

EFFECTS OF TILLAGE ON WATER INFILTRATION – PROJECT SUMMARY

Stewart Wuest, John Williams, and Tami Johlke

Abstract

Soils in the dryland wheat-growing region of the Pacific Northwest are very susceptible to water erosion when tilled and left bare of crop residue. In cropping systems that do not involve tillage, organic matter accumulates on and near the soil surface, and structural changes develop deeper in the soil. Both of these features allow more rapid infiltration of water, greatly reducing the chances of runoff or erosion. Even with tillage, if depth of tillage and burial of surface residues is minimized, increased organic matter at the soil surface results in greater infiltration capacity than traditional moldboard-plow tillage.

Keywords: dryland wheat production, erosion, soil aggregation, water infiltration

The inland Pacific Northwest is an ideal environment for growth of cool-season grasses. The region receives 70 ~~%percent~~ of its annual rainfall during ~~a~~ relatively mild winters. Extensively, soils are loessial (windblown) in origin, have good water-holding capacity, and allow deep rooting. Springs are warm with low relative humidity and low incidence of leaf diseases. The dry summers are ideal for harvest of high-quality grain. Native grasslands were fairly stable and free of wind and water erosion before humans started to utilize them for animal and crop production.

Grazing and tillage became major land ~~uses~~ in the later half of the 1800's. Over ~~a~~ century of cultivation has resulted in the loss of soil organic matter, ~~which—that~~ had accumulated under native grasses. Perhaps more important, natural stratification of organic matter near the surface has been replaced by a thoroughly mixed plow layer, so that the very high organic matter levels

naturally found on the surface of the soil are now diluted by being mixed with deeper soil. Organic matter near the soil surface provides a steady supply of food for microorganisms that bind soil particles together. At the same time, surface residue protects aggregates from the direct impact of rainfall and reduces the intensity of wetting and drying cycles. The loss of surface organic matter makes the soil much more prone to erosion by water and wind. As a result, a significant amount of the original topsoil has been lost over the past century.

Our challenge is to develop farming practices that prevent further loss of soil. We have been conducting research aimed at learning why native grasslands, long-term pastures, and long-term no-till fields have much greater water infiltration capacity than conventionally tilled fields. Insight on how soil management affects water infiltration will make it possible for farmers to choose techniques that maximize profitability and minimize erosion. This report summarizes our findings.

The most important factor determining whether water will soak in or run off is the ability of the soil surface to resist slaking and reconsolidation or crusting of the soil surface. Slaking is when soil aggregates (clusters or clumps of soil) break apart in water into separate soil particles. When the individual sand, silt, and clay particles are free to move, they settle into a very compact layer. Soil aggregation is therefore a very important property of most soils, as it controls water infiltration to a greater extent than the amounts of sand, silt, and clay,

The soils of the dryland wheat growing regions of the Columbia Plateau form very

fragile (weak) aggregates (Pierson and Mulla, 1990). This is partly because most loessial soils have low clay content (<less than 25 percent), and also these –soils are relatively young and the –warm, semi-arid environment does not allow –much organic matter to accumulate. Clay helps bind aggregates of sand, silt, and clay particles–, making them more resistant to slaking. Organic matter is even more important in creating and binding soil particles into aggregates and making them resistant to slaking.

The effect of soil organic matter on aggregation and infiltration can be illustrated with data from long-term plots maintained by Oregon State University and the Agricultural Research Service at Pendleton, Oregon (Machado et al., 2005). The Crop Residue Experiment was established in 1931 to test the effect of residue management and manure applications on soil and crop production. These plots are in a winter wheat-summer fallow crop rotation with different residue management and fertility treatments. These treatments result in varying amounts of residue being returned to the soil. After winter wheat harvest, residue is treated in

various–several ways; one treatment is burned in the fall, three others are burned in the spring. Another treatment receives ten 10 tons (wet weight) of barnyard manure, and another receives one–1 ton of pea-vine hay collected after fresh pea harvest. All plots are plowed in the spring, followed by cultivation and rodweeding through the summer-fallow period.

Figure 1 shows treatment combinations and nitrogen (N) fertilizer rates used, arranged in decreasing order of soil organic matter measured in the top four–4 inches after 70 years (Wuest et al., 2005). Aggregate stability, shown in–the middle chart (Figure, 1), mimics organic matter very closely, because it is–the soil organic matter that holds aggregates together. The scale in each is a–relative–scale, with the no-burn, 80 lb N/acre (fourth bar from the top) set as being 100%–percent on the scale. This allows comparison of the effect of soil organic matter on soil aggregates. For example, a ton of pea vines applied in the spring every other year for seventy–70 years (35 tons) increased organic matter relative to the no-burn, 80 lb N/acre by 10%–percent. It increased aggregate stability by about 20 percent.

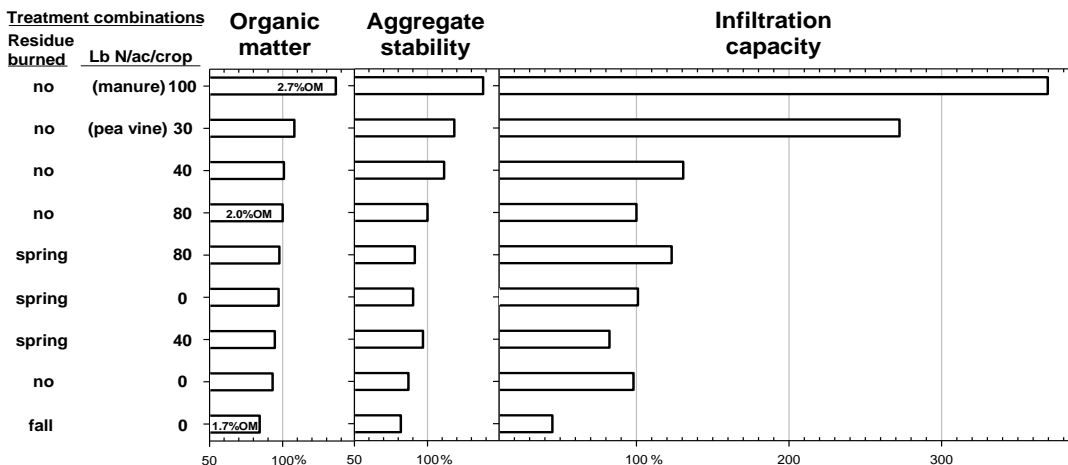


Figure 1. Treatments of the Crop Residue experiment, Pendleton, Oregon, arranged in order of soil organic matter in the surface 4 inches (bar chart on left). All three charts have the bottom axis scaled so that the fourth treatment down (no burn, 80 lb/acre) is 100%–percent.

The third chart in Figure 1 shows the measured infiltration rate using a ponded infiltration method. The pea vine treatment increased infiltration capacity by about 170 [percent](#) compared to the no-burn, 80 lb N/acre treatment. This shows that a small increase in soil organic matter can have a substantial effect on soil aggregation and a very important effect on water infiltration, even in a highly tilled cropping system, where [increased](#) organic matter levels are very difficult to achieve or maintain near the soil surface. In the Crop Residue experiment, higher organic matter levels were achieved by addition of manure and pea vine.

Significant improvements in infiltration capacity can also be achieved by reducing depth of tillage and the amount of mixing done by tillage. Figure 2 shows infiltration capacity measurements made on two other long-term experiments located at Pendleton. The upper graph is from the Tillage Fertility experiment. This experiment compares three primary tillage methods for establishing summer fallow in the spring: 1) moldboard plow, 2) tandem disk, and 3) sweep plow. All secondary operations are the same, but the different initial tillage methods produce different amounts and depths of soil- and residue mixing, and leave different amounts of residue on the surface. The moldboard plow incorporates almost all residue into the tillage layer.

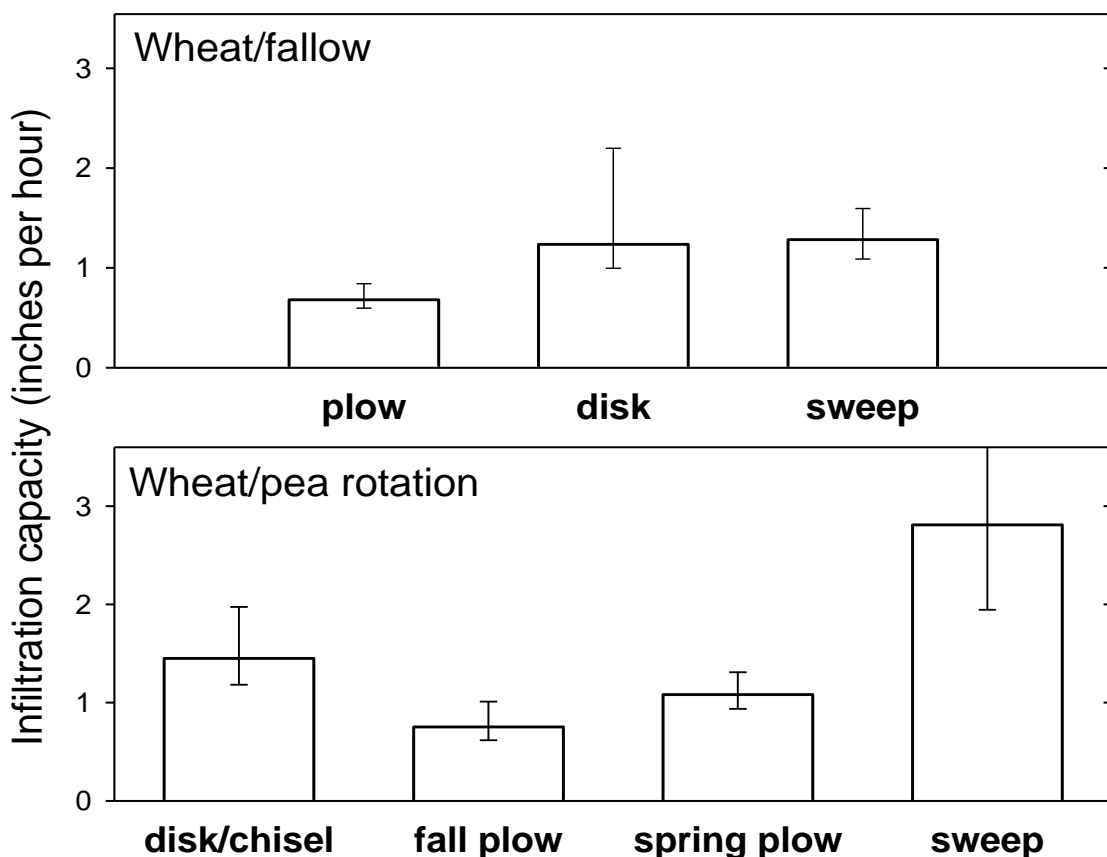


Figure 2. Pondered infiltration measured in two long-term experiments. The upper graph is the 45-year-old Tillage Fertility experiment where three initial spring tillage tools are compared, with all other summer-fallow tillage being the same. The lower graph is the 40-year-old Wheat/Pea Rotation comparing timing of plowing, disk/chisel, and Noble sweep at 4- to 6-inch depth. Error bars are ± 10 [percent](#) UMVUE Confidence Limits, method of Land.

The disk leaves intermediate residue levels on the soil surface—and residue ~~distribution mixing with depth~~ is more shallow; and the sweep plow, operated at about 4-6 inches, leaves the most residue at the surface and has the shallowest incorporation. The upper graph shows that, after 45 years, the disk and sweep plots have about twice the infiltration rate compared to the plowed plots.

The lower graph in Figure 2 shows measurements from the Wheat/Pea Rotation experiment— (Wuest, 2001). After ~~forty~~ 40 years, the disk/chisel (wheat stubble is disked in the fall, pea stubble is chiseled before planting winter wheat) and especially Noble sweep systems have much greater infiltration capacity compared to fall or spring plowing. The sweep system involves

the 80-inch-wide Noble sweep at 4- to 6-inch depth as the only preparation of wheat stubble and pea vine before planting.

How is it that less aggressive tillage is improving infiltration? Figure 3 shows soil organic matter content and distribution with depth in the wheat/pea rotation long-term plots. In the 0- to 4-inch soil increment, organic matter is greater in the disk/chisel and Noble sweep treatments. At 4- to 8-inch depth, the Noble sweep has *less* organic matter because the blade does not bury residues that deep. In the moldboard-plowed plots, the organic matter levels are almost the same throughout the plow layer (~~depths of 0-4 and 4-8 inches depths~~). The disk/chisel mixes the soil more than the Noble sweep, and less than plowing.

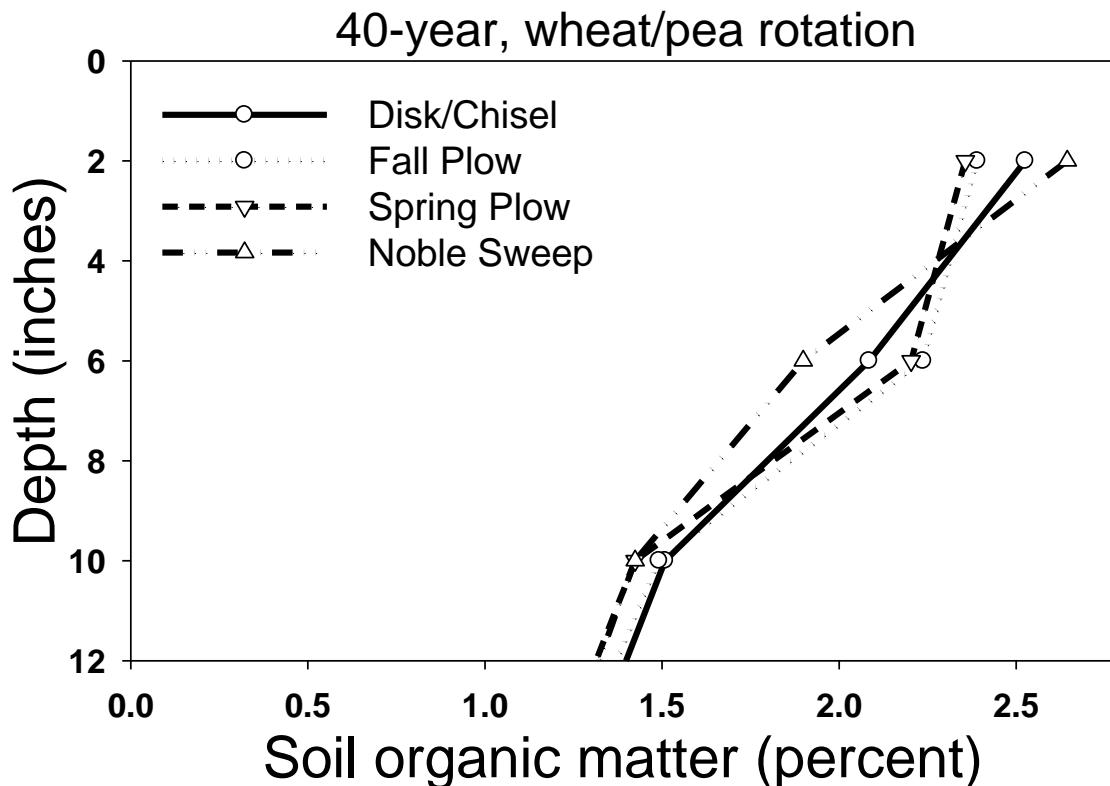


Figure 3. Soil organic matter in the Wheat/Pea Rotation experiment. Soil samples were taken from ~~depths of 0-to-4, 4-to-8, and 8-to-12 inches depths~~. Plowing mixes surface residues into the plow layer, which lowers organic matter levels near the surface and increases them at lower depths. Sweeping allows organic matter to accumulate near the surface, and decreases subsurface organic matter.

In addition to reducing soil organic matter and aggregation at the soil surface, tillage has another effect on water infiltration. The fracturing and mixing of soil below the surface interrupts the formation of zones of fast infiltration that conduct water rapidly from the surface to well below the plow layer. When we apply dye to the water used in our infiltration tests, we see in long-term no-till plots and perennial grass stands a network of dyed paths that rapidly carry water below our ~~ten~~10-inch sample depth. In tilled fields, the dyed water backs up and moves more slowly, wetting the entire soil mass. A long-term no-till field will allow dye to reach ~~eighteen~~18 inches or more in ~~ten~~10 minutes, while a conventionally tilled field will allow dye to reach only ~~two to six~~2-6 inches.

Changes in surface organic matter and deeper soil structure ~~take place slowly~~. Some of the benefits of surface residue are

immediate, because the presence of surface residue protects soil aggregates from rain, wind, and other ~~forces of weather~~ events. Substantial changes in soil aggregation, however, take several years. For example, we measured a doubling of water-stable aggregates in one experiment that has been under no-till for ~~seven~~7 years (Fig. 4). Infiltration in those plots has not yet achieved the capacity seen in the sweep plots of the ~~forty~~40-year-old Wheat/Pea experiment (Fig. 2, lower graph), because the deeper structural changes have not had time to fully develop. Those structural changes that occur in untilled soil will continue to develop, probably for several decades. Deep changes may improve drainage and water storage in years of above-normal rainfall or severe freeze-thaw events, and may create significant improvements in water infiltration on steep slopes.

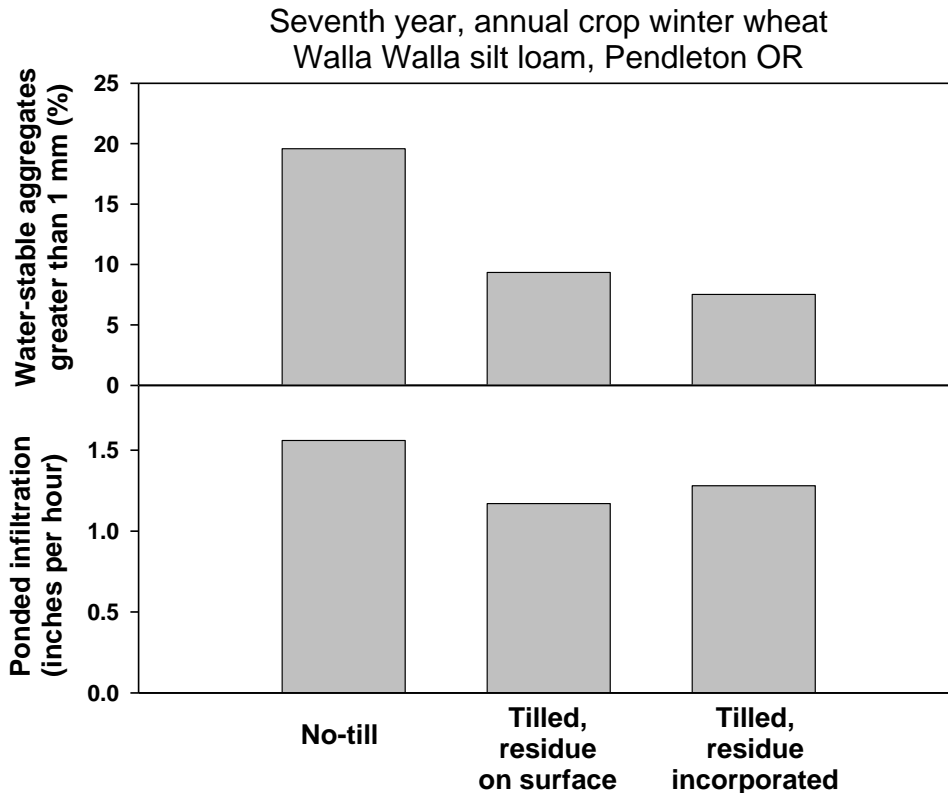


Figure 4. After ~~seven~~7 years of no-till, annual crop winter wheat, soil aggregation in the top ~~two~~2 inches is ~~over more than~~ twice that of tilled plots. Ponded infiltration, however, does not yet show the effects of deeper structural changes that will gradually increase infiltration capacity to more than double that of tilled soil.

To further test our conclusions, we performed infiltration measurements on farmer's fields chosen to represent seven major soil types in Umatilla County, Oregon. At each location, we measured ponded infiltration capacity on a conventionally tilled field, a no-till field, and perennial grass in a Conservation Reserve Program (CRP) field. The measurements were performed during the wheat cycle of the wheat/fallow rotation, and repeated two years later. The results shown in Figure 5

demonstrate the year-to-year and field-to-field variation that we experienced year-to-year and field-to-field. The different responses to no-till and perennial grass compared to conventional tillage can mostly be explained by the length of time each practice has been in place. Land recently converted from conventional tillage to CRP or no-till has had little time to develop higher organic matter levels at the surface, and certainly not time to develop deeper structural changes below the surface.

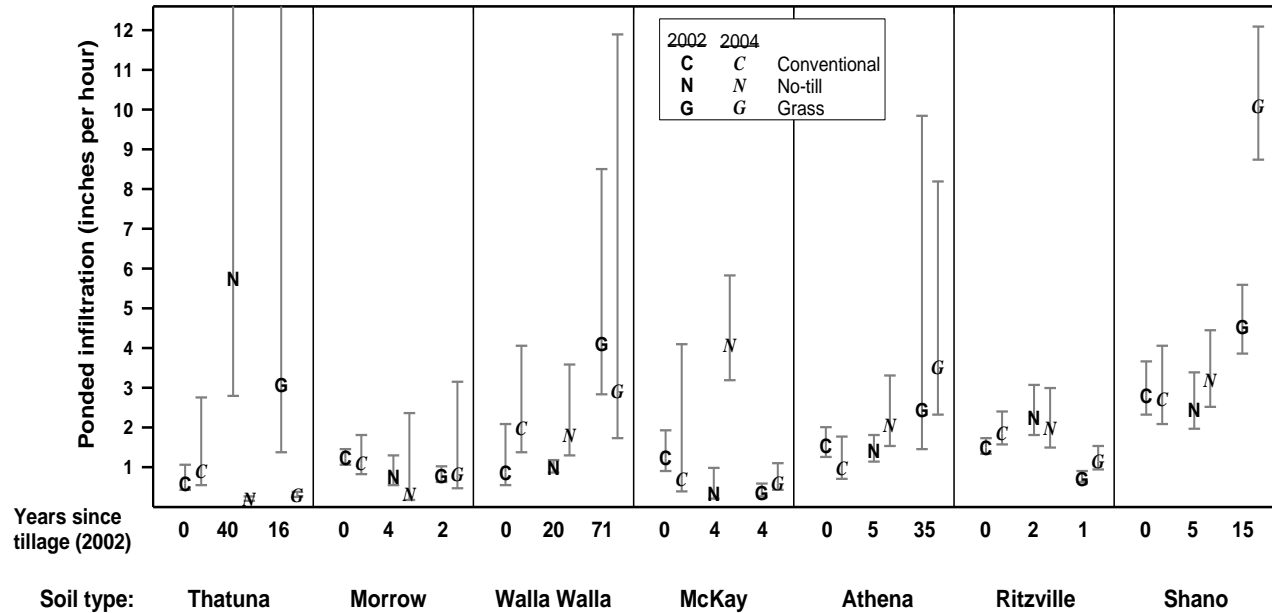


Figure 5. Ponded infiltration measurements made at seven locations in Umatilla County, Oregon in 2002 and again in 2004. The number of years the no-till or perennial grass had been in place when the first measurement was taken is shown under each graph. The error bars are 80 percent confidence intervals for each mean. The seven soil series are in order of decreasing silt content, left to right.

(For descriptions of soils see Soil Survey of Umatilla County Area, Oregon, Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Also available online: Soil Series Classification Database. Available URL: "http://soils.usda.gov/soils/technical/classification/scfile/index.html" [Accessed 21 March 2006]).

Even though we have measured and observed very rapid and deep infiltration with our infiltration tests on long-established no-till fields, there is no reason to be concerned that infiltration will be so rapid or so deep that water will be lost below the root zone. Water that penetrates the well-aggregated surface into a well-structured subsoil will be rapidly absorbed into dry soil encountered along the way.

These findings portray an optimistic picture for Pacific Northwest farmers as they work toward environmentally positive and economically sustainable cropping systems. Where no-till or direct-seed systems are profitable, they will provide maximum soil protection. Where tillage is necessary, the soil disturbance should be as shallow as possible and residue retained on or near the soil surface. Mimicking nature by maintaining the highest possible levels of soil organic matter near the surface and providing continuous residue cover is a key element to developing sustainable agricultural production for the Pacific Northwest.

References

- Machado, S., K. Rhinhart, S. K., Petrie, S., S. Wuest, R. S., Correa, R., and T. Johlke, T. 2005. Long-term Experiments at CBARC-Pendleton, 2004. [Pages](#) 73-86 *in* S. Petrie, S. and D. Long, D., Eds., Agricultural Experiment Station, Oregon State University, Special Report 1061, June 2005. <http://cbarc.aes.oregonstate.edu>.
- Pierson, F.-B., and D.-J. Mulla. 1990. Aggregate stability in the Palouse Region of Washington: effect of landscape position. *Soil Sci. Soc. Am. J.* 54:1407-1412.
- Wuest, S.-B. 2001. Earthworm, infiltration, and tillage relationships in a dryland pea-wheat rotation. *Appl. Soil Ecol.* 18:187-192.
- Wuest, S.-B., T.-C. Caesar-TonThat, S.-F. Wright, and J.-D. Williams. 2005. Organic matter addition, N, and residue burning effects on infiltration, biological, and physical properties of an intensively tilled silt-loam soil. *Soil Till. Res.* 84:154-167.