SOUTHEAST PURDUE AGRICULTURAL CENTER (SEPAC)

Soil drainage and nitrate losses to surface waters:

Insights from long-term SEPAC study

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Long-term drainage experiment insights on crop yield, cover crop growth, soil improvement, water flow, and chemical transport in southeastern Indiana: Part 3 of 3-part series.

Drainage pays!

This is Part 3 (of 3) of a study detailing key findings of a 35-year project conducted at the Southeast Purdue Agricultural Center (SEPAC) in Butlerville, Indiana, six miles east of North Vernon in Jennings County.

Part 1 (AY-397-W) focuses on cash crop establishment and yield as affected by drain spacing.

Part 2 (AY-398-W) discusses the effects of drainage on cover crop growth and the effectiveness of other conservation practices on improving crop growth and soil properties.

Part 3 (AY-399-W) discusses drain spacing effects on the amount of water and nitrate-nitrogen leaving the field in drainflow and the effects of cover crops on those losses. Key conclusions:

- **Closer drain spacings lose more water and nitrate in tile drainflow**
- **Cover crops reduce nitrate losses from tiles**

Although these results are specific to this study on the Clermont silt loam soil at SEPAC, most of the findings are more generally applicable across other poorly drained soils, although the specific values will vary with soil and climate.

Parts 1, 2, 3 and the executive summary (AY-396-W) can be downloaded for free at Purdue Extension Education Store. https://www.edustore.purdue.edu/

Background and field design

Subsurface "tile" drainage is a common water management practice for many naturally occurring poorly drained soils throughout Indiana and much of the Midwest. Although tile drainage is an essential water management practice for good crop production on these soils, it leads to greater nitrate-nitrogen losses from the rootzone to drainage water and ditches, due to the greater water flow through the soil profile. These nitrate losses are an economic loss to the producer as well as a water quality impairment contributing to hypoxia in coastal waters. Researchers and farmers have been studying ways to reduce nitrate losses while maintaining adequate drainage for crop production. Our long-term studies on tile drainage and water quality at the Southeast Purdue Agricultural Center (SEPAC) have contributed to increased knowledge of and practical implications for balancing necessary drainage with reducing nitrate losses from drained agricultural fields.

The original goals of the SEPAC drain spacing studies were to evaluate the impact of subsurface drain spacings on drainage flow and corn growth and yield. Additional objectives were added over the years, especially related to movement of agricultural chemicals (nitrate-N and pesticides) through the soil into the drainage waters. This publication, Part 3 of a 3-part series, focuses on water flow and nitrate loss through the drain tiles. Please see Parts 1 and 2 for discussion of crop yields, cover crop growth, and soil health management practices as affected by drainage.

The drain spacing experiment consisted of three drain spacings plus an "undrained control", replicated twice in the field (Figure 1). Drains were installed at spacings of 5, 10, and 20 m (16, 33, and 66 ft), with the undrained control being at a spacing of 40 m (133 ft). Due to the very slow permeability of the Clermont

SEPAC drainage research site

- Drainage installed at four spacings to research spacing effect on yield.
- 5m, 10m, 20m, 40 m
- (16 ft, 33 ft, 66 ft, 132 ft)
- 2.5-3 ft depth
- 4-inch plastic drain tube, no sock or filter

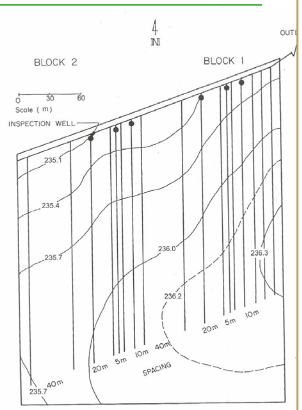

Figure 1. SEPAC drainage spacing field layout.

Photo 1. Lateral drain installation, exiting into culvert for measurement

Photo 2. Tipping bucket flow gauge, to measure drainflow

Photo 3. Automatic water sampler for drainflow sampling.

silt loam soil (now sometimes called Cobbsfork), the 40 m spacing was considered to be a good proxy for "undrained" conditions. Lateral drains were 4-inch diameter perforated plastic drain tubes, with no sock or filter, installed at a 0.4% grade at a depth of 2.5-3 ft. The installation depth kept the tiles above the depth of the restricting layer (fragipan) which was generally at 3.5-4 ft deep. The center drains of each of the 5, 10, and 20 m plots exited to a metal culvert (Photo 1) where the flow

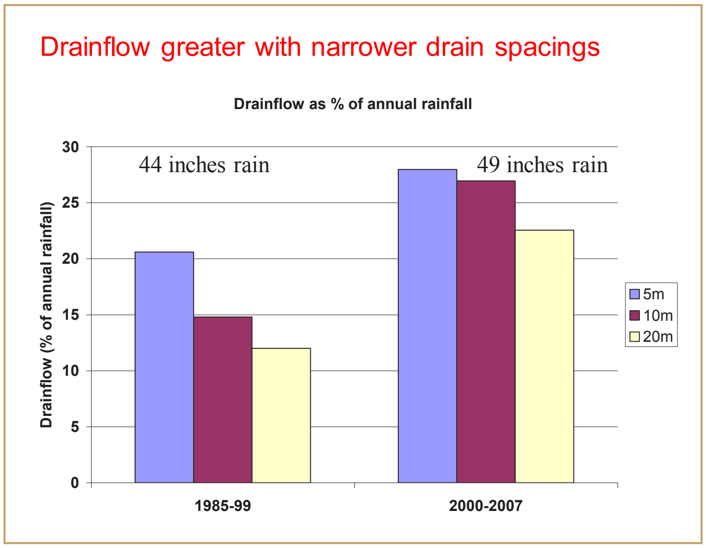

Figure 2. Drainflow as affected by tile drain spacing, during 1985-1999 and 2000-2007 time periods.

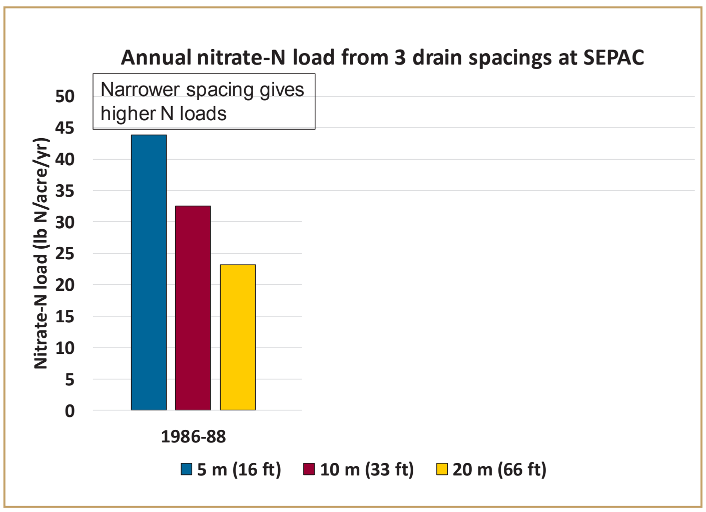

Figure 3. Average annual nitrate-N load during 1986-1988, as affected by drain spacing.

was measured with tipping bucket gauges (Photo 2) and water samples were collected on a flow-proportional basis with an automated water sampler (Photo 3), before the water was routed to the main drain and subsequently left the field.

Closer drain spacings lose more water and nitrate in tile drainflow

Tiles are installed to remove excess water from the field. When tiles are installed closer together, at narrower spacings, it is done to remove more water faster. Figure 2 shows the average annual drainflow as a percent of the average annual rain, for the three measured tile drain spacings during two different time periods at SEPAC. During 1985-1999, the average annual rainfall at SEPAC was 44 inches. The widest spacing (20 m; 66 ft.) removed about 12% of the annual rainfall as drainflow. As the tiles were brought closer together, more water was removed: about 15% for the 10 m spacing and 21% for the 5 m spacing. During the next 8-yr period (2000-2007), average rainfall increased by 5 inches to an annual 49 inches, with most of this increase occurring in winter-early spring. Thus drainflow was increased by nearly the same amount. Drainflow as a percent of rainfall increased to about 23%, 27%, and 28% for the 20, 10, and 5 m drain spacings, respectively. These data clearly show that closer drain spacings remove more water per acre in drainflow than do wider drain spacings.

Because there is more water lost per acre with narrower drain spacings, that means there is more water flowing through the soil, carrying nitrate-N to the drains. Thus more nitrate-N will be lost in the drainflow with narrower drain spacings. At the SEPAC site, the nitrate-N concentrations did not vary among the three drain spacings, because the crop yield differences among the three drain spacings (5, 10, 20 m) were relatively small. But since the water flow did differ greatly among the three drain spacings, the nitrate-N loads also differed greatly. Figure 3 illustrates nitrate-N loads during the first time period. The 20 m (66 ft) spacing lost an average of 23 lbs N/acre/year during the 1986-1988 time period. As drainage intensity increased, so did N losses. The 10 m (33ft) spacing lost 33 lbs N/A/yr, and the narrowest spacing (5m; 16 ft) lost 44 lbs N/A/yr. These results clearly show that as drains are put closer together, both more water and more nitrate per acre come out in the drains. We'll return to this point in the next section.

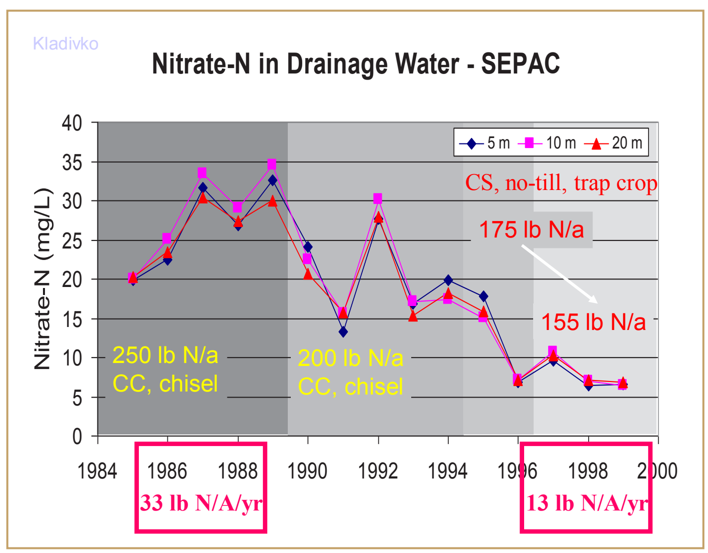

Figure 4. Nitrate-N concentrations in drainflow from 1985-1999, showing changes with time as management practices were changed. See text for detailed explanations.

Cover crops reduce nitrate losses from tiles

Cover crops reduce nitrate-N concentrations and loads in tile drainflow. Figure 4 illustrates a number of points related to cover crops and other management practices as we changed them over time during the experiment. Concentrations are given as mg/liter, or ppm; the drinking water standard is 10 ppm nitrate-N. Note that the concentrations of all three drain spacings were essentially the same. During the first 5 years of the experiment, we grew continuous corn, using spring chisel tillage and with preplant anhydrous ammonia at 250 lb N/A, along with a small starter application. These rates matched the Extension recommendations at the time for a yield goal of 200 bu/A. The annual flow-weighted concentrations were between 20 and 35 ppm, which were high but typical around the Midwest for the time.

In 1989 the Extension recommendations had changed, and we applied 200 lb N/A as preplant anhydrous, along with about 25 lb N/A as starter. The concentrations dropped to 15 to 30 ppm, still with year-to-year variability based on weather, crop yield and other factors. For example, the higher concentrations in 1992 were due at least in part to the low corn yield in the drought year of 1991, which left greater residual nitrate-N that leached out in the winter-spring of 1992.

After 10 years of continuous corn, we switched to a soybean-corn rotation, switched from chiseling to no-till, and added a cover crop to trap residual N after the corn years. Because we now had a rotation with soybean, the N fertilizer rate was reduced first to 175 lb N/A and then to 155 lb N/A, along with starter at about 25 lb N/A. The nitrate-N concentrations dropped to consistently at or below the 10 ppm drinking water standard. The limitation of this study is that we cannot separate how much of the final drop in concentration is due to the reduction in fertilizer N rate and how much is due to the cover crop. But other studies around the Midwest have consistently shown reductions in concentrations due to cover crop growth, and we are confident that the concentration reductions at SEPAC are due in large part to the cover crop scavenging 10-30 lbs N/A each year it was grown.

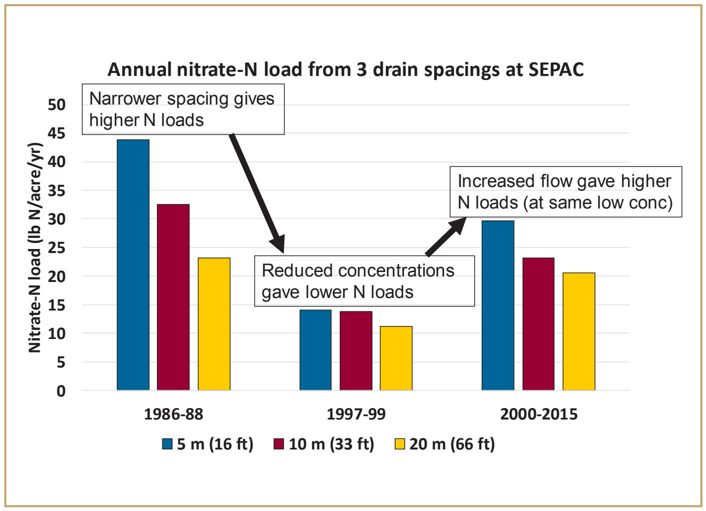

Figure 6. Average annual nitrate-N loads from 3 tile spacings, during three different time periods of long-term study. See text for detailed explanations.

Has the lower concentration continued even after cover crops have been used for many years? Figure 5 shows the nitrate-N concentrations from 2000-2015 remaining consistently in the 5-10 ppm range. Cover crops were grown on average every 2 years out of 3 during this period, rather than just every 2nd year, and species were varied, but the lower concentrations have remained.

The total nitrate-N loads from the 3 drain spacings during 3 different time periods are shown in Figure 6. The high nitrate-N loads in 1986-1988 have been discussed previously, when illustrating the greater losses occurring in the narrower drain spacings. These loads were high but again typical of the time period in the Midwest. During the 1997-1999 time period, after the conversion to no-till corn-soybean rotation with the lower N fertilizer rate and the cover crop growth, loads were greatly reduced to about 10-14 lb N/A/yr. There was still evidence of greater losses with the narrower spacings, but the overall loads were much reduced. In 2000-2015, the concentrations remained low (Figure 5), but the rainfall and therefore drainage went up (Figure 2), thus causing an increase in nitrate-N loads. Again, the narrower drain spacing lost more N out the drain than did the wider spacing.

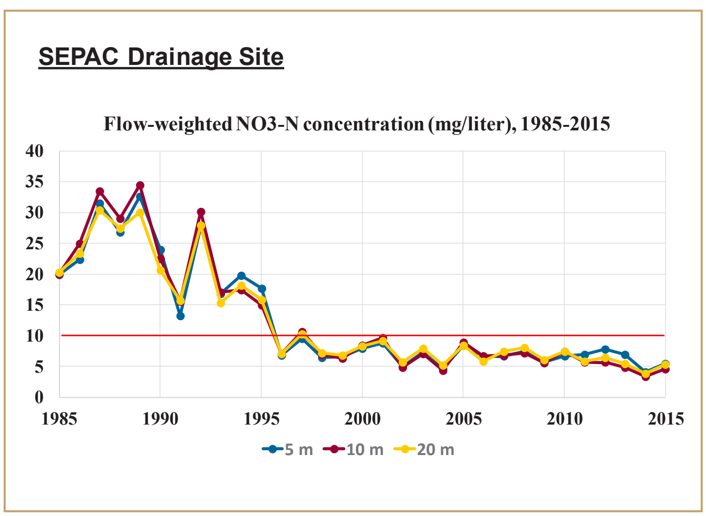

Figure 5. Nitrate-N concentrations in drainflow from 1985-2015. See text for detailed explanations.

The bottom line from these data

- Drain spacing matters. The narrower the drain spacings, the more water and more nitrate will be lost in the tile drains.
- Rainfall (excess) matters. A year with greater rainfall, especially if it is in the non-growing season, will give more drainage and more nitrate loss.
- Cover crops reduce nitrate-N concentrations and loads in tile flow.
- Implication: If we intensify drainage, which will increase flow, then we should also intensify management of some other aspects of the system, such as cover crops or controlled drainage, to reduce the "leakiness" of the system. Figure 7 illustrates the concept of cover crops in this regard.

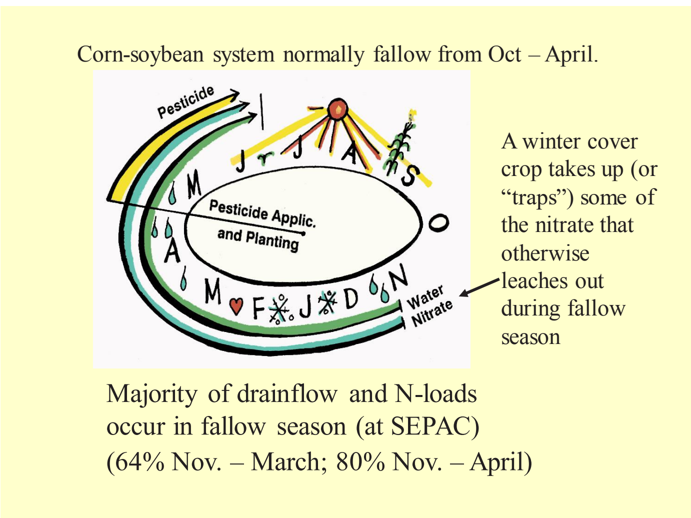

Figure 7.

Drainage is an essential water management practice for many soils in Indiana and the Midwest. Managing nitrate losses from the soil into drainage waters is important both for producer economics and for water quality. Readers are encouraged to check out the regional publication "Ten ways to reduce nitrate loads from drained cropland in the Midwest" http://draindrop.cropsci.illinois.edu/index.php/i-drop-impact/ten-ways-to-reduce-nitrogen-loads-from-drained-cropland-in-the-midwest/ for more discussion on ways to provide adequate drainage for crop production while reducing nitrate losses to downstream waters.

Acknowledgements

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