What Every CCA Should Know About Drainage

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Water table management through the use of artificial subsurface drainage systems is of primary importance in humid areas with poorly or somewhat poorly drained soils to maximize agricultural productivity. Excess precipitation throughout much of Midwestern agricultural watersheds is removed artificially via subsurface drainage systems that intercept and usually divert it to surface waters. Subsurface drainage systems have been installed to allow timely seedbed preparation, planting and harvesting and to protect crops from extended periods of flooded soil conditions. While there are significant production benefits of subsurface drainage, there are also concerns about the environmental impacts of the practice. A specific concern is related to nitrate-nitrogen loss through subsurface drainage systems. Nitrogen, either applied as fertilizer or manure or derived from soil organic matter, can be carried as nitrate with the excess water in quantities that can cause deleterious effects downstream. The movement of nitrogen from agricultural fields via drainage waters is a major factor in nonpoint source pollution of surface waters and, ultimately, of the Gulf of Mexico where it has been implicated as a cause of the Hypoxic Zone (Mitsch et al., 2001; Rabalais, et al., 1996). Understanding some basic underlying principles relative to subsurface drainage, drainage design, drainage management, and the environmental impacts of drainage are important for those involved with agriculture in the drained landscape.

Impacts of Drainage on Water Movement: Subsurface drainage removes excess or drainable water from the soil, thereby allowing for aerated soil conditions. The drainage water is water that can be drained by gravitational forces. Overall, the use of subsurface drainage systems takes little water out of the system that would be ultimately beneficial for crop production, but does allow for aerated soil conditions that are essential for crop growth. By draining some of the excess water out of the system there is greater storage capacity within the soil for subsequent rainfall events. As a result, at the field scale, drainage has the potential to reduce surface runoff.

Impacts of Drainage on Crop Yields: Obviously, there are crop production benefits of subsurface drainage, otherwise there would not be the widespread use of drainage systems. However, the overall crop production benefits vary from year to year due to various weather conditions and due to soil conditions. An example of this from southeast Iowa is where crop yield benefits of drainage varied from 7% to 25% over the period from 2007–2009. One thing to keep in mind is that there are certain soils that do not respond to drainage either because they are naturally well drained so there is little excess water stress conditions. In distinct contrast to this are soils that may be so poorly drained that they do not respond to drainage, no matter how close the drains are spaced. Before installing drainage systems, the potential response of the soils to drainage should be considered by examining the soil survey.

Impact of Drain Spacing: A frequent question related to drainage systems is how close the drains should be spaced. There are economic and environmental factors to consider when determining the drain spacing. Skaggs and Chescheir (2003) demonstrated that as drains are spaced closer together, the volume of subsurface drainage increases and, subsequently, the nitrate loss increases. Also, as the drains are spaced closer together, the cost per acre for the drainage system increases. However, as drains are spaced further apart there can be a decrease in crop production, which would have a negative economic impact. So, while taking into account these factors, what spacing should be used? The answer will also depend on soil conditions and the depth of drain placement. Local knowledge and local drainage guides provide useful information on recommended drain spacing. Overall, the closer the drains are spaced, the quicker the water table can be drawn down after a significant rainfall event, which may be very important depending on the time of year and conditions of the crop. If a shallow depth is used, the drains should be spaced closer together to allow for similar rates of water table drawdown after rainfall events. The spacing used should also consider the objective of the installation. If the objective is to minimize excess water stress during very wet years, one would want to install the drains closer together than if the objective is to maximize the long-term return from the investment in drainage. State or regional drainage guides are excellent resources along with local knowledge to estimate reasonable drain spacing.

Impact of Drainage Outlet Size: A main factor relative to drainage design is the size the drain pipes themselves. Two factors control drainage. One is how quickly water can get to the drains, which is a function of the soil and how close the drains are to each other. Another factor is the size of the infield pipe and outlet pipe of the drainage system. A term used to size drainage systems is the drainage coefficient, which is the equivalent amount of water from the drainage area that can be removed in a 24-hour period. Modern design standards for row-crop systems call for a drainage coefficient of 3/8–1/2 inch per day for systems where surface intakes are not present. While frequently there is discussion of the recommended drain spacing, often the sizing of the outlet, which also controls drainage rate, is not given much consideration. Frequently the drain size and ,specifically, the outlet is significantly under-sized relative to modern design standards. This usually occurs in areas where the drainage mains were put in decades ago and designed for different cropping systems, which required less drainage. Outlet size may limit the crop production benefits from a well-designed pattern drainage system. For example, based on recent modeling in Iowa, a relative yield increase of 10% might be expected if the outlet had a capacity of 3/8 inch per day rather than 0.2 inch per day.

Impact of Nitrogen Management on Water Quality: Often there are statements that high nitrate-nitrogen levels exiting from drainage systems are a result of excess nitrogen application. However, long-term research has shown that even at economic optimum nitrogen application rates, nitrate-nitrogen concentrations can exceed the drinking water standard of 10 ppm. As shown in Figure 1 from long-term monitoring data in Iowa, to have average nitrate-nitrogen levels below 10 ppm from a corn-soybean rotation the nitrogen application rate to corn would need to be below 100 lb-N/acre, which is below the recommended rate for corn following soybeans in Iowa (Lawlor et al., 2008). While the recommended nitrogen application rate will vary from state to state, it is important to recognize that nitrogen application rate does impact nitrate-nitrogen concentrations in tile lines and that, while over application should be avoided,even when appropriate rates are used there can be high levels of nitrate-nitrogen in the drainage water.

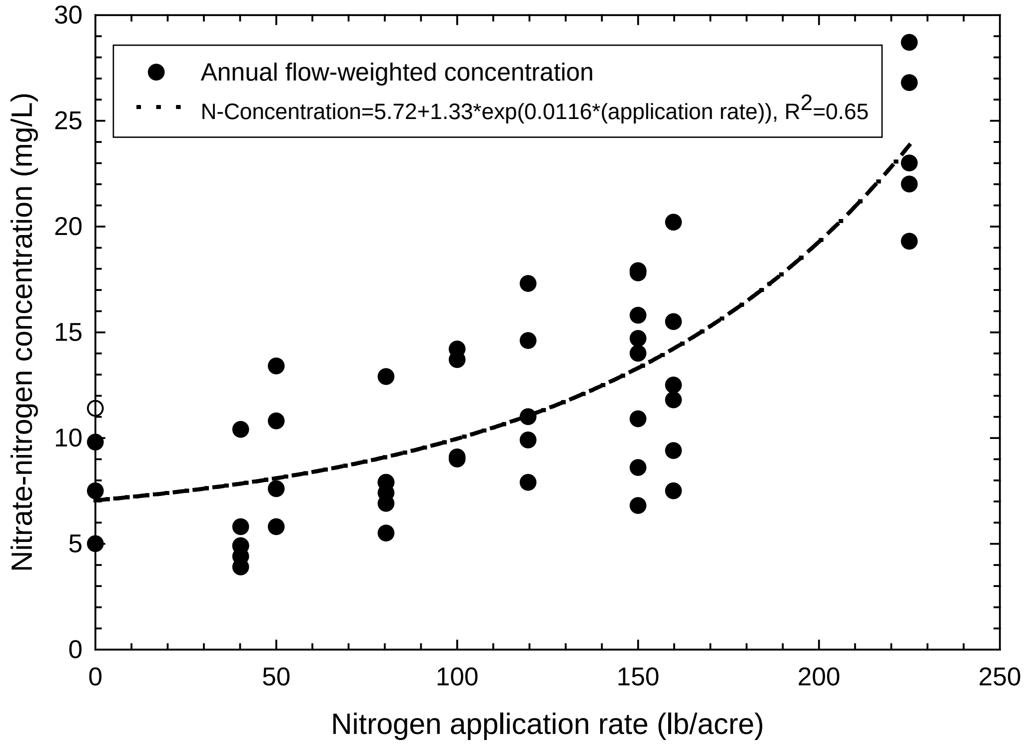

Figure 1. Overall nitrogen application rate effect on nitrate-nitrogen concentration in drainage water from a corn-soybean rotation

Impact of Landuse of Drainage Water Quality: The corn-soybean production system has significant periods of the growing season when there is little vegetative growth. This, combined with needs for nitrogen fertilizer for the corn crop, result in a system where there is nitrate in the soil profile during periods when there is little vegetative use, which leads to a loss of nitrate-nitrogen with drainage water during periods of excess precipitation. So, a question that frequently arises is how land-use changes or presence of perennial vegetation might influence nitrate-nitrogen levels. As shown in Figure 2 from recent monitoring data in Iowa, nitrate-nitrogen levels below grass-based forage cropping systems are dramatically lower than nitrate-nitrogen levels from the corn-soybean system. It should be noted that prior to planting the grass-forage system in 2005, this area was in a corn-soybean system with recommended fertilization rates. So, within 2–3 years there was a dramatic decline in nitrate-nitrogen concentrations. While a perennial based system would be expected to dramatically reduce nitrate-nitrogen levels, at present, there would be limited economic value for the agricultural products. This is why use of a winter cover crop has potential, since it may provide some of the same benefits of having growing vegetation during periods when the main cash crop is not growing while still allowing for corn-soybean production.

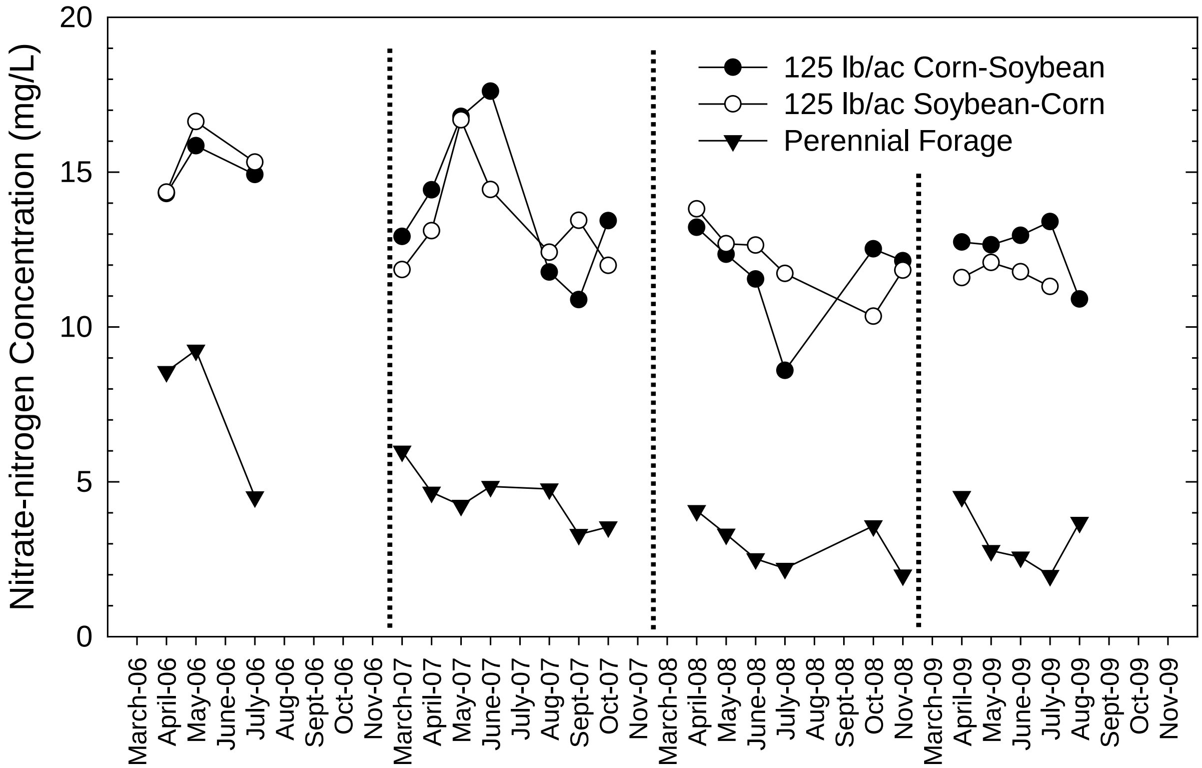

Figure 2. Impact of land use on nitrate-nitrogen concentration in drainage water

Design and Management of Drainage Systems for Environmental and Economic Benefits: As societal concerns relative to water quality increase, the design and management of drainage systems become increasingly important. As noted above, decreasing drainage spacing increases the volume of subsurface drainage. So, drain spacing should balance the crop production benefits and the potential discharge of water. In many cases, long-term yields can be maintained at high levels with slightly wider drain spacing, which can have positive impacts on reducing drainage volumes and, as a result, nitrate-nitrogen loss. An additional way to reduce drainage volumes would be to reduce the drain spacing and the depth of drainage installation. Recent research is showing that shallower drain placement, even when spaced closer together can reduce the outflow of drainage water by on the order of 25%. Another technology that can be used to reduce drainage volume and potentially increase crop yield is drainage water management, commonly referred to as controlled drainage. This technology employs a control structure at the outlet of the drainage system, which can be used to manage the water table within the crop field. This system can be used to manage the water table during the growing and fallow season but allows for normal drainage functioning during the planting and harvest season. Additional information on this technology can be found in Frankenberger et al. (2006). Not only can this technology reduce the volume of subsurface drainage, but since water is being stored within the soil profile during certain times of the year there also is the potential for crop production benefits.

Methods for Reducing Nitrate Concentrations from Drained Lands: Within the growing concern about nitrate-nitrogen levels, there are frequent questions about how we can reduce nitrate-nitrogen concentrations and export while still maintaining agricultural productivity—specifically corn-soybean production. As noted above, a couple of methods have potential, including the use of winter cover crops within the corn-soybean rotation system and the use of alternative drainage design and drainage water management. Cover crop systems have the potential to reduce the volume of drainage if the cover crop can use water that might have ultimately been exported through the drainage system while also reducing the concentration of nitrate-nitrogen in the drainage water. Alternative drainage and drainage water management practices have the potential to reduce the volume of drainage, but research has shown little if any impact on nitrate-nitrogen concentrations. However, if the volume of drainage can be reduced, the mass export of nitrate-nitrogen can be reduced.

Two other potential end-of-pipe technologies also hold great promise for reducing nitrate-nitrogen export to downstream waterbodies. These are nutrient removal wetlands and subsurface drainage bioreactors. Research in Iowa has shown that nutrient removal wetlands that are 0.5–2% of the watershed area and are strategically sited to intercept subsurface drainage water can reduce nitrate-nitrogen concentrations by 40–70%. While the size of the wetland needed for the 40–70% reduction would be expected to vary across the cornbelt, the nutrient-removal wetland technology has great promise for reducing nitrate-nitrogen levels while taking a proportionally small percent of the land out of production and providing benefits beyond the water quality enhancements through significant habitat value. Another emerging technology is subsurface drainage bioreactors, where drainage water is routed through a trench filled with a carbon source where denitrification occurs to reduce nitrate-nitrogen concentrations. Currently, the carbon source that is being used is wood chips. Research has shown substantial reductions in nitrate-nitrogen concentration from water flowing through the bioreactor, but there is a need to further investigate sizing guidelines to route enough water through the bioreactor to provide significant load reductions. A bioreactor sized to take all the water from a drainage system would be cost-prohibitive, so at present a portion of the water is allowed to bypass the bioreactor and current research is investigating design guidelines based on drainage area and needs for nitrate-nitrogen reductions.

Summary

The use of subsurface drainage is essential for modern agricultural production throughout most of the Midwestern United States. While use of subsurface drainage will be necessary to meet the future demands for agricultural products there is also increasing demand for improved water quality from subsurface drained lands. To meet these demands in the future will require a combination of in-field practices, drainage design, drainage management, and end-of-pipe practices. These include utilizing appropriate in-field nitrogen management, use of winter cover crops where applicable, alternative drainage design and management to reduce drainage volumes, and the use of end-of-pipe or edge-of field technologies, such as nutrient removal wetlands and subsurface drainage bioreactors.

References

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