Drainage and the Free Lunch

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Introduction

The concept of the free lunch is a familiar one that dates back to a time when patrons in a saloon would be offered a free lunch if they bought one or more drinks. Of course, the lunch was not free; the cost was factored into the cost of the drinks and the benefits that accrued from increased business. In his book, *The Moon is a Harsh Mistress*, Robert Heinlein discussed an economic system in which some costs are not readily apparent, and coined the phrase, “there ain't no such thing as a free lunch.” The concept can also be applied to agriculture in general, where the consumer expects a ready supply of inexpensive food with but little thought for the economic well being of the producer, and to drainage in particular, where its effect on the environment is often not considered.

For the producer, the decision to install or improve a drainage system is a practical one based on principles of good economics and good husbandry. If the benefits outweigh the associated costs, then drainage makes good sense. However, the cost/benefit analysis is not always cut and dried. The benefits of drainage include better soil aeration, more timely field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, and better root development; all leading to increased crop yields. Associated costs include the cost of laterals and mains and installation and maintenance costs. There may also be other costs, such as increased haulage costs, associated with the increased yield that comes from drainage. Even more difficult to grasp and to quantify are the hidden costs associated with water quality degradation, and other deleterious environmental effects. Nevertheless, it is imperative that these factors be considered.

All across the Midwest, research is being conducted on management practices that improve drain outflow water quality without adversely affecting crop yield. Conservation Drainage, as these practices are collectively termed, is the optimization of drainage systems for production, environmental, and water supply benefits. In light of the importance of drainage to agriculture in the region, conservation drainage practices (CDPs) should reduce nutrient transport from drained land without adversely affecting drainage performance or crop production.

Conservation Drainage Practices

Bioreactors

Bioreactors are essentially subsurface trenches filled with a carbon source, mainly wood chips, through which water is allowed to flow just before leaving the drain to enter a surface water body. The carbon source in the trench serves as a substrate for bacteria that break down the nitrate through denitrification or other biochemical processes.

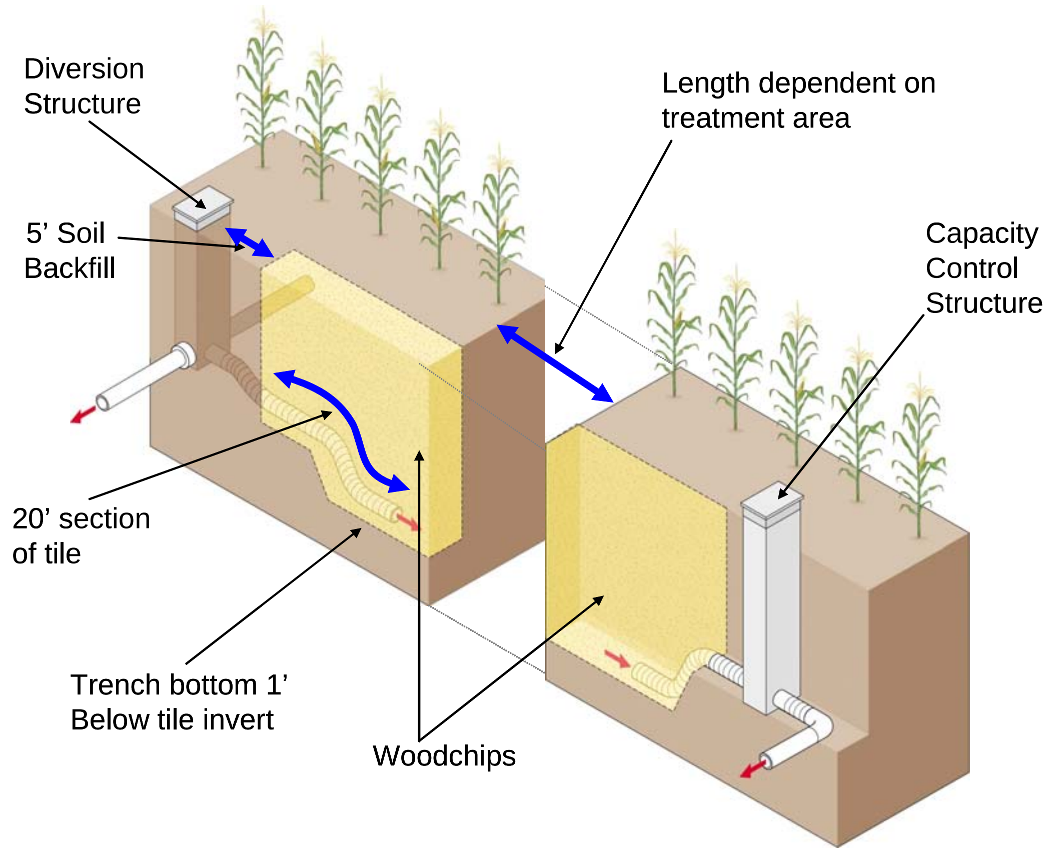

Figure 1. Schematic diagram of edge-of-field subsurface bioreactor.

Bioreactors provide many advantages:

- **They use proven technology.**
- **They require no modification of current practices.**
- **No land needs to be taken out of production.**
- **There is no decrease in drainage effectiveness**
- **They require little or no maintenance.**
- **They last for up to 20 years.**

To ensure that there is no decrease in drainage effectiveness, water is allowed to bypass the system when the tile flow rate exceeds the flow capacity of the bioreactor. Typically, only 20-30% of the annual tile flow passes through the bioreactor and is treated. Most of the flow bypasses the bioreactor during high-flow events.

Bioreactors have no adverse effects on production and are designed so that they do not restrict drainage. Unlike other edge-of-field practices they do not necessitate taking land out of production. They are also very cost effective. As this practice is currently in the development phase, there are no financial incentives for a producer to install one of these systems. Like other conservation practices, such as wetlands and buffer strips, it is expected that as these systems are further developed they will be considered worthy of public funding. The NRCS has expressed interest in classifying bioreactors as an innovative practice.

Drainage Water Management

In drainage water management, a control structure is placed at the outlet of a tile system to control the outlet level. This practice can be used to raise the water level after harvest, thereby reducing nitrate loading from tile effluent, or to retain water in the soil during the growing season. The normal mode of operation in Illinois is to set the water table control height to within 6 inches of the soil surface on November 1, and to lower the control height to the level of the tile on March 15. Thus, water is held back in the field during the fallow period. In experiments in Illinois, reductions of up to 46.6 % and 82.5 % were measured for nitrate and phosphate, respectively. Similar research is being conducted in other Midwestern states.

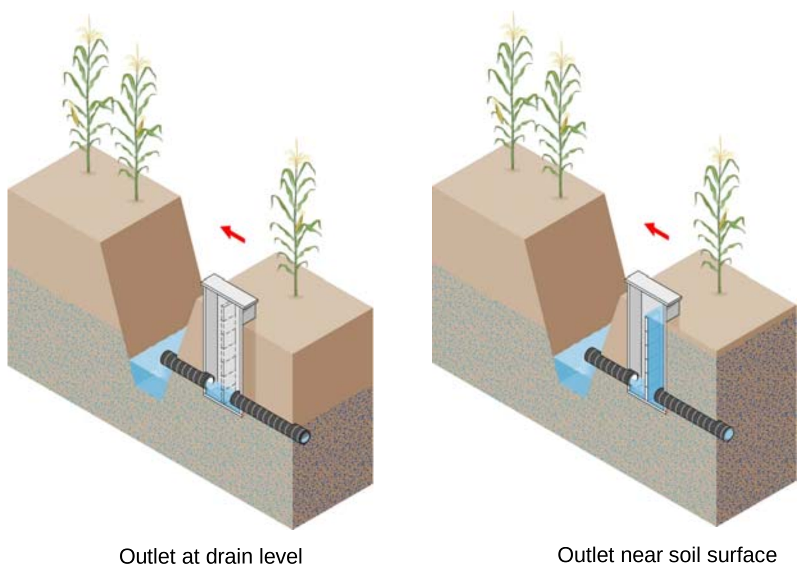

Figure 2. Using control structures to manipulate water table levels.

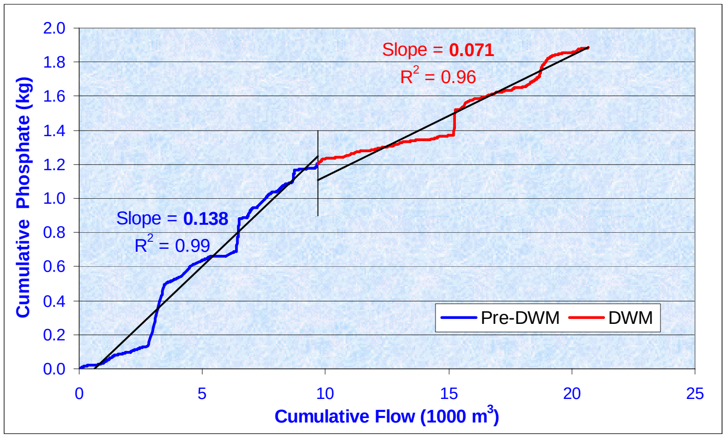

Figure 3. Phosphorus transport from a drainage system before and after the implementation of drainage water management (DWM).

Analysis of phosphorus data is complicated by the fact that there are few events in which inordinately large amounts of phosphorus are transported through the drains. It is surmised that these events result from preferential flow and experiments to further explicate this phenomenon have been initiated. The dominant mechanism for nitrate reduction is not denitrification, but the reduction of flow volumes that result from implementing drainage water management.

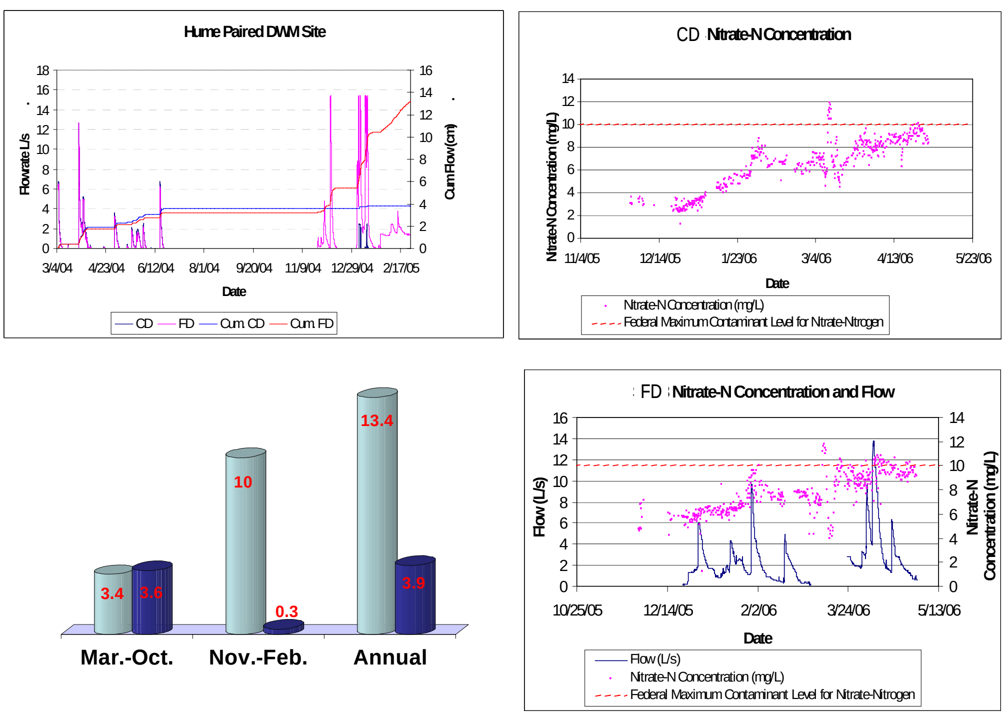

Figure 4. Outflow data from a paired system consisting of a free drainage field (FD) and a field under managed drainage (CD).

Existing drainage systems can be retrofitted for drainage water management by installing control structures at a cost of $20-$50 per acre. For new systems additional costs are incurred by laying out the drainage systems to optimize the benefits of drainage water management.

Many tools have been developed to assist in the determination of the profitability of drainage. The Illinois Drainage Guide, for example, includes an economic calculator that can be used to determine the profitability of a drainage system. It provides many measures of profitability, but they are all consistent with each other, and are but a reflection of user preference. The measures of profitability used in the Guide are listed below.

- **Net Present Value (NPV). The Net Present Value is the present value of the expected future cash flows minus the initial cost. A positive NPV value is indicative of a profitable system.**
- **Profitability Index (PI). The Profitability Index, also known as the Benefit-Cost Ratio, is the ratio of the Net Present Value and the Initial capital Investment. If the NPV is positive, then the Profitability Index is greater than 1.0, indicating that the benefits of a system outweigh the costs.**
- **Internal Rate of Return (IRR). The Internal Rate of Return in the rate at which the future cash flows, discounted back to the present, equals its price. It can be viewed as the interest rate that results in an NPV of zero or a PI of one. If the IRR exceeds the interest rate at which capital can be obtained, then the system is profitable.**
- **Discounted Payback Time (DPT). The Discounted Payback Time is the length of time it takes to recover the cost of an initial investment, with regard to the time value of money. For this measure, the value of future income is discounted by the cost of obtaining capital, that is, the interest rate charged on a loan.**
- **Undiscounted Payback Time (UPT). The Undiscounted Payback Time is the length of time it takes to recover the cost of an initial investment, without regard to the time value of money. In effect, the UPT is the same as evaluating the DPT under the assumption that the cost of capital, the interest rate, is zero.**

Historically, drainage systems are normally laid out to minimize the cost of installation. However, such installations do not necessarily maximize the benefits of drainage water management. Shown in Figure 5 are two possible drainage systems that could be installed on the same field. In all likelihood, this lower cost system would be the one selected for installation. In this instance, based on average installations costs, the difference in cost is $75/acre.

Drainage water management systems can be managed so that they store water during the growing season (Figure 6). This stored water can result in increased yields. One relationship between the additional cost of a drainage water management system and the corresponding break-even income is shown in Figure 7. A system that costs $100/acre, for example, has a break-even income of $7.05. Thus, it does not take a large yield increase to pay for the installation of a drainage water management system.

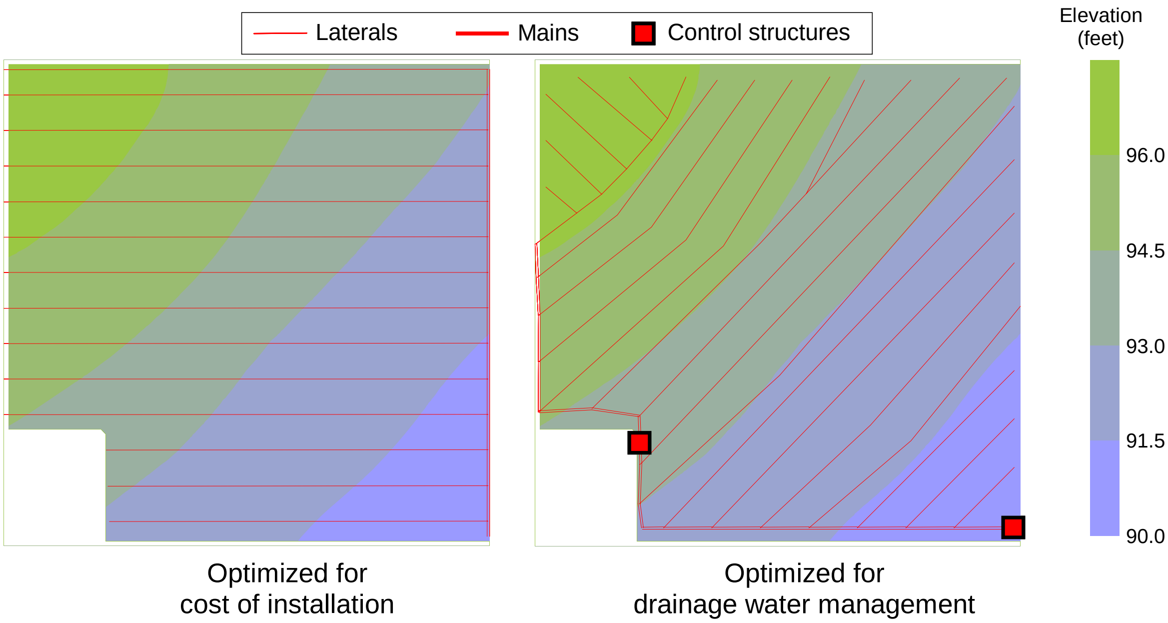

Figure 5. Effect of design objective on drainage system layout.

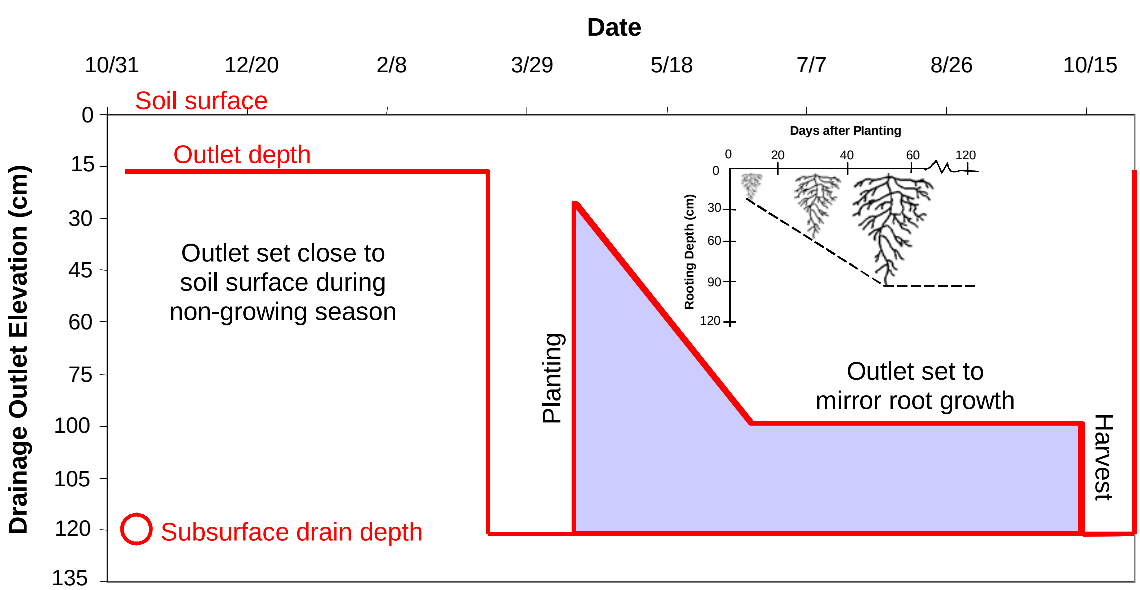

Figure 6. Drainage water management systems operated for both water quality and production benefits.

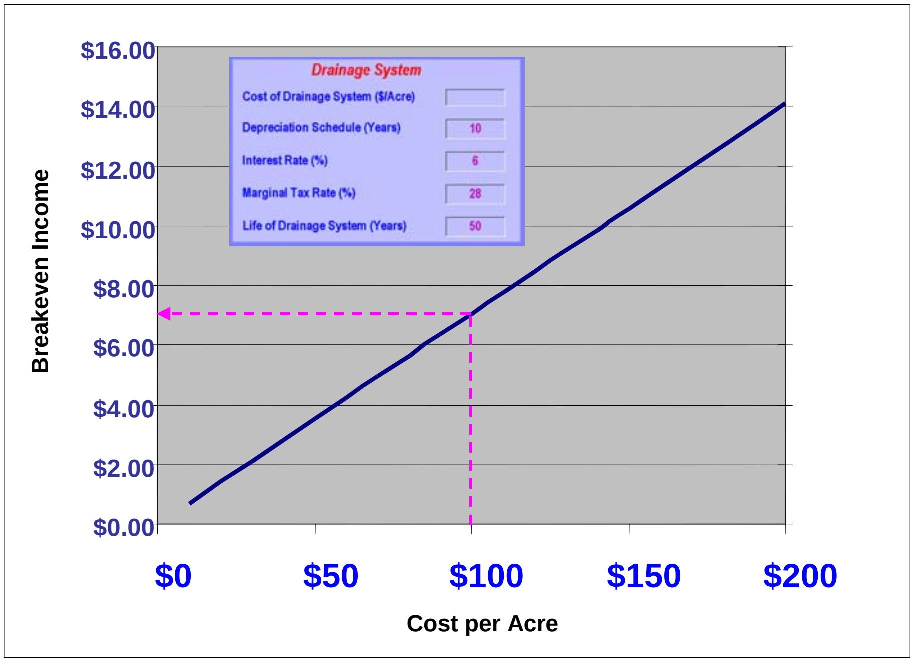

Figure 7. Relationship between cost and breakeven income for a drainage water management system.

Depth/Spacing Relationships

Originally, tile systems were designed for the sole purpose of quickly removing excess water from the plant root zone to prevent wet stress and to improve crop yields. Drainage intensity is expressed as the drainage coefficient, the depth of water to be drained to lower the water table from to a foot below the soil surface in 24 hours. Different combinations of depth and spacing result in the same drainage coefficient (Figure 8), but they may be different in their water quality response.

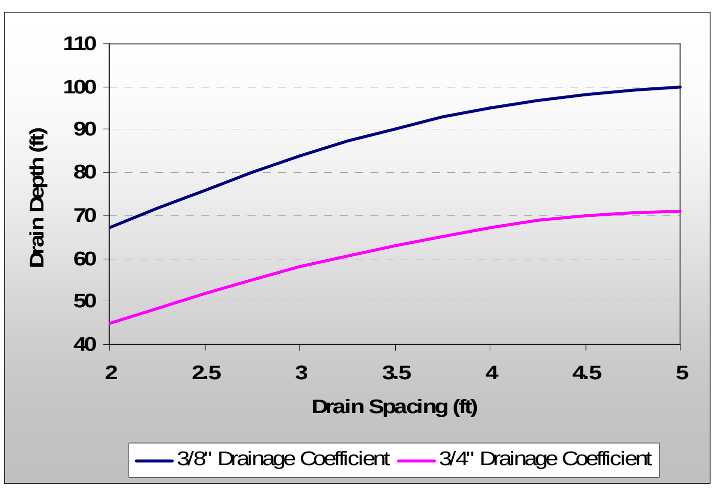

Figure 8. Drainage coefficient as a function of depth and spacing for Drummer Silty Clay Loam.

Experiments are being conducted on several different soil types to determine depth/spacing combinations that optimize productivity with minimum adverse water quality effects. Preliminary results, shown in Figure 9, seem to suggest that shallower tiles placed closer together are more suitable than deeper tiles placed farther apart.

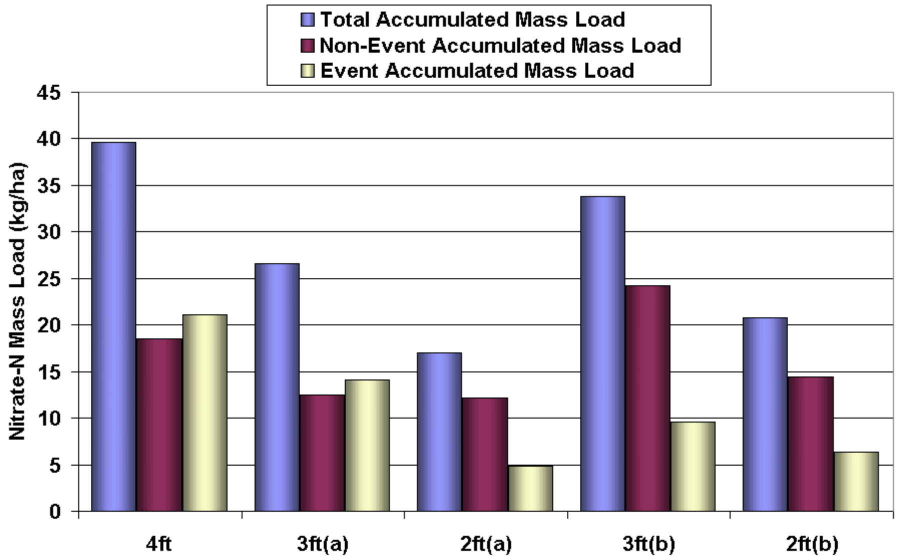

Figure 9. Nitrate loss at various drain depths in a depth/spacing experiment.

For a specified drainage coefficient, shallower tiles are associated with narrower spacings, and thus drainage cost increases with decreasing tile depth. The relationship between spacing and average installation cost is shown in Figure 10. Also shown is the relationship between computer simulated yield from a silt loam and spacing, using 30 years of weather data from Urbana. While the yield ratio varies with soil type and location, and the cost ratio varies with the contractor, the general form of the curves are representative of what can be expected in Illinois. Note that there is a threshold spacing beyond which no yield benefits can be obtained by putting the tiles closer together.

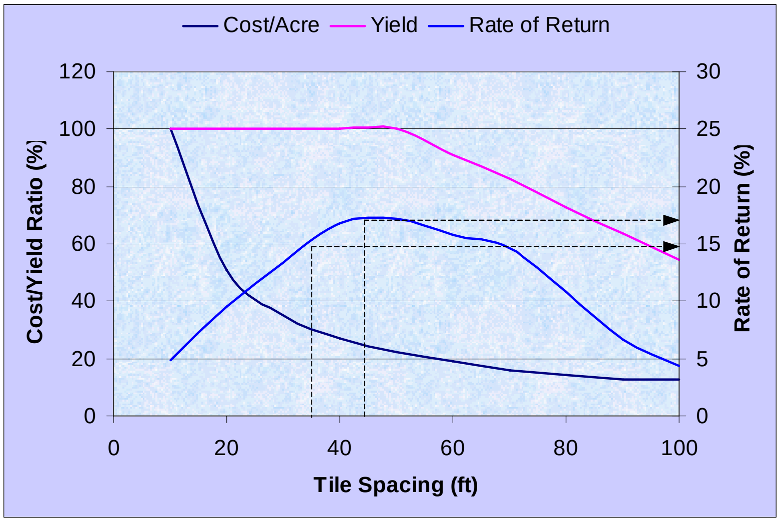

Figure 10. Simulated tile spacing/cost/yield relationship.

The yield and the cost curves can be used to determine the spacing that maximizes the rate of return on the investment in drainage. In this instance the maximum rate of return was 17%, obtained at a spacing of 45 feet. If the spacing were reduced to 35 feet so as to improve the quality of the drain effluent, the rate of return on the drainage investment would drop to 15%. This is still a substantial rate of return for the producer. Further benefits would also accrue from the improvement in downstream water quality.

Conclusions

The importance of drainage to agricultural production has been known for more than two millennia. Here in the Midwest, the introduction of tile drainage has brought millions of otherwise uncultivable acres under agricultural production. The decision to install a drainage system is primarily an economic decision. There are tools available on the Internet and elsewhere, which producers can use to determine if the benefits of drainage a field or a section of a field exceeds the cost. One such tool, an economic calculator, is available on the Illinois Drainage Guide (Online).

Conservation drainage practices are designed to provide water quality benefits. They are most likely to be adopted if they do not adversely affect profits. Some practices can be managed to provide production benefits. If these benefits exceed the costs, then there is economic incentive to implement these practices. Other practices only provide benefits to the society at large and it is not unreasonable to expect that they should be funded through grants or cost share programs.