TECHNICAL NOTE

Brooke Rust and John D. Williams
USDA/ARS Columbia Plateau Conservation Research Center, Pendleton, Oregon.

How Tillage Affects Soil Erosion and Runoff

An increasing number of dryland farmers in the Pacific Northwest are implementing conservation tillage systems to improve soil and water conservation. Conservation tillage is a tillage method that results in 30 percent or more residue coverage after planting. Conventional, inversion tillage is any method that leaves less than 30 percent ground coverage and usually involves the use of moldboard plows, disks, and chisels in tillage operations. Switching from conventional intensive tillage systems to conservation systems results in greater water infiltration and reduced soil erosion due to increased crop residue coverage.

Table 1. Tillage Classification.

Tillage Type		Definition
Conservation	Minimum tillage	Leaves 30 percent or more ground cover. Involves the use of chisel plows or disks.
	No-till	Leaves 50 percent or more ground cover because the soil surface is left undisturbed from harvest to planting. No more than one-fourth of the row width can be disturbed. Produces the least amount of runoff and erosion.
Conventional, inversion		Leaves less than 30 percent ground cover. Involves the use of moldboard plows, disks, and chisels. Residue burning after harvest is common. Produces the most runoff and erosion.

Soils are tilled to prepare the seedbed for planting, control weeds, and preserve soil moisture. Minimum tillage is a type of conservation tillage that maximizes crop residue on the soil surface throughout the year and increases beneficial soil qualities. However, there are still management changes that can be made with lower soil disturbance levels to better conserve these qualities. Soil and water conservation goals can be better met by increasing crop intensity, changing to the no-till practice, or both. No-till leaves the soil undisturbed from harvest to planting; seed bed preparation, planting, and fertilizer application cannot disturb more than one-fourth of the row width. Recent research demonstrates the effectiveness of no-till systems, combined with an intensified crop rotation, in improving residue cover of the soil surface thereby increasing water infiltration into the soil, and decreasing runoff and soil erosion. This technical note compares no-till to both inversion and minimum tillage in terms of these characteristics.

Factors Contributing to Soil Erosion

Dryland crop production in the inland Pacific Northwest is conducted in one of three zones described as low (<12 in/yr), intermediate (12-18 in/yr), and high (>18 in/yr) rainfall. This technical note addresses efforts to improve soil and water conservation in the intermediate rainfall zone.

Erosion is a form of soil degradation that the Pacific Northwest has experienced since the beginning of crop production in the early 1900's. Before the adoption of conservation tillage practices, average soil loss rates exceeded the established USDA soil loss tolerance limits for sustained economic productivity in most areas of the region.

Soil erosion is affected by weather and management decisions that determine the condition of the soil surface. The inland Pacific Northwest is unique in that the period of greatest erosion occurs from November to March when low intensity rainfall during prolonged storms fall on frozen soil with or without snow cover, or snow covered unfrozen soil. Tilled and unprotected soil on slopes and hills moves down-slope in the absence of rainfall when the top 1-2 inches of soil thaws and creates a viscous flow. The condition of the soil surface in which these weather events occur determines the degree to which the soil will erode.

How Residue Coverage Reduces Erosion

The amount of residue left on the soil surface after tillage greatly affects water infiltration. Adequate residue on the soil surface is necessary to protect soil from raindrop impact. When residue decomposes and breaks down, voids are created in the soil surface that provide vertical flow pathways for percolation. Fungi, bacteria, and other decomposers produce a biochemical residue that acts as glue and forms stable aggregates, or tiny clumps of soil, that are resistant to bursting. If surface organic matter is not present aggregates cannot form, or will be weak and break apart. Small particles of mineral soil are then able to move with water. When dry, they form a crust on the surface which does not allow infiltration and creates runoff and erosion.

Conventionally tilled soil has less residue cover on the surface because moldboard plows and chisels mix the organic matter on the surface with the sub-soil. Soil lacking adequate surficial organic matter is at risk for breakdown from hydrologic processes (Wuest 2009).

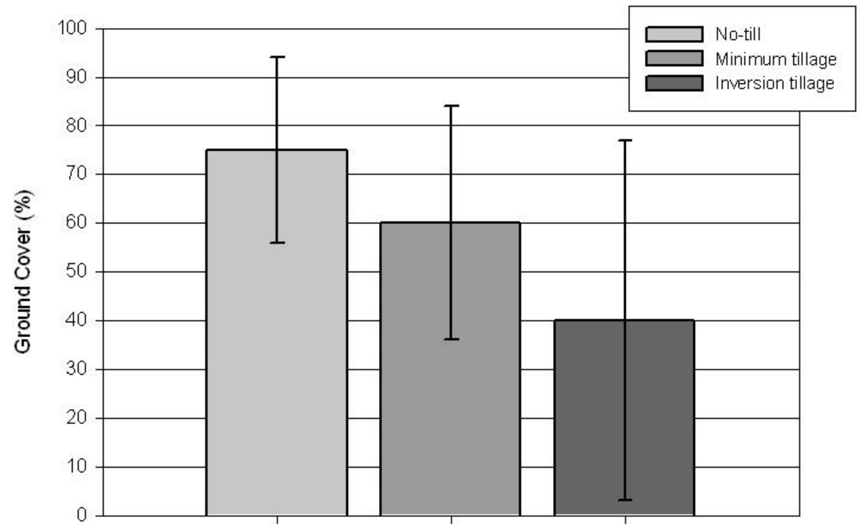
Residue also prevents runoff and erosion through retention of water (acting like a sponge, keeping water within the soil and not flowing across the surface) and detention of water (like a dam, holding water back from creating more runoff).

For more discussion on the concepts of infiltration, please refer to the Soil Quality Information Sheet, *Soil Quality Indicators: INFILTRATION* (http://soils.usda.gov/sqi/publications/files/Infiltration.pdf).

Results from studies comparing tillage methods show significant increases in crop residue ground coverage levels under the no-till systems (Figure 1).

Figure 1.

Ground cover percentage across tillage methods.



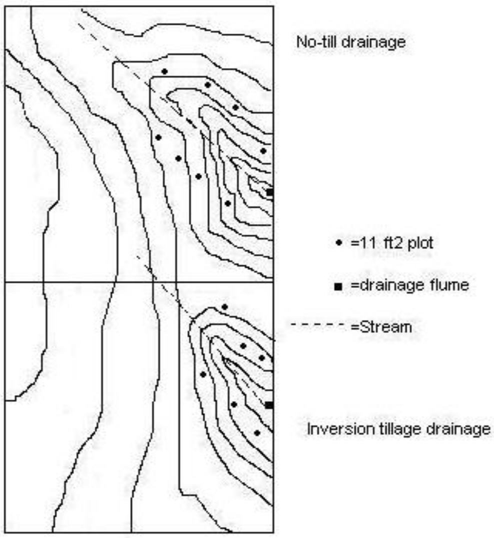
Two different experiments conducted at the Columbia Plateau Conservation Research Center in Pendleton, Oregon illustrate the value of surface residue to soil and water conservation.

Experiment #1

The first experiment took place during crop years 2001-2004. Runoff (Figure 3a and 4a) and soil erosion (Figure 3b and 4b) were recorded within two 15-25 acre drainages. Measurements were taken at the bottom of each drainage using a flume and at numerous 11 ft^2 plots within the 15-20 percent sloped drainage area.

Figure 2.

Topography of test plots.



The first drainage was farmed in a two-year conventional tillage winter wheat-fallow rotation. The second was in a no-till four-year rotation of winter wheat-chick peas-winter wheat-fallow.

Subsequent measurements among the 11 ft^2 plots and drainages were made in 2003 and 2004.

Table 2.

Four-year crop rotation of second drainage.

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG
Year												
FIRST	Seed wheat										Harvest wheat	
SECOND	Post harvest stubble						Seed peas				Harvest peas	
THIRD	Seed wheat										Harvest wheat	
FOURTH	Post harvest stubble								Summer fallow			

Erosion period

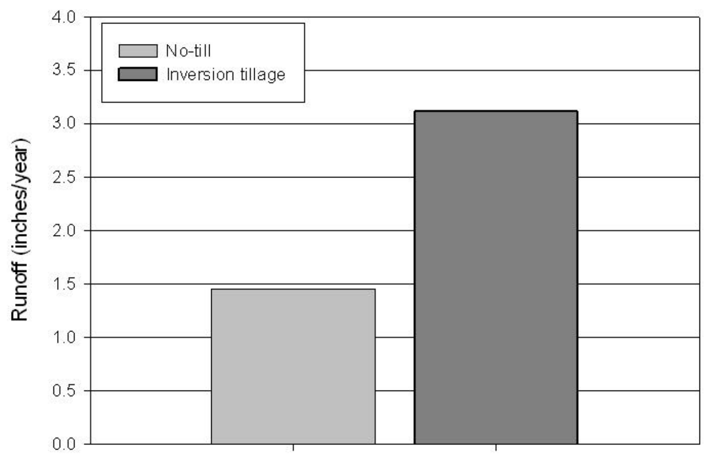
No-till is more effective than inversion tillage at reducing runoff and erosion on hill slopes and from watersheds. In the 11 ft^2 plots, the inversion tillage system produced significantly more runoff (over 2 times), and eroded material (47 times) than the no-till system (Figure 3). The values from the drainage scale were significantly less in the no-till system compared to the inversion tillage system where more runoff (over 12 times) and more eroded material (54 times) were produced (Figure 4).

Hill slope runoff at the 11ft^2 inversion tillage plots in 2003-2004 was 3.11 inches (Figure 3a); however, the average runoff leaving the inversion tillage drainage was .10 inches (Figure 4a), leaving 3 inches of water that infiltrated into the lower slope and drainage bottom before entering the flume. This represents a substantial redistribution of precipitation across the field and indicates stored water in the lower slopes and drainage bottoms.

Figure 3.

Average values for (a) runoff and (b) eroded materials collected from 11 ft^2 plots on a 15-20 percent slope during crop year 2003 and 2004.

(a)



(b)

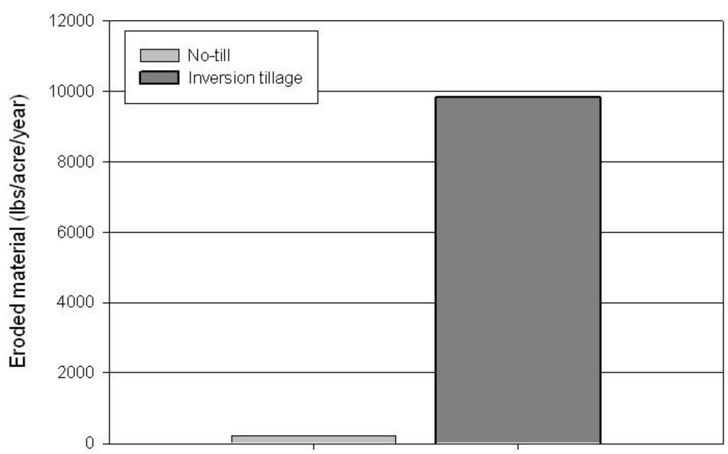
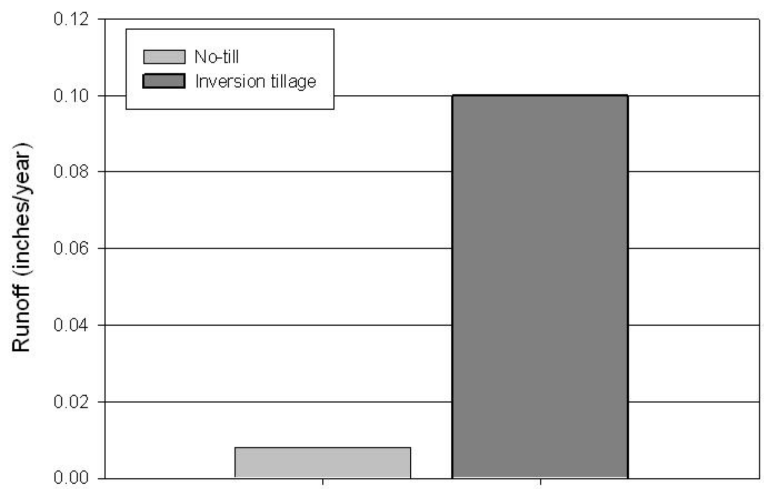


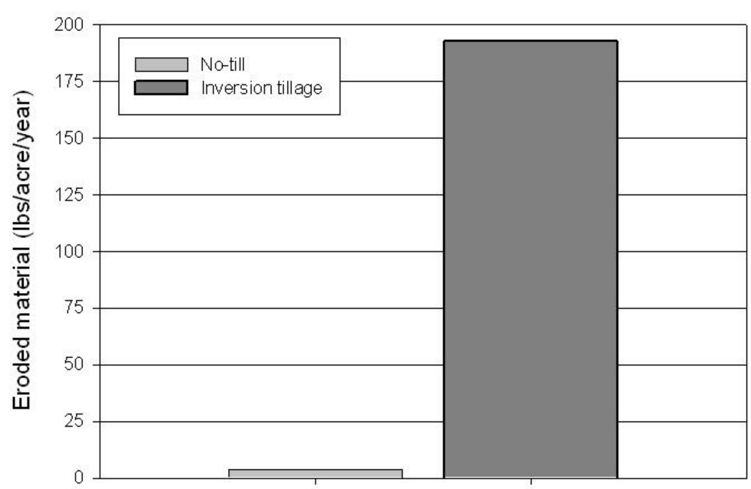
Figure 4.

Average values for (a) runoff and (b) eroded material recorded at the bottoms of multi-acre drainages during crop years 2003-2004.

(a)



(b)



Experiment #2

The second experiment was performed during the 2005-2008 crop years and used a four-year winter wheat-spring pea-winter wheat-fallow rotation on a 5 percent slope and compared infiltration (Figure 5), runoff (Figure 6a), and erosion (Figure 6b) rates in the no-till and minimum tillage systems.

The no-till treatment had significantly higher infiltration rates than the minimum tillage treatment, mainly due to the amount of residue remaining after winter wheat and spring pea crops. Runoff and soil erosion were significantly greater using minimum tillage than using no-till. Generally, there was less runoff and soil erosion in each phase of the rotation using the no-till system.

Figure 5.

Infiltration rates from Experiment #2 measured nine months after the 2008 (final) harvest.

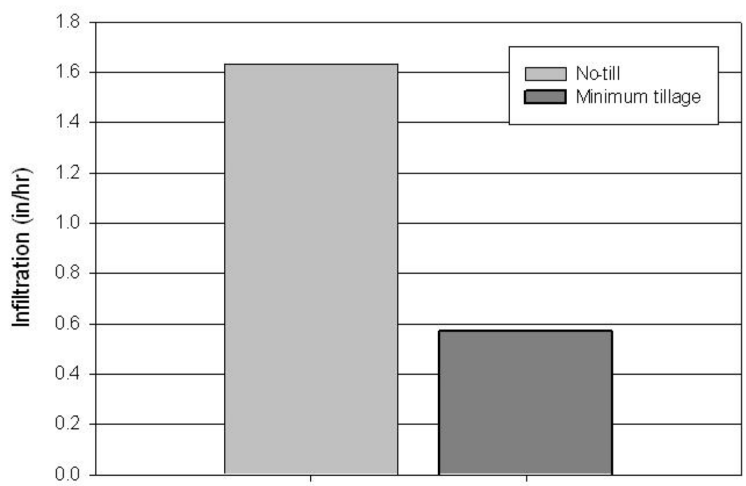
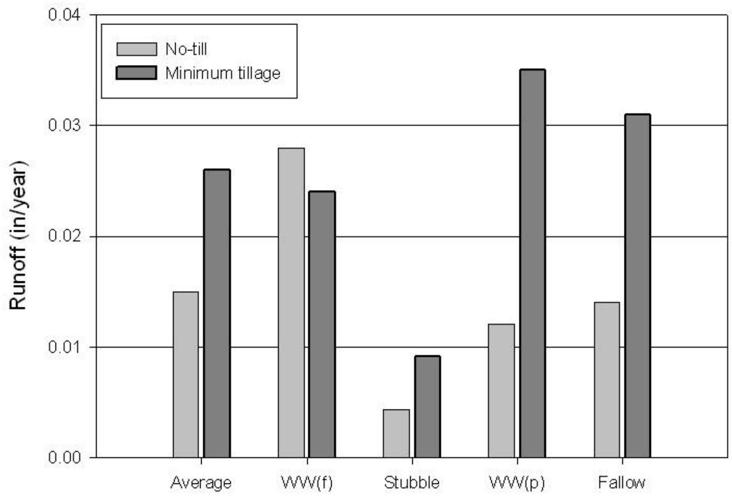


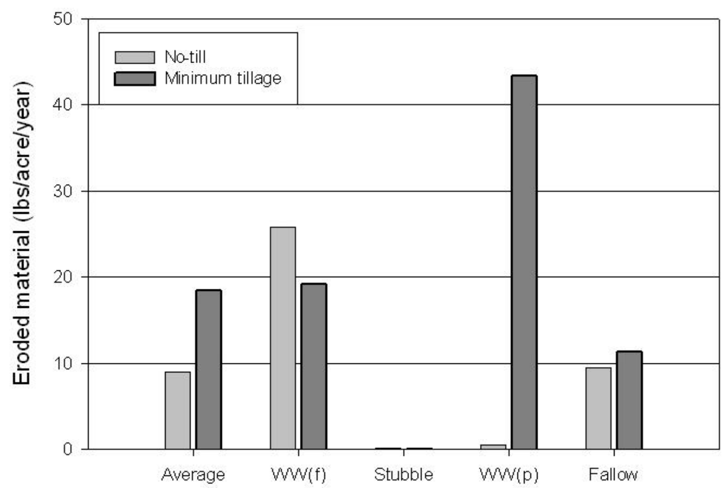
Figure 6.

Four-year average winter runoff (a) and soil erosion (b) levels, by tillage treatment, for each phase of the four-year rotation.

(a)



(b)



Notes: WW(f)=winter wheat following summer fallow. Stubble=wheat stubble between WW(f) and spring peas. WW(p)=winter wheat following spring peas. Fallow=summer fallow.

Summary

Combining no-till with an intensive crop rotation is the most effective means of maximizing soil coverage, improving water infiltration and minimizing runoff and erosion. While conservation tillage methods strive to increase soil and water qualities, the no-till system's benefits surpass that of both minimum tillage and conventional tillage systems.

No-till's success in reducing runoff and erosion is due to increased crop residue and surface organic matter. Low soil disturbance leaves the surface with adequate residue and organic matter that resists soil aggregate breakdown and soil crusting, which are causal factors contributing to runoff and erosion. These studies illustrate that the soil and water conservation qualities of no-till are superior to that of conventional tillage.

References

Williams, J.D., and S.B. Wuest. 2009. Conservation effectiveness of no tillage and conservation tillage under an intensive four year crop rotation in the intermediate precipitation zone, inland Pacific Northwest.

Williams, J.D., H.T. Gollany, M.C. Siemens, S.B. Wuest, and D.S. Long. 2009. Comparison of runoff, soil erosion, and winter wheat yields from no-till and inversion tillage production systems in northeastern Oregon. Journal of Soil and Water Conservation 64(1):43-52.

Wuest, S.B. 2009. How Tillage Affects Water Infiltration. Oregon Soil Quality Technical Note No. 3.