Modern Drainage Water Management to Reduce Drainage Volumes and Nitrogen Losses

R. Wayne Skaggs and Mohamed A. Youssef*

Introduction

Artificial drainage is necessary to farm some of the world's most productive soils. Drainage ditches or subsurface drain tubes are used to lower water tables, improve trafficability, prevent water-logging, control soil salinity and increase yields. Subsurface drainage reduces surface runoff, sediment losses and the movement of contaminants attached to the sediment, such as pesticides and phosphorus, into surface waters. However, subsurface drainage increases the losses of nitrogen (N) to surface waters, and has been cited as one of the primary sources causing algal blooms and hypoxia in major water bodies. For example, N losses from over 20 million ha of intensively drained cropland in the U.S. Midwest have been cited as a major contributor to excessive N and hypoxic conditions in the northern Gulf of Mexico. The development of methods to reduce N losses from agricultural drainage systems has become an important objective of researchers, engineers and drainage professionals.

In the U.S., the Agricultural Drainage Management Systems (ADMS) Task Force (http://extension.osu.edu/~usdasdru/ADMS/ADMSindex.htm) was organized in 2002 with the objective of developing and implementing methods to reduce nutrient losses to surface waters from drained lands. The current focus of the Task Force is to reduce N losses from drained lands to the Mississippi River and Gulf of Mexico.

Drainage Water Management

Research has shown that drainage volumes and nitrogen losses through the drains can be substantially reduced by a practice called Controlled Drainage (CD). This practice, which is also referred to as the more general term, Drainage Water Management (DWM), involves the use of a weir or an overflow device to reduce drainage rates by raising the water level in the drainage outlet (Figures 1 and 2). DWM may also include subirrigation, where water is pumped into the drains or the drainage outlet to supply irrigation water via the water table during dry periods. CD reduces the hydraulic gradient to the drain, subsurface drainage rates and annual subsurface drainage volumes. Since drainage requirements for crop production vary with season, CD can be used to reduce drainage rates during periods when intensive drainage is not necessary, such as the winter months. Based on research conducted in the 1970s and 1980s CD was accepted as a best management practice (BMP) in the state of North Carolina for reducing N and phosphorus (P) loads to surface waters and is cost shared to support its implementation. More recent research by a number of investigators has shown that the practice is effective for a wide range of soils and climatological conditions, and it is now being promoted and applied in the U.S. Controlled drainage has reduced drainage volumes ranging from 17% to 85% compared to conventional or uncontrolled drainage, in all cases studied. In some cases the reduction of N losses to surface and groundwater is nearly equal on a percentage basis to the reduction in drainage volume. In others it is clear that the route of N loss has been changed, but the magnitude of reduction, if any, is uncertain. CD conserves water and increases yields, but the magnitude of the yield response may not be a sufficient incentive to promote its application at full potential.

Figure 1. A flash-board riser structure used to implement Controlled Drainage during periods when drainage intensities may be reduced.

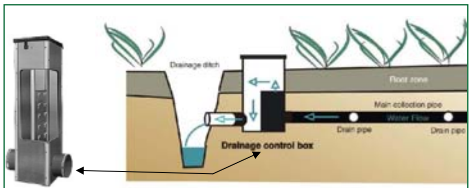

Figure 2. A control structure used with buried drain lines.

Use of DRAINMOD-NII

The magnitude of N losses in drainage water, and the effect of CD on those losses, depends on soil factors, drainage system design, crop species, rotation and yields, fertilization amounts and timing, weather variables and cultural practices. Field experiments have shown the effect of CD on both N losses and crop yields for some combinations of these factors, but only for a few of the many possibilities. Further, the effectiveness of CD varies from year to year because of differences in weather. The best alternative for quantifying the effect of CD on N losses in drainage water spatially and temporally is the application of simulation models. The DRAINMOD-NII model was developed to describe N dynamics in poorly drained soils. The model has been tested against field measurements and found to reliably predict N losses in drainage water for a range of soils and locations across the U.S. and Europe.

As an example application, DRAINMOD-NII was used to evaluate the annual and long term average effects of CD on N losses in drainage water for fields in the Lower Coastal Plain of North Carolina. CD reduced the 35-year average annual predicted N losses in drainage water by 37% (from 42 to 26 kg/ha/yr) for continuous corn and by 34% for a corn-wheat-soybean rotation. Both predicted N loads in drainage water and the reduction of those loads in response to CD varied widely from year to year. Predicted annual N loads for conventional drainage on continuous corn varied from 12.3 to 87.3 kg/ha (Figure 3). CD reduced the predicted annual N loads in drainage water by 18 to 58% over the 35 year period.

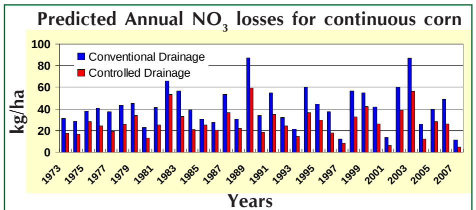

Figure 3. Predicted annual NO_3-N losses for continuous corn under conventional drainage and controlled drainage on a Portsmouth sl soil at Plymouth, NC.

❍

* W.N. Reynolds District University, North Carolina State University, Raleigh, NC27695-7625, Prof. R. Wayne Skaggs may be contacted at <wayne_skaggs@ncsu.edu>