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Vertical and Subsurfer Tillage Reduce Surface Runoff of Nutrients and Fecal Steroids from Poultry Litter-Amended Fields

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And the 2012 Changes to Maryland's Nutrient Management Guidelines

Researchers from the University of Maryland (UM) studied the effects of three raw poultry litter tillage techniques on the surface transport of fecal steroids, nitrogen (N), phosphorous (P) and Total Suspended Solids (TSS) following rain-induced runoff from research watersheds. The four-year study shows that incorporating poultry litter into soil could significantly reduce nutrient and estrogen runoff to the Chesapeake Bay.

The UM research results helped provide the scientific basis for the 2012 revision of Maryland's Nutrient Management Regulations that require organic nutrient sources, such as poultry litter, to be incorporated into the soil. The revised regulations do not require incorporation on fields containing highly erodible land.

Based on the study results, the regulations requiring litter incorporation should result in significant reductions in nutrients and estrogens to Chesapeake Bay especially in late spring/early summer when phytoplankton productivity is rapidly increasing and many organisms are spawning and producing young.

On Average, the No-till Watershed had Higher Levels of Runoff of Steroids, Nutrients and Suspended Solids

The UMD researchers compared three tillage practices using paired 20-acre research watersheds between 2008 and 2011. Researchers applied litter using standard no-till (NT) surface application, Subsurfer (Subsurface) litter injection (SS), or Turbo-till® vertical tillage (TT).

- Turbo-till® reduced estrone by a three-year average of 43% and estrogenicity by 62% compared to no-till.
- The Subsurfer technique reduced estrone an average of 82% compared to no-till.
- Average surface runoff nitrogen losses in the TT watershed during May 2008-2010 were approximately fivefold lower compared to the NT watershed.
- TT reduced phosphorous losses early in the growing season by approximately 50%.
- Total Suspended Solids losses were greater from TT compared to NT.

- The SS/NT observed patterns of nutrient loss were similar to the TT/NT comparison, with lower runoff concentrations early in the growing season.
- TSS losses were slightly less following SS compared to NT.

Study Spanned Four Years and Forty Acres of Watershed

In 2008-2011, researchers applied whole broiler house cleanout litter to paired 20-acre research watersheds located at the University of Maryland Wye Research and Education Center (WREC) in Queenstown, MD (Figure 1). Both watersheds used the same cropping regime with corn, followed by rye as a cover crop. Poultry litter was applied to both watersheds after the rye was killed via herbicide.

The litter used each study year came from a single poultry house from individual integrators. It had an average dry weight of 70.4% and an average N/P mass ratio of 2.9.

WREC scientists have measured the nutrient and contaminant transport patterns of the watersheds almost continuously since 1984. The nutrient application rate of 3 tons/acre was the normal rate for corn used on Maryland's Eastern Shore.

Soils in the watersheds are typical of those used for crop production in this area of the Eastern Shore. The two primary soil types are Mattapex silt loam and Whitemarsh silt loam. The research watersheds exhibit slopes of 0-3% and a range in hydraulic characteristics from poorly to moderately well-drained.

In May of each study year, researchers used standard no-till (NT) surface litter application in one watershed while in the other they used either Turbo-till® vertical tillage (TT) (2008-2010) or Subsurfer (2011) litter injection (SS) (Figure 2). Following litter application, corn was planted on each watershed. Corn yields between tillage techniques or years did not differ significantly.

In TT, litter was lightly tilled and mixed into the soil after surface application. SS tillage cuts a furrow in the soil into which the litter is dropped from a hopper, then covered, resulting in buried poultry litter with little surface disruption. The Subsurfer was developed by Dr. Dan Pote of the Dale Bumpers Small Farms Research Center, U. S. Department of Agriculture, Agricultural Research Service.

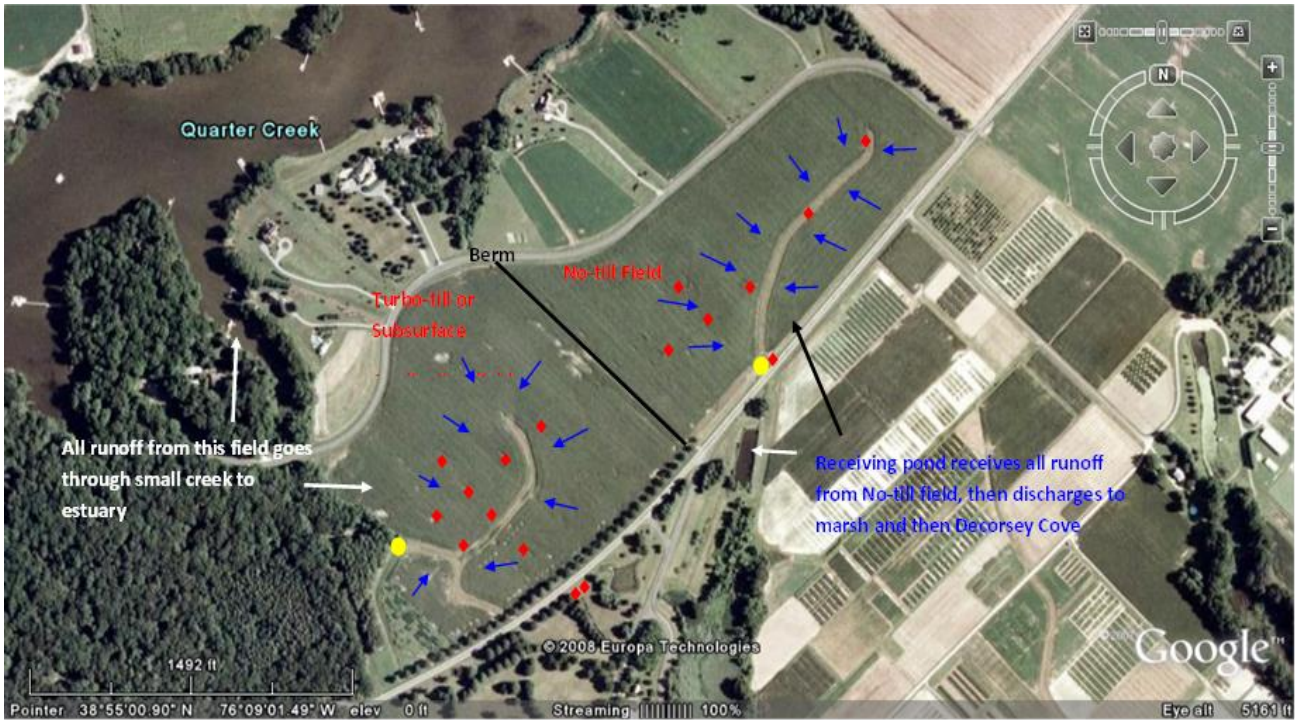
Researchers collected aqueous runoff samples from each field using automatic flow-weighted composite samplers. Estrogens and estrogenicity were sampled from each runoff event during the summer, either as a single grab at peak flow or a composite sample around peak flow. The Nitrogen (N), Phosphorous (P) and Total Suspended Solids (TSS) samples came from every runoff event during the year to calculate yearly flow-weighted values.

Dr. Steve Hutchins (U.S. Environmental Protection Agency (USEPA) National Risk Management Research Laboratory, Ada, OK) used GC/MS/MS with derivatization to analyze the samples for estrone (E1) and 17-β estradiol (E2). Dr. Vickie Wilson (USEPA Reproductive Toxicology Division, Research Triangle Park, NC) used an In-vitro estrogen-inducible reporter-gene assay (K_{BLUC}) to measure for estrogenicity as estrogen equivalents (EEQ). Dr. Ken Staver (WREC) analyzed nitrogen, phosphorous, and total suspended solid.

Tillage Techniques Affected Contaminant Runoff Following Precipitation

As one would expect, differences in steroid, nutrient and total suspended solids surface runoff versus tillage technique were driven by precipitation events, especially when events occurred closely following litter application. It is also noteworthy that differences in estrogen and nutrient losses were primarily in the dissolved phase.

Figure 1. The paired 20-acre watersheds used for the study are located at University of Maryland Wye Research and Education Center in Queenstown, MD



♦ Groundwater wells screened at water table; → Surface flow to collection channels; ● Automatic runoff collection flumes, all surface runoff passes through these flumes for sampling.

Figure 2. Researchers applied poultry litter using three tillage techniques

Table 1. Subsurface tillage resulted in largest reduction in fecal estrone compared to no-till

Year	Tillage Practice		% Reduction in Fecal Estrone from No Till	% Reduction in Estrogenicity from No Till
2008	NT	TT	58%	66%
2009	NT	TT (Event 2)	28%	71%
	NT	TT (Event 3)	Sample lost	66%
2010	NT	TT	43%	43%
2011	NT	SS (Grab)	79%	Not measured
	NT	SS (Composite)	84%	Not measured

NT= no till. TT=Turbo-till®. SS=Subsurface litter injection.

The average (2008 – 2010) percentage reduction of estrone and estrogenicity for Turbo-till® compared to No-till was 43% and 62%, respectively (Table 1). For the Subsurfer technique the average (2011) percentage reduction in estrogens compared to No-till was 82%.

Average surface runoff nitrogen losses during May were approximately fivefold lower from the Turbo-till® watershed compared to the no-till watershed (Figure 3). Turbo-till® reduced phosphorous losses early in the growing season by approximately 50 percent (Figure 4).

Figure 3. Turbo-till® reduced average dissolved and particulate nitrogen runoff losses in May

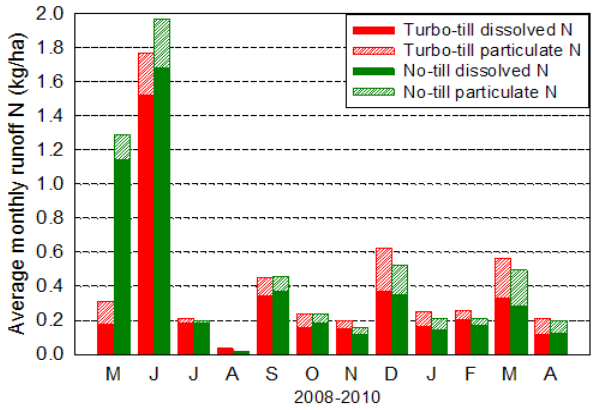
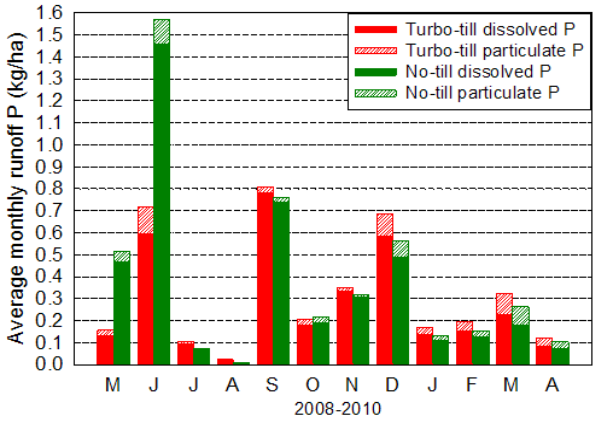


Figure 4. Turbo-till® reduced average dissolved and particulate losses of phosphorous in early spring



Similarly, injection of poultry litter using Subsurfer tillage reduced nutrient runoff concentrations early in the growing season compared to no-till (Figures 5 and 6). Even after almost 3 months of drought prior to Tropical Storm Irene in 2011, there was a significant benefit to Subsurface injection, especially for nitrogen.

Figure 5. Despite drought and a tropical storm, Subsurfer tillage significantly reduced dissolved and total nitrogen losses late in the growing season

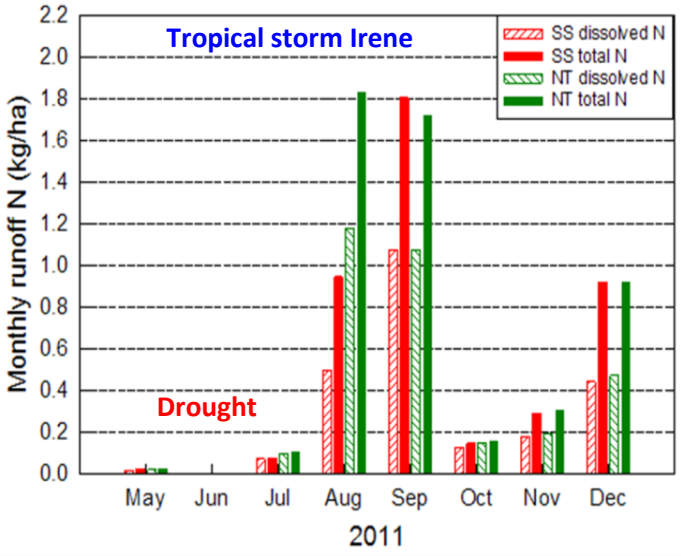
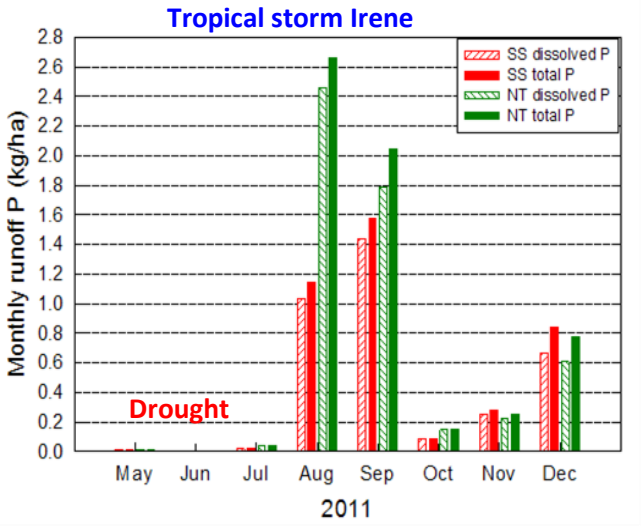
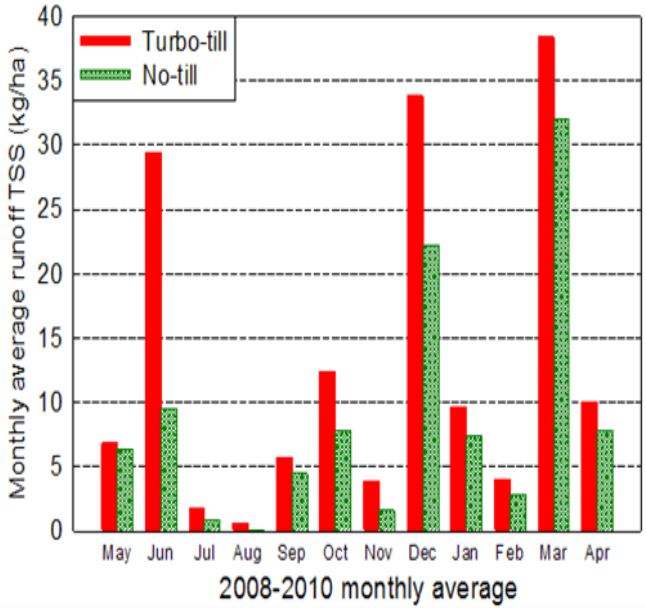


Figure 6. Subsurfer tillage reduced average dissolved and total phosphorus losses by more than half in August 2011, despite significant weather events



Total Suspended Solids losses were greater from the Turbo-till® field than the No-till field (Figure 7). No-till litter application was designed specifically to reduce losses of soil to the Chesapeake Bay. Even though Turbo-till produces significant reductions in nutrient losses, the downside is an increase in soil loss compared to no-till.

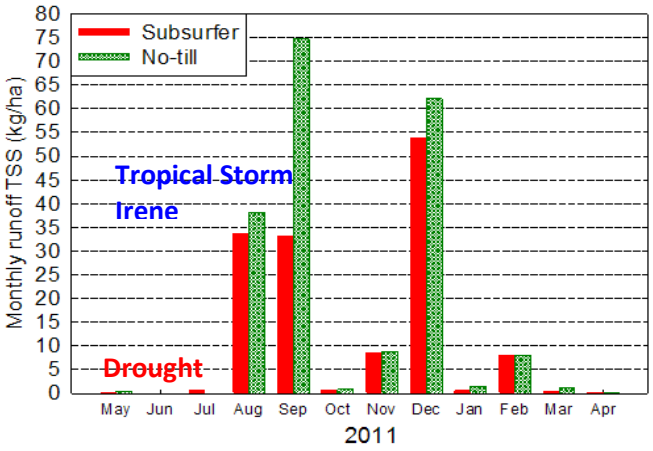
Figure 7. Turbo-till reduces nutrient runoff but increases soil (TSS) loss



Specifically, Turbo-till® vertical tillage increased soil losses by approximately 50 percent relative to no-till, with most of the increase occurring early in the growing season. Overall soil losses were very low for cropland though, averaging 156 kg/ha/yr from the TT watershed versus 102 kg/ha/yr from the NT watershed during the three-year comparison.

In contrast to vertical tillage, even after almost three months of drought Subsurfer litter application resulted in less loss of total suspended solids than no-till while still providing significant benefits from a nutrient and estrogen loss standpoint (Figure 8).

Figure 8. Monthly total suspended solids (TSS) in surface runoff were lower in the Subsurfer watershed



When viewed on a yearly basis, total estrogen and nutrient losses appear relatively small. It is important to remember that the greatest reductions occurred after spring litter application following precipitation. Previous WREC studies have shown that poultry estrogens in no-till runoff can cause endocrine disruption in fish.

Other research has also shown the detrimental effects of excess nutrient runoff to aquatic ecosystems. Spring/early summer is a very sensitive time for these ecosystems and so reductions in pollution are very important during this time period.

Maryland's 2012 revised Nutrient Management Regulations require that organic nutrients be injected or incorporated into soil as soon as possible, but no later than 48 hours after application. Nutrient runoff data generated in this study on the efficacy of alternative tillage techniques helped provide the scientific basis for these regulations. The results are for watersheds with shallow slopes and a range in hydraulic characteristics from poorly- to moderately well-drained. The revised regulations do not require incorporation for fields containing highly erodible land as defined by the USDA-Natural Resource Conservation Service in its Field Office Technical Guide.

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Additional information on this research can be obtained by contacting Dr. Daniel Fisher (dfisher2@umd.edu).

Daniel J. Fisher (dfisher2@umd.edu), Kenneth W. Staver (kstaver@umd.edu) and Lance T. Yonkos (lyonkos@umd.edu)

This publication, *Vertical and Subsurfer Tillage Reduce Surface Runoff of Nutrients and Fecal Steroids from Poultry Litter-Amended Fields* (FS-1017) is a series of publications of the University of Maryland Extension and Environmental Science and Technology Department/Wye Research and Education Center. The information presented has met UME peer review standards, including internal and external technical review. For more information on related publications and programs, visit http://agresearch.umd.edu/wye . Please visit http://extension.umd.edu to find out more about Extension programs in Maryland.