SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 31

Reducing Nitrate Losses from Drained Lands

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Subsurface (tile) drainage removes excess water; improves trafficability; reduces excess water stress, soil compaction, surface runoff, erosion, and phosphorous transport; enhances soil aeration; encourages root development; removes excess salts; and leads to greater and more consistent yields. In spite of these numerous benefits, tile drainage can also increase the transport of nitrate from the field to nontarget areas. Nitrate is transported from surface soil to nontarget areas with percolating water because it is not attached to the soil particles. The goal of this chapter is to discuss in-field and edge-of-field practices that reduce nitrate transport through tile-drained systems (Fig. 31.1).

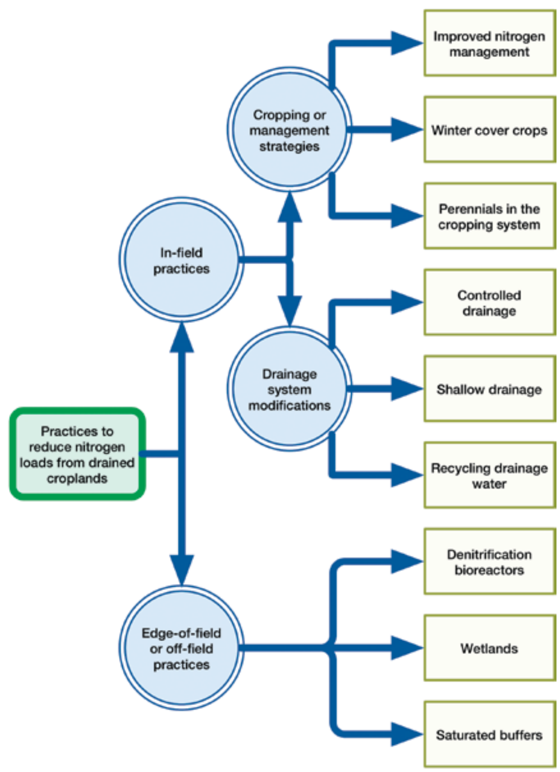

Figure 31.1 Classification diagram of practices for reducing nitrogen loads from drained croplands. (Modified from Christianson et al., 2015)

The Nitrate Problem

Nitrate-N concentrations in drainage water are highly variable and often exceed the EPA drinking water standard of 10 ppm (mg/L). Reducing high nitrate concentrations to levels at or below the EPA drinking water standard can be expensive and may require expanding urban and rural water treatment facilities. For example, the Des Moines Water Works installed expensive nitrate-removing treatment facilities to clean river water that receives tile-drainage waters from upstream sources. To recover these costs, it filed a lawsuit against three Iowa counties where tile drainage is prevalent. In South Dakota, nitrate-N concentration in ground and surface waters is highly variable, ranging from near zero to much higher than 10 ppm. Generally, however, nitrate-N concentrations in South Dakota rivers are less than 10 ppm.

On a broader scale, nitrate-N derived from drained croplands in the Upper Midwest is a major contributor to hypoxia in the Gulf of Mexico (Alexander et al., 2008; US EPA, 2007). The hypoxic zone results from nitrogen and phosphorous stimulating microbial growth in the Gulf of Mexico. The dissolved oxygen in the water decreases when the microbial organisms die and are decomposed, which reduces oxygen availability to desirable species. Hypoxia has environmental and economic consequences because the amounts of harvestable fish and shellfish from the affected regions are reduced. To reduce hypoxia, states along the Mississippi River, not including South Dakota, have been tasked with reducing nutrient loading to streams and tributaries that feed the Mississippi River (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). The strategy to achieve this goal is the adoption of nutrient Best Management Practices (BMPs). The feasibility and potential impacts of nutrient BMPs on nitrate loading in Iowa is available in IDALS (2014) from the Iowa Department of Agriculture and Land Stewardship. In South Dakota, cost share may be available for implementing BMPs from the USDA NRCS. As public scrutiny about drainage and water quality increases, the potential exists for increased regulation. One way for farmers to be proactive about water quality is to voluntarily adopt practices that reduce off-site nitrate deposition. This chapter describes some of the most promising practices currently available.

In-field Practices

Cropping and Management Strategies

Improved nitrogen management. Applying N in excess of plant requirements increases the risk of nitrate leaching. Nitrate-N concentrations in drainage water can be reduced by multiple practices, including adopting N management strategies that improve N-fertilizer efficiency. These practices include reducing fall N applications, splitting the N application into two or more applications to target plant uptake requirements, and adopting cropping systems that enhance nutrient cycling (Fig. 31.1). Optimizing nitrogen application rates, timing, and using nitrification inhibitors can limit nitrate losses and improve N efficiency. Additional information about alternative in-field techniques is available in Chapters 20 and 29.

Cover crops. Cover crops reduce nitrate losses by utilizing NO_3-N that otherwise would be lost through leaching (Chapter 15). In South Dakota, integrating cover crops into corn and soybean rotations is complicated by the region's short growing season. Research is being conducted to overcome this limitation. In Iowa, it was estimated that cover crops have the potential to reduce nitrate loading by 31% (IDALS, 2014), whereas in Minnesota, it was estimated that cover crops have the potential to reduce nitrate loading by 20% (State of Minnesota, 2014). Similar estimates are not available for South Dakota.

Perennial crops. Including perennial plants, such as alfalfa or native grasses, in a cropping rotation, has the benefit of reducing N fertilizer additions and nitrate losses while providing habitat for wildlife and insect pollinators. In Iowa, it was estimated that adopting a crop rotation that consists of two years of alfalfa, followed by three years of annual crops, could reduce nitrate loading 42% (IDALS, 2014).

Drainage System Modifications

Controlled drainage. Controlled drainage (or drainage-water management) uses flow-control structures to manage the timing and amount of drain flow by controlling the outlet elevation (Fig. 31.2). Many controlled drainage systems raise the outlet elevation during the late fall and winter. Reducing drain flow by raising the outlet elevation reduces total nitrate transport. In the spring and perhaps during harvest the outlet

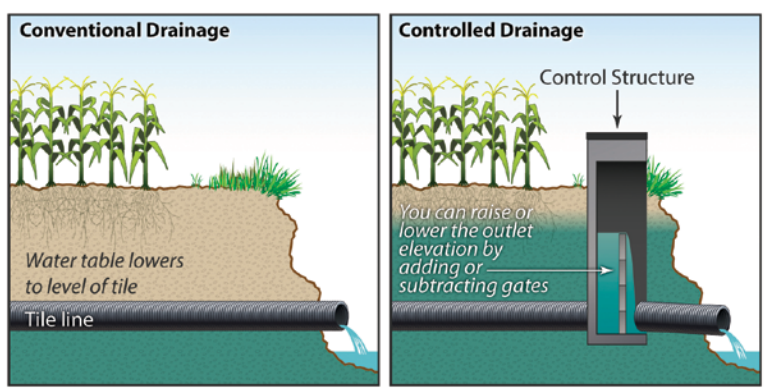

Figure 31.2 Controlled drainage (or drainage-water management) uses control structures to raise and lower the outlet elevation. The outlet is raised at times when drainage is not needed (the nongrowing season) or after spring field operations to store water in the soil for later availability for the crop. By reducing drain flow, controlled drainage also reduces nitrate losses from the drainage system. (Courtesy of Christianson et al., 2015)

is lowered and the system operates like a conventional drainage system. Water for the growing crop is increased by raising the outlet following spring operations. It is important to note that controlled drainage only manages the outlet elevation and that the actual water-table level is a function of precipitation, evapotranspiration and other water losses. In drainage systems requiring a lift station, this often is accomplished by turning off the pump.

Controlled drainage is best suited to relatively flat fields (< 0.5% slope). Typical recommendations are to install a control structure for each 1- to 2-foot change in field elevation. For fields with slopes greater than 1%, more control structures are required, which increases the cost. Aligning the drainage laterals with the field contours minimizes costs and maximizes the area served by each control structure. In some situations, traditional drainage systems can be retrofitted with control structures. However, if this option was not considered during the drainage design process, retrofitting may be impractical on all but the flattest of fields. Producers can receive technical and financial assistance through the USDA NRCS to help with the installation of a controlled drainage system.

Controlled drainage has little effect on actual nitrate concentrations in the water. Instead, nitrate load reductions are achieved by reducing the amount of drain flow. In a review of controlled drainage studies, Skaggs et al. (2012) found that controlled drainage reduced nitrate loading 18% to 79%. In Iowa, it was estimated that controlled drainage reduced nitrate loading 33% (IDALS, 2014). The costs of installing controlled drainage can be partially recovered by higher yields (Skaggs et al., 2012).

Shallow drainage. In shallow drainage systems, the tile lines are installed 2.5- to 3-feet deep in the soil as opposed to > 3.5 feet (Fig. 31.3). Placing the tile lines at shallower depths reduces the total amount of water drained from the soil, which reduces nitrate losses. However, shallow drainage, when compared with deep drainage, requires more tile lines, which increases cost. By not lowering the water table as deeply, more water is stored in the soil, which may contribute to higher yields.

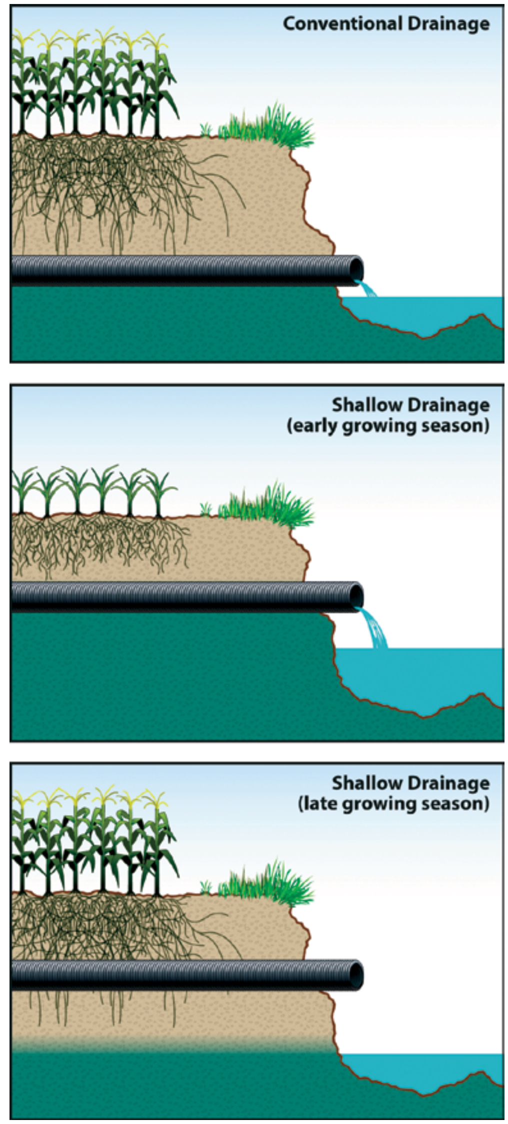

Figure 31.3 Shallow drainage is the practice of installing the drain lines at shallower depths (2.5- to 3-feet deep) instead of at deeper conventional depths (> 3.5 feet). By not draining the water table as deeply, shallow drainage reduces nitrate losses from the drainage system. In order to have the same drainage effectiveness, however, the drain lines must be spaced more closely than for conventional drainage. (Courtesy of Christianson et al., 2015)

Like controlled drainage, shallow drainage reduces nitrate losses by reducing drain flow. However, unlike controlled drainage, shallow drainage does not have any topographic limitations. In Iowa, it was estimated that shallow drainage could reduce nitrate loading 32% (IDALS, 2014). Similar estimates for South Dakota are not available.

Recycling drainage water. In drainage-water recycling, captured drainage water is stored in a holding pond or reservoir, and used to irrigate the crop in the summer (Fig. 31.4). The benefits of this approach include increased yields and recycled nutrients. Although the practice of drainage-water recycling is attractive, it is limited by topographic requirements, the availability of a storage reservoir, unknown economic returns, and, if high in other salts, could result in soils with greater salinity problems (Chapter 32).

Edge-of-field Practices

Denitrification Bioreactors

A denitrification bioreactor is a trench filled with a carbon source, typically wood chips. Drainage water is diverted though the bioreactor by a control structure (Figs. 31.5 and 31.6). During periods of high flow, a portion of the drainage water is allowed to bypass the bioreactor so that drainage in the field is not affected. In the drainage water that passes through the bioreactor, a portion of the nitrate is transformed to benign nitrogen gas through the microbial respiration process of denitrification. The bioreactor is designed to enhance this process by providing food (the woodchips) and minimizing dissolved oxygen in the water. Since denitrification is a biological process, the nitrate reduction depends on the temperature and the water flow rate. Water that does not flow through the bioreactor receives no treatment.

Bioreactors can be retrofitted to wide variety of drainage systems, and they can generally fit within the edge-of-field buffer areas. Bioreactors are best suited for fields < 80 acres and they should function for 10 to 15 years before the woodchips need replacement.

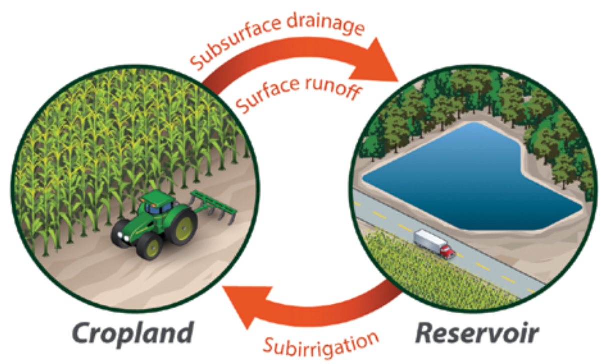

Figure 31.4 Drainage-water recycling is the practice of capturing subsurface drainage water, along with surface runoff, in a storage reservoir. The captured water is then used as an irrigation water supply for the crop during periods of deficit water conditions. By recycling some or all of the drainage water, the nitrate in that drainage water is also recycled, resulting in reduced losses of nitrate downstream. (Courtesy of Christianson et al., 2015)

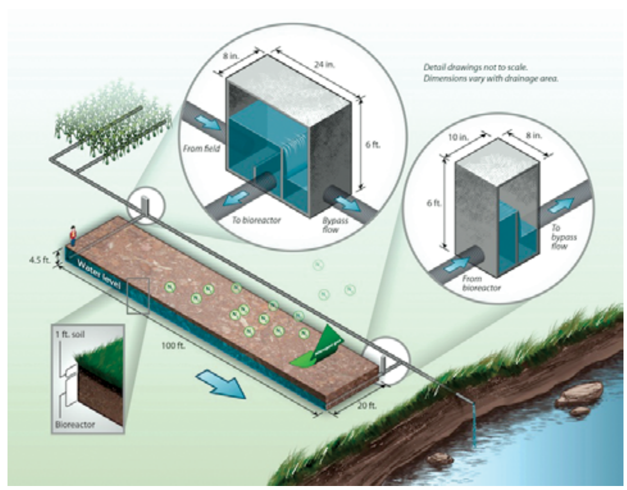

Figure 31.5 Schematic diagram of a denitrifying bioreactor. A control structure is used to divert water from the drainage system through a trench filled with woodchips. Another control structure is used to regulate the time the water spends in the bioreactor. Denitrifying bacteria in the woodchips convert nitrate in the drainage water into inert nitrogen gas, reducing the amount of nitrate delivered to the outlet. Water in excess of the bioreactor is allowed to bypass the system so that drainage in the field is not impeded. (Courtesy of Laura Christianson and Matt Helmers)

Testing Bioreactors in South Dakota

Four bioreactors have been installed and monitored for performance in South Dakota. Findings from these reactors suggest that their efficiency decreases with increasing flow rate. During periods of high flow, nitrate concentrations can be reduced 30% to 40%, whereas during periods of low flow, nitrate concentrations can be reduced > 90%. In Iowa, it was estimated that bioreactors reduced nitrate concentrations 43% (IDALS, 2014). The estimated cost (2016) for installing a bioreactor in South Dakota is approximately $10,000. Unfortunately, bioreactors provide no real benefit to the farmer; the benefits are all downstream. Cost-share assistance is available through the USDA NRCS.

Wetlands

By routing drainage water through a wetland, the nitrate concentration can be reduced, while simultaneously providing habitat for wildlife, pollinators, and a variety of other benefits. The nutrient reduction results from the combination of plant nutrient uptake, microbial immobilization, and denitrification. An analysis of Iowa wetlands showed that on average nitrate concentrations were reduced 52% (Helmers et al., 2008). Compared to bioreactors, wetlands require a much greater land area, making them better suited for the capture of water from multiple fields.

Saturated Buffers

Vegetated buffers between the edge of the field and the surface water are a long-established practice to reduce sediment and nutrient losses from surface runoff. However, in fields with subsurface drainage, the drainage water has no chance for it to interact with the buffer since it's confined to the pipe. Saturated buffers work by using a control structure to divert drainage water through the buffer area's soil (Fig. 31.7). By reconnecting the drainage water with the soil in the buffer, nitrate concentration in the water is reduced. Saturated buffers are relatively new, so limited information is available about their long-term effectiveness. However, in an Iowa study, most of the nitrate was removed from water diverted into the buffer (Jaynes and Isenhart, 2014). The major drawback to this practice is that there is generally insufficient buffer area to handle all of the drainage water during high flows, so a bypass may be required. The bypass water receives no treatment, so the nitrate removal efficiency of the saturated buffer is a function of how much water can be diverted through the buffer. In Iowa, it was estimated that saturated buffers have the potential to reduce nitrate loading 50% (IDALS, 2014).

Figure 31.6 Photo of a partially completed bioreactor near Baltic, SD, showing the woodchips, plastic liner, geotextile cover, and soil cap. (Courtesy of C. Hay)

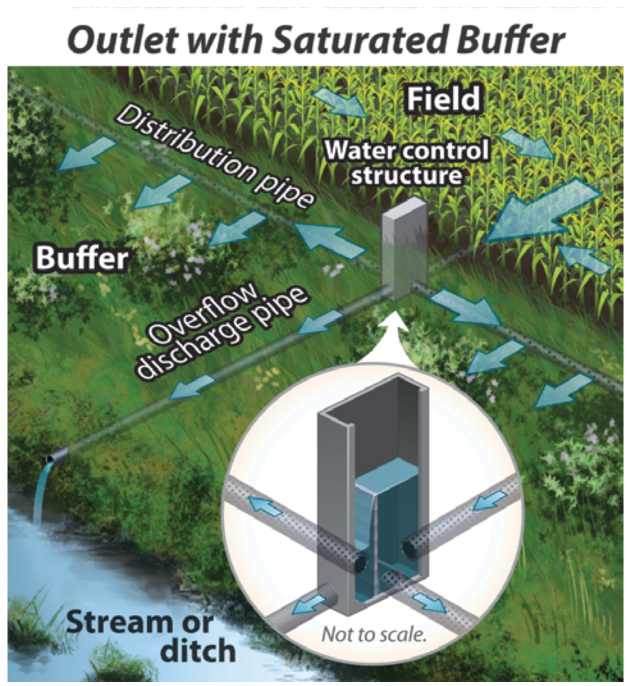

Figure 31.7 Saturated buffers use a control structure to divert water laterally in the buffer through perforated distribution pipes that release the water into the soil in the buffer. The water flows through the soil in the buffer, where it has a chance to interact with the vegetation and bacteria in the buffer for additional nitrate removal, before it discharges into the receiving water. (Courtesy of Christianson et al., 2015)

Summary

Subsurface drainage, or tiling, provides a number of economic production benefits to corn producers. However, impacts of drainage on the environment are mixed. Drainage can reduce sediment and phosphorous losses but increase nitrate-N losses compared with undrained croplands. There is increasing pressure to reduce nitrogen losses from subsurface drained land because of concerns over the Gulf of Mexico hypoxic zone from excess nutrients and public health concerns over elevated nitrate levels. A number of practices are emerging to maintain the production benefits of drainage while reducing the nitrate-nitrogen lost from these systems. A few of these practices offer the potential of added yield benefits to the producer, but many do not. There are, however, cost-share incentives in place to assist with implementing many of these practices. Adopting one or more of these practices is a proactive way for agricultural producers to demonstrate a commitment to water quality. Even if a practice won't be implemented immediately, evaluating and planning for practices that could be implemented within a producers cropping and drainage system will make it much easier for future adoption if financial or regulatory incentives change.

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