No-Till Series

Impacts of No-till on Water Quality

Kansas farmers are rapidly adopting no-till production practices. It is readily accepted that reducing tillage leads to less soil erosion and sediment loss from crop fields. The effects of adopting no-till on the loss of pesticides and nutrients from crop fields are not fully understood and results are mixed. In some cases, research studies find that shifting from a tilled to a no-till cropping system reduces runoff and leaching of pesticides and nutrients. Kansas State University researchers have studied the water quality effects that occur as farmers shift to no-till systems. This publication discusses the water quality effects of adopting no-till systems.

Effect on Soil Quality

Long-term changes in soil physical properties can be expected when using no-till cropping systems compared to tilled cropping systems. Generally, no-till management increases soil organic matter content, surface soil porosity, soil macropores, aggregate stability, and soil surface infiltration rates.

No-till results in improved macrospore formation and stability. Macropores are small channels in the soil caused by earthworms, soil cracking, or root development. Tillage that mixes the soil destroys macropores. Macropores allow water to rapidly infiltrate the soil, which theoretically increases the opportunity for rapid downward movement of pesticides and nutrients through the soil profile. Kansas studies that examined downward movement of nitrogen and atrazine under various tillage systems found little difference among tillage systems.

Aggregate stability is how resistant soil aggregates are to being broken down by water during rainfall. Increasing aggregate stability reduces soil erosion.

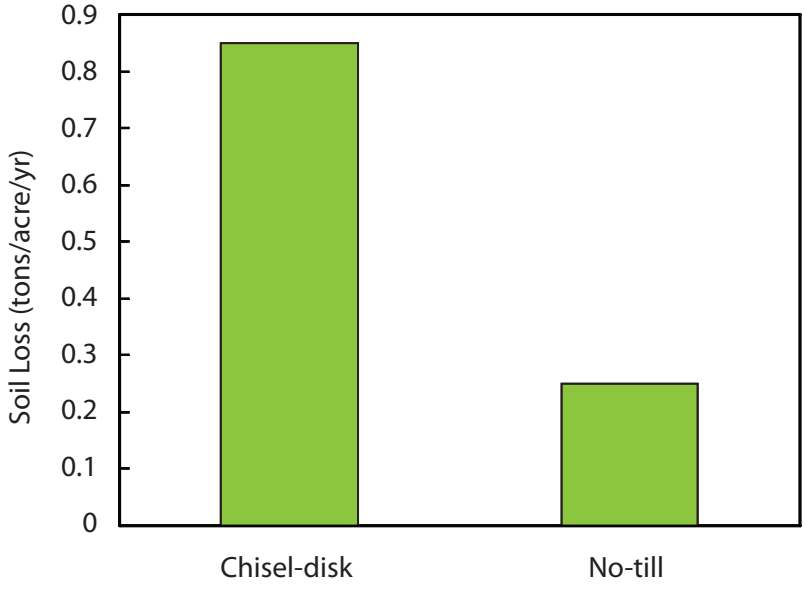
Effect on Water Runoff Amount

Contaminants leave fields in both the water and the sediment portion of runoff. Many pesticides, i.e. atrazine herbicide, and soluble nutrients leave primarily with the water and not with the sediment. Generally, the greater the water loss from a field, the greater the loss of waterborne contaminants.

Although no-till reduces sediment loss compared to other tillage systems, water runoff may or may not be reduced. Studies on a somewhat poorly drained, Woodson silt loam soil near Ottawa, Kansas, of a soybean/grain sorghum rotation found 75 percent more season-long water runoff from a no-till system than from a chisel-disk tillage system (Figure 1). However, a similar study conducted on a Grundy silty clay loam soil near Powhattan, Kansas, in a continuous corn rotation found 50 percent less season-long water runoff from a no-till system than from a conventional disk tillage system (Table 1).

Studies comparing water runoff and tillage in eastern Kansas often find greater water runoff with no-till than

Figure 1. Soil erosion losses from sorghum-soybean rotation in Franklin County, Kansas, 3-year average.



conventional tillage in the first runoff event following spring planting. In subsequent runoff events, similar levels of water runoff occur with either tillage system.

The greater water runoff in no-till in the first runoff event may be explained by two different possibilities. The first possibility is that crusting in no-till due to rainfall before planting may cause the higher water runoff. The other possibility is that near the soil surface of no-till fields in eastern Kansas, the fields are often at field capacity for moisture at planting time so greater water may run off in the first storm event.

In contrast, in tilled fields, the tillage before planting may dry the surface soils at planting so there is less runoff in the first storm event following planting. In central and western Kansas, because of less potential for fields being at field capacity for moisture at planting time, one would not expect there to be as much potential for greater water runoff from no-till in the first runoff event compared to tilled soils.

No-till generally results in greater water use efficiency and water storage under dryland systems than do systems with greater tillage frequency. Over a 4-year period at Garden City, Kansas, in a wheat fallow cropping system, more than twice the soil moisture was stored during fallow with a no-till system compared to a conventional tillage system. Higher soil moisture availability to the crop generally results in higher crop yields, reduces seasonal yield variability, and increases profit.

Suspended Solids

Sediment is the largest pollutant by volume of surface waters in Kansas. Much of this sediment derives from cropland. Sediment increases the cloudiness (turbidity) of water; reduces light penetration, which impairs photosynthesis; and can lead to reduced levels of dissolved oxygen and food supplies for aquatic organisms. The increased turbidity may cause shifts in the populations and species of aquatic organisms present in a water body. Removal of sediment also increases the cost of water treatment for drinking water. Nutrients and pesticides also may be attached to the sediments running off fields. The nutrients attached to sediments may lead to algal blooms in reservoirs. Many lakes and reservoirs in the state are being filled by sediments, which reduces the effective water storage capacity.

Table 1. The effect of tillage system on water, sediment, and atrazine runoff in continuous corn, averaged over 3 years in Brown County, Kansas.

Tillage System	Water Runoff (%)	Sediment Loss (tons/acre/yr)	Atrazine Loss (% of applied)
Chisel-disk - atrazine incorporated	28	10.7	0.59
No-till - atrazine surface applied/non incorporated	14	0.20	0.86

Source: Brian Marsh, K-State Research and Extension.

Table 2. The effect of tillage system on annual phosphorus runoff in a grain sorghum – soybean rotation over a 3-year period, Ottawa, Kansas.

	Phosphorus Runoff Loss		
Tillage System	Total	Sediment	Soluble
	---------- (pounds/acre) ----------		
Chisel-disk	0.92	0.88	0.02
No-till	0.69	0.51	0.15

Source: Janssen, K. A., G. M Pierzynski, and P. L. Barnes. 1998. Phosphorus losses in runoff water as affected by tillage and phosphorus fertilizer. K-State Research and Extension Report of Progress 810.

No-till management practices can significantly reduce soil erosion and sediment loss from crop fields. Studies in northeast Kansas on a Grundy silty clay loam soil with continuous corn in a field with 3 percent slope found annual sediment loss of 10.7 tons per acre when using disk tillage compared to annual sediment loss of 0.20 tons per acre with no-till (Table 1). At Ottawa, in east central Kansas, annual sediment losses with a grain sorghum/soybean rotation in a field with 1 percent slope found annual sediment losses of 0.8 tons per acre with a chisel-disk tillage system and 0.3 tons per acre with a no-till system.

Nutrients

Movement of phosphorus and nitrogen into surface water and leaching of nitrogen into groundwater are serious environmental concerns in Kansas. Changing tillage practices affects the amount of nutrient runoff and leaching.

Phosphorus can run off crop fields and move into surface waters and is considered to be the nutrient contaminant of greatest concern to surface waters of Kansas. In most soils, phosphorus exists in one of four forms: (1) associated with soil particles; (2) in mineral forms as aluminum, iron, or calcium compounds; (3) soluble compounds dissolved in soil water; or (4) incorporated in organic matter.

Phosphorus can move into surface waters associated either with soil particles during erosion or as soluble phosphorus with runoff water. Greater than 75 percent of the phosphorus

in surface water is associated with or bound to soil particles. Much less is soluble phosphorus. The most effective way to reduce phosphorus pollution of surface water is to reduce soil erosion. No-till reduces total phosphorus losses by approximately 40 percent. Total phosphorus consists primarily of insoluble phosphorus attached as soil particles, freestanding inorganic compounds, and soluble phosphorus.

No-till generally has higher losses of soluble phosphorus than do tilled systems. To reduce losses of soluble phosphorus under no-till systems, phosphorus fertilizers should be deep banded or placed near the seed. Further information on phosphorus best management practices (BMPs) can be found in K-State Research and Extension publication, *Best Management Practices for Phosphorus*, MF-2321. Using recommended BMPs for phosphorus will minimize phosphorus losses from no-till fields.

Nitrogen, in the nitrate form, readily moves with soil water and can move downward as water moves down through the soil profile. Eventually, the water and nitrate may leach far enough to enter groundwater and be an environmental concern. The major sources of nitrogen in soils include commercial fertilizer, animal manure, plant residues, soil organic matter, and biological fixation by legumes. More macropores occur in long-term no-till fields than in fields using tillage. Macropores allow greater quantities of water to rapidly infiltrate the soil, causing concerns that the use of no-till may result in greater nitrate leaching to groundwater. However, research in Kansas comparing tillage systems and nitrogen leaching has not found higher nitrate movement with no-till.

Regardless of tillage system, one should always be concerned about nitrate leaching on environmentally sensitive soils, such as sandy soils overlying groundwater supplies and near water sources for human or livestock consumption. Kansas State University recommended BMPs for nitrogen will effectively reduce the potential of nitrate leaching to groundwater.

Pesticides

Pesticides are used widely in Kansas to control weeds, insects, and diseases in crops. Pesticides may be moved by wind and surface water runoff into streams and lakes. Pesticides also may leach into groundwater. In Kansas, herbicides are the most common pesticide found in water and generally surface water is at a higher risk for contamination than is groundwater. Changing to a no-till system can influence the amount of herbicide runoff to surface water.

Chemical characteristics of a pesticide determine whether the pesticide runs off a field in either the sediment or the water portion of runoff. Adsorption is one of the major chemical characteristics. Adsorption describes a chemical's tendency to bind or stick to soil particles, primarily clay and organic matter.

Some herbicides, such as glyphosate or paraquat, are strongly adsorbed, while others, such as atrazine, are weakly adsorbed. Weakly adsorbed herbicides are more likely to leave the field in the water and not with eroding soil particles whereas strongly adsorbed herbicides are more likely to leave the field with eroding soil particles and not with the water. Weakly adsorbed herbicides are also more likely to be leached to groundwater.

No-till will reduce the loss of herbicides that are attached to soil particles by reducing soil erosion, but may have limited value in reducing the loss of weakly adsorbed herbicides from leaving the field. The loss of weakly adsorbed herbicides is generally directly related to water runoff from a field. Generally, the greater the water loss from a field, the greater the herbicide runoff (of weakly adsorbed herbicides).

Regardless of tillage system, it is essential that BMPs be used that will minimize herbicide runoff and leaching. Changing from conventional or reduced tillage to no-till without adopting appropriate herbicide management practices may lead to greater runoff of weakly adsorbed herbicides, such as atrazine.

For example, at Powhattan, Kansas, moving from a chisel-disk system that used the atrazine BMP of soil incorporation to a no-till system in which atrazine was applied preemergence increased atrazine runoff by 59 percent over a 3-year period (Table 1). However, changing application timing from preemergence to early preplant (before April 15) reduces potential atrazine runoff by 50 percent. Further reduction in atrazine runoff can be accomplished by using postemergence applications, which reduces potential atrazine runoff by 67 percent, compared to preemergence applications. Other atrazine BMPs are discussed in K-State Research and Extension publication, *Managing to Minimize Atrazine Runoff*, MF-2208.

Conclusion

No-till systems significantly reduce soil erosion and soil-attached contaminant losses compared to conventional and reduced tillage systems. Generally, soil organic matter content, surface soil porosity, soil macropores, and soil surface infiltration rates increase with no-till. Studies have indicated that, depending upon the characteristics of soils within a field and previous soil moisture conditions, water runoff and loss of water-laden contaminants may be more or less with no-till compared to other tillage systems. If recommended BMPs are adopted, losses of waterborne contaminants can be minimized.

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