage operations prior to planting need careful examination. Additional operations are often unnecessary and only increase soil losses, compaction and production costs.

Table 1. Advantages, disadvantages and typical field operations for selected tillage systems ^a

System	Typical field operations	Major advantages	Major disadvantages
Moldboard plow	Fall or spring plow; one or two spring diskings or field cultivations; plant; cultivate.	Suited for poorly drained soils. Excellent incorporation. Well-tilled seedbed.	Major soil erosion. High soil moisture loss. Timeliness considerations. Highest fuel and labor costs.
Chisel plow	Fall chisel; one or two spring diskings or field cultivations; plant; cultivate.	Less erosion than from cleanly tilled systems and less wind erosion than fall plow or fall disk because of rough surface. Well adapted to poorly drained soils. Good to excellent incorporation.	Little erosion control. High soil moisture loss. Medium to high labor and fuel requirements.
Disk	Fall or spring disk; spring disk and/or field cultivate; plant; cultivate.	Less erosion than from cleanly tilled systems. Well adapted for lighter to medium textured, well-drained soils. Good to excellent incorporation.	Little erosion control. High soil moisture loss.
Ridge-till	Chop stalks (on furrow irrigation); plant on ridges; cultivate for weed control and to rebuild ridges.	Excellent erosion control if on contour. Well adapted to wide range of soils. Excellent for furrow irrigation. Ridges warm up and dry out quickly. Low fuel and labor costs.	No incorporation. Narrow row soybeans and small grains not well suited. No forage crops. Machinery modifications required.
Strip-till	Fall strip-till; spray; plant on cleared strips; postemergent spray as needed.	Clears residue from row area to allow preplant soil warming and drying. Injection of nutrients directly into row area. Well suited for poorly drained soils.	Cost of preplant operation. Strips may dry too much, crust, or erode without residue. Not suited for drilled crops. Potential for nitrogen fertilizer losses.
No-till	Spray; plant into undisturbed surface; post emergent spray as needed.	Maximum erosion control. Soil moisture conservation. Minimum fuel and labor costs.	No incorporation. Increased dependence on herbicides. Some limitations with poorly drained soils, especially with heavy residue. Slow soil warming.

^a Jasa et al., 1991

Table 2. Typical diesel fuel requirements from Nebraska on-farm survey for various row crops and tillage systems ^a

	Moldboard	Chisel		Ridge-	Strip-till
Operation	plow	plow	Disk	till	or No-till
----- Fuel use, gal/ac -----					
Chop stalks				0.55	
Moldboard plow	2.25				
Chisel plow		1.05			
Fertilize, knife	0.60	0.60	0.60	0.60	0.60
Disk	0.74	0.74	0.74		
Disk	0.74		0.74		
Plant	0.52	0.52	0.52	0.68	0.60
Cultivate	0.43	0.43	0.43	0.86(2) ^a	
Spray					0.23(2) ^a
Total	5.28	3.34	3.03	2.69	1.43

^aOperation performed two times: Jasa et al., 1991

Table 3. Typical labor requirements calculated from machinery management data for various tillage systems in Nebraska ^a

	Moldboard	Chisel		Ridge-	Strip-till-
Operation	plow	plow	Disk	till	or No-till
----- Labor, hr/ac ^a -----					
Chop stalks				0.17	
Moldboard plow	0.38				
Chisel plow		0.21			
Fertilize, knife	0.13	0.13	0.13	0.13	0.13
Disk	0.16	0.16	0.16		
Disk	0.16		0.16		
Plant	0.21	0.21	0.21	0.25	0.25
Cultivate	0.18	0.18	0.18	0.36(2) ^b	
Spray					0.11(2) ^b
Total	1.22	0.89	0.84	0.91	0.49

^aJasa et al., 1991

^bHr/ac assume 100 hp tractor and matching equipment for average soil conditions. ^bOperation performed two times.

^a Reprinted from *Exploring Chemistry with Electronic Structure Methods*, J. B. Foresman and A. Frisch, 1993, p. 216

Conclusions

One of the basic and important components of agricultural production technology is soil tillage. Various forms of tillage are practiced throughout the world, ranging from the use of simple stick or jab to the sophisticated para-plough. The practices developed, with whatever equipment used, can be broadly classified into no tillage, minimum tillage, conservation tillage and conventional tillage. Energy plays a key role in the various tillage systems. The farming methods instead of using conventional tillage, conservation tillage is used to. This means that this method such as rummage soil tillage systems are not common in the soil for at least 30 percent crop residue prior to shall be preserved. This farming method is based on the protection of soil, water and plant based and one of the most effective ways to exit from the crisis, drought, water management and soil organic matter for farmers economic compensation. Another benefit of this

approach farming lessens soil compaction, moisture, increases soil organic matter, prevent erosion, and disruption of the soil structure It is also, increasing water use efficiency, pH adjustment and support for micro and macro soil organisms⁷.

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