

Reducing Tillage in Arid and Semi-arid Cropping Systems: An Overview

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INTRODUCTION

Reduced tillage is gaining attention among growers in the arid and semi-arid cropping systems of New Mexico and other parts of the Southwest because of the undesirable effects conventional tillage has on the environment and soil quality, as well as economic benefits



Figure 1. A moldboard plow.

associated with less intensive tillage operations. Conventional tillage, which presently is the preferred land preparation method used by growers in this region, has led to accelerated soil erosion by wind and water as well as degraded soil quality. Conventional tillage management often involves one or more of the following practices:

- **Plowing:** Tilling and turning the soil layer, usually to a depth of up to 6–8 inches. Plowing turns over the soil completely, bringing soil materials from under the plow layer to the surface and burying materials from fertile topsoil to a lower depth. With plowing, growers are looking for complete residue incorporation, a soil surface free of vegetation, and better seed-to-soil contact. Some farmers plow twice depending on their soil conditions. A moldboard plow (Figure 1) is commonly used for plowing.
- **Ripping or subsoiling:** Ripping is done to facilitate root growth and to access subsoil moisture. Deep ripping machines (Figure 2) can be used to break through a compacted pan or constraining soil layer, allowing root access to unconstrained soil water beneath this layer. Compaction often occurs in modern agricultural practices due to farm traffic and the use of heavy equipment, especially when the soil is very wet. For more information on soil compaction problems,

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Figure 2. A deep ripper.



Figure 3. A disking machine.



Figure 4. Plow-till soil (plowed, subsoiled, and disked twice).

see NMSU Extension Circular 672, *Understanding and Managing Soil Compaction in Agricultural Fields* (http://aces.nmsu.edu/pubs/_circulars/CR672.pdf; Idowu and Angadi, 2013). Deep ripping can go up to 20 inches, e.g., disc ripper, in-line ripper, etc.

- **Disking and harrowing:** Disking and harrowing are shallower operations than plowing. By using a disking machine (Figure 3) or harrows, growers aim to break down large soil clods close to the soil surface (0–6 inches). In some cases, growers in arid and semi-arid regions use multiple disking or harrowing operations to achieve a good breakdown of large soil aggregates into smaller aggregates and to create a smooth seedbed for optimal seed germination and seedling growth.

Continuous and frequent conventional tillage using the techniques and equipment described above has considerably degraded the soil quality of many arid farmlands. This degradation of soil quality is evidenced by low to very low soil organic matter found in many arid and semi-arid soils of New Mexico (Idowu and Flynn, 2013). Other indicators of soil degradation linked to the use of intensive tillage practices include surface crusting, soil compaction, poor soil structure, poor water and nutrient holding capacity, high carbon dioxide emissions, limited biological activities, and high susceptibility of crops to soil-borne pests and pathogens (Daraghmeh et al., 2009; Kandeler et al., 1999; Tebrügge and Düring, 1999; Figure 4).

Reduced tillage encompasses several tillage methods that reduce the frequency and/or intensity of soil disturbance. At the opposite end of the spectrum to conventional tillage is strict no-tillage in which the soil is not broken up except by the incision made in the soil for seed placement.

WHY DO WE NEED TO REDUCE TILLAGE?

Soil erosion control

One of the primary reasons for reducing tillage is to prevent soil erosion by wind and water, both of which are common in agricultural fields. During the early part of the spring season, strong winds often occur in New Mexico. Unfortunately, the windy period coincides with the time farmers have prepared their seed-bed using conventional tillage practices, which leaves the soil bare, smooth, and unprotected by surface residue (<15% residue cover) and predisposes such soils to wind erosion.

Significant amounts of sediment are blown away from farmlands every year. Wind erosion accounts for about 75% of erosion on non-federal and rural lands in New Mexico (Davis and Condra, 1989). Total wind erosion on cultivated cropland in New Mexico increased from 13.64 tons/acre/year in 1982 to 22.82 tons/acre/year in 2012 (U.S. Department of Agriculture, 2015), which is more than the estimated rate of soil formation of between 0.22 and 0.44 ton/acre/year (Pimentel and Burgess, 2013). Wind erosion reduces soil productivity due to loss of moisture, loss of plant nutrients, degradation of soil structure, and increased spatial variability of farm fields. In addition, windblown soil particles can severely damage and even cut small plants off at the surface, especially during intense wind events. This can lead to complete crop failure and significant economic stress on the cropping system.

Sediment that is blown away and deposited elsewhere reduces water reservoir storage capacity, clogs streams and drainage channels, deteriorates aquatic habitats, muddies recreational waters, increases water treatment costs, damages water distribution systems, carries agricultural chemicals into water systems, can make fences dysfunctional, and blocks roadside ditches.

Suspended sediments in the air due to wind erosion reduce visibility, increase respiratory problems in humans, and disrupt highway transportation, which often results in human injury or death (Davis and Condra, 1989).

In addition to wind erosion, short-duration intense rainfall events, which are common in arid and semi-arid climates, often result in significant soil erosion and surface runoff, especially if the soil is weakly aggregated and without adequate surface cover. Soil erosion by water not only has negative environmental impacts but also hinders the system's ability to provide adequate crop yields because moisture is not captured and utilized. This is especially a problem in dryland cropping systems in New Mexico.

The onsite cost due to damages from wind erosion in New Mexico alone was estimated at about \$10 million annually, and this cost was associated with direct crop damages and the loss of soil productivity (Davis and Condra, 1989). The off-site cost due to wind erosion damages has been estimated to be far higher: \$466 million per year in the 1980s (Huszar and Piper, 1986). Several studies

have linked on-farm soil erosion problems to soil quality deterioration (Carter, 2002), which increases production costs as more inputs are required to improve or maintain soil fertility.

Soil organic matter accumulation

Organic matter consists of the living, dead, and decomposing biological materials in the soil. Organic matter plays a key role in soil health. With intensive plow-based tillage, organic matter becomes easily broken down by soil microbes, leading to a loss of carbon, the energy powerhouse for nutrient cycling in the soil (Lal, 2004). Intensive soil tillage exposes more organic matter to soil organisms and, together with better aeration of the soil, the organic material is broken down more rapidly compared to soils that are not tilled intensively. Research has shown that continuous tillage in a dryland wheat–fallow system lost as much as 63% of organic matter reserves in the soil profile (Ghimire et al., 2015). Reduced tillage practices can minimize that loss or significantly increase soil organic matter accumulation (Balesdent et al., 2000) compared to continuous plowing and disking of the soil.

Soil health considerations

Yearly intensive plow-based tillage can have negative impacts on the soil health of agricultural lands. The increased number of tractor and equipment passes associated with conventional tillage practices can lead to soil compaction (see NMSU Extension Circular 672, *Understanding and Managing Soil Compaction in Agricultural Fields*, http://aces.nmsu.edu/pubs/_circulars/CR672.pdf; Idowu and Angadi, 2013). Also, the loss of soil organic matter associated with intensive tillage practices will affect many other soil properties, such as the infiltration of water, soil moisture retention, soil aggregation, and overall soil fertility.

Soil organisms are also affected by intensive tillage. For example, studies have shown that earthworm counts are greatly reduced in soils that experience regular plowing compared to soils with no tillage (Tebrügge and Düring, 1999). Regular plowing disrupts earthworm channels, thus preventing their continued functions in agricultural soils. Some studies have also shown that the soil microbial diversity and numbers could be negatively affected through constant intensive tillage of agricultural lands (Kandeler et al., 1999).

Soil moisture conservation

Water availability for crop production is particularly challenging in arid and semi-arid agroecosystems. Plants are often water-stressed due to factors such as low precipitation, high temperatures, strong desiccating winds, inconsistent irrigation supplies, and poor irrigation efficiencies. Any method that can conserve moisture in the soil will help reduce the impacts of these factors and ensure crop survival against short-term droughts common in New Mexico. Enhanced crop growth increases the opportunity to return more organic matter into the cropping system, which in turn increases soil moisture retention. Reduced tillage systems such as strip tillage and no-tillage have been shown to retain more moisture in the soil than conventional tillage practices (Blevins et al., 1983).

Economic considerations

Fuel, labor, and other costs for tillage operations constitute one of the major recurrent expenditures on the farm. Most of the plow-based intensive tillage systems may require up to 5–7 equipment passes to create a smooth seedbed. Each extra pass of the equipment in the process of land preparation will lead to increased fuel usage and more labor hours, adding to the farm costs. With reduced tillage, the number of passes is reduced, thus requiring less fuel and labor hours for land preparation. For the first few years, yields may be reduced due to relatively inadequate soil conditions and weed challenges. However, in the long-term and with good management, crop yields can catch up or even become higher than in conventional tillage systems, allowing for opportunities to increase net profitability. Yield and economic benefits of reduced tillage are more evident in the areas with greater drought potential.

BASICS OF REDUCED TILLAGE

Reduced tillage, as the name implies, is the reduction of soil disturbance in the field during cultivation. With constant disturbance of soil in the field, it becomes very difficult to accumulate organic matter in the soil. Soil organic matter, however, is

very critical to the health and the overall functioning of the soil for crop production. Due to less soil disturbance in reduced tillage systems, more organic carbon will accumulate in the soil since less carbon is exposed to the surface by tillage for oxidation (Balesdent et al., 2000).

Reduced tillage strategies often involve the retention of residue or stubble on the soil surface, which offers protection for the soil from water and wind erosion. Therefore, a successful reduced tillage system may involve the use of cover crops to provide the needed residue for soil protection and for soil quality improvement in the long run.

Another important principle in reducing tillage is avoiding deep soil inversion such as plowing. Growers often consider plowing as the solution for residue incorporation and weed control, and in some cases for disease control. While this may be true, there are other ways to handle the previous crop residue and weeds without engaging in full, deep soil inversion. One such way is to mow down the previous residue, giving time for the residue to undergo some decomposition on the soil surface, followed by a shallow disking of the residue. Shallow disking of the residue will take care of the early weeds that have emerged. Another method is to mow the previous crop residue and leave up to 10-inch-high stubble, followed by strip tillage (Figure 5). Particularly tall residues such as those associated with cover crops can be pushed down using roller crimpers. This protects soil from erosion, minimizes water loss, and conserves nutrients while providing an opportunity for planting into residue.

Strip tillage allows for some amount of tillage, especially in rows where seeds will be planted, leaving a significant portion of the soil untilled and covered with residue. Such systems combine the benefits of conventional tillage with no-tillage (Figure 6).

Cover crops are also very beneficial in reduced tillage systems since they can provide appropriate ground cover in between the cash crops and supply residue for improving soil quality. For more information on cover cropping, see NMSU Extension Guide A-150, *Principles of Cover Cropping for Arid and Semi-arid Farming Systems* (http://aces.nmsu.edu/pubs/_a/A150.pdf; Idowu and Grover, 2014).

WHICH REDUCED TILLAGE PRACTICE SHOULD I CHOOSE?

One of the tools that farmers can use to address problems associated with intensive conventional tillage is to reduce the intensity and/or frequency of tillage in agricultural fields. Reduced tillage may be a better “first step” than strict no-tillage when transitioning from conventional tillage. The adaptability of no-tillage can be difficult in some soils, and it is often problematic to go into strict no-tillage after several years of conventional tillage practices. No-tillage practices are generally more successful when started in coarse-textured soil (sandy ground) compared to heavy clay soils (Cox et al., 1992). However, it is still possible to transition to no-tillage in heavy soils, although it may take a few more years for the system to maintain or improve on crop yields when compared with conventional tillage.

There are several ways that farmers can practice reduced tillage on the farm to help mitigate the problem of soil degradation and erosion. Any practice that reduces the frequency or intensity of mechanical tillage can be considered reduced tillage, e.g., strip tillage, direct seeding, spraying, etc. Direct seeding of winter wheat or cover crops into previous cash crop residue is regarded as reduced tillage because tillage operations that turn over the soil have been avoided (Figure 7).

HOW DO I PROCEED WITH REDUCING TILLAGE?

Reduced tillage practices cannot be approached with “one size fits all.” Reduced tillage options that you can choose will depend on conditions such as type of crop rotation, soil type, water availability for cover cropping, finance to purchase new soil management tools, and your goals for reducing tillage.

It is advisable to discuss first with your Cooperative Extension Service county agent (<http://aces.nmsu.edu/county/>) or agricultural consultant before you engage in any particular practice. It is also good to discuss with other growers who have successfully tried different reduced tillage options in your region to learn from their experiences, successes, and failures. It is possible to encounter many obstacles as you strive to practice reduced tillage, but by carefully troubleshooting the system and discussing with educators, consultants, and other growers, such issues can be worked out.



Figure 5. Terminated winter wheat cover crop ready for strip tillage.



Figure 6. Corn strip-tilled into winter wheat stubble.



Figure 7. No-tillage winter wheat drilled after corn silage harvest (Doña Ana County, NM).

CHALLENGES INHERENT IN REDUCED TILLAGE SYSTEMS

While reduced tillage offers several benefits for farmers, there are also several challenges that can arise when practicing reduced tillage. One of the challenges may be weed control. Planning effective weed control strategies may be necessary to prevent an explosion of weeds in reduced tillage systems. Fall weed control (mechanical and chemical), using cover crops, and covering the soil surface with residue for weed suppression have been successfully used by farmers engaged in reduced tillage systems. Another challenge could be related to soil-borne diseases and pests. Some soil-borne pests and pathogens can survive in the previous year's crop residue and may affect the following cash crop. In case you experience disease or pathogen problems in your reduced tillage system, four major strategies can be used as possible control options: application of chemicals, biological control, host resistance, and cultural control (Bockus and Shroyer, 1998). Crop rotation coupled with reduced tillage will also help overcome some of the pest and pathogen problems (Bockus and Shroyer, 1998).

Another challenge that has been observed is low soil temperature in the spring due to surface residue cover. At higher elevations, having thick residue cover takes soils longer to warm up, which can delay spring planting and the integration of cover crops into the cropping system. Very high amounts of biomass from previous crops can also become a challenge for direct seeding and seed germination. If heavy surface residue causes lower temperature in your soil, leading to delayed crop establishment, it is advisable to use strip tillage rather than no-tillage. Seeding rows created by strip tillage will warm up quickly in the spring.

It is advisable to talk with your county Extension agent (<http://aces.nmsu.edu/county/>) or agricultural consultant if you discover pests or diseases in your reduced tillage field. They can help you with disease or pest identification and developing effective control strategies.

SUMMARY

Reduced tillage practices are systems in which the intensity and/or frequency of tillage has been reduced relative to conventional plow-based soil inversion tillage. Constant, intensive tillage leads to accelerated soil erosion and soil quality degradation. There are many benefits of reducing tillage, including erosion control, soil organic matter accumulation, reduced costs for tillage, and improvements in soil moisture and soil health. There are several ways for New Mexico farmers to reduce tillage in their crop production practices. Such methods often depend on the individual farm situation. Farmers are advised to discuss first with their county's Cooperative Extension Service agent (<http://aces.nmsu.edu/county/>) or an agricultural consultant before deciding to invest in reduced tillage practices. Reducing tillage may be a difficult and involving task at the beginning, but benefits to the farming system are very significant in the long run.

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