To: Gregorio
From: Mark Dittrich
7-16-09

Demonstrating the Management of Subsurface Agricultural Drainage

Minnesota Conservation Drainage Demonstrations: Improving Water Quality

An on-farm demonstration of the benefits of conservation drainage practices on crop yields, water quality, and drainage flow in southern Minnesota.

www.mda.state.mn.us/protecting/conservation/drainage.htm

DRAFT

Note From the Commissioner

Agriculture is a cornerstone of Minnesota's economy and vital to the health of rural communities. Each year farmers face new challenges as they protect our air and water resources. Our farmers have a strong tradition of farmland water management through hard work, innovation and collaboration with water quality experts, such as tile drainage contractors, crop consultants, and soil and water technicians.

This on-farm conservation drainage project is a success story in farmland water management. I applaud the farmers and agencies for their vision and support as we work together to find cost-effective, voluntary and practical designs to protect our lakes, rivers and streams.

Gene Hugoson
Commissioner of the Department of Agriculture

CIG Goals

Conservation Innovation Grants Program (CIG) is a voluntary program that stimulates innovative conservation approaches and technologies. CIG also leverages state and federal investments in agricultural production for environmental enhancement and protection. NRCS administers CIG through funds made possible by Environmental Quality Incentives Program (EQIP).

CIG enables agencies and organizations to accelerate technology transfer and adoption of promising practices, designs, structures, technologies and approaches to address pressing natural resource concerns. CIG benefits agricultural producers by providing more options for environmental enhancement.

The CIG is not a research grant program but a vehicle to stimulate use of conservation strategies that have been studied, that show potential, and that NRCS can support in a technical and a practical application.

John Brach
Minnesota NRCS Engineer.

Sponsors

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Natural Resources Conservation Service
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Agricultural Drainage Management Coalition
(ADMC)

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PROJECT OVERVIEW

The Minnesota Conservation Drainage Demonstration Pilot Project was designed to show the potential impacts of drainage system design and management on drainage water quality, drainage water flow, and crop yields. Two representative sites were selected and new subsurface drainage systems were installed using typical and current equipment and materials. At each site, 2 replicated plots each about 10 acres in size were developed for each of the following drainage system designs:

- Conventional with plastic drainage pipe installed at a depth of 4 feet and the recommended spacing of 80 feet.
- Shallow drainage with plastic drainage pipe installed at a depth of 3 feet and the recommended spacing of 50 feet.
- Managed drainage with plastic drainage pipe installed at a depth of 4 feet with a spacing of 50 feet and water control structures to manage the water table.

To determine the impacts of the different drainage system designs, the flow of drainage water, nitrate concentration in the drainage water, and soybean or corn yields were determined.

Through this project, a better understanding can be gained of the potential economic and environmental benefits of improved subsurface drainage system designs.

INTRODUCTION

The rural drainage system, which includes private drain tiles, public ditches and other water conveyance systems, is an extensive and aging infrastructure in Minnesota. Drainage is a vital part of agriculture in Minnesota. Without a constructed drainage network, many parts of the landscape of Minnesota would be dominated by shallow wetlands and wet soils. This landscape combination would make traditional row crop agriculture nearly impossible, severely impacting the current agricultural economy and the supporting community businesses.

There are several potential environmental problems due to agricultural drainage. Drainage may increase flow rates in local streams and rivers, causing stream bank erosion. Subsurface drainage may increase the transport of nitrate from agricultural land and its conveyance to receiving streams and rivers. This nitrate may eventually reach the Gulf of Mexico where it is thought to contribute to the development of the hypoxic zone. The nitrate in drainage water may also cause increased concentrations in water resources used for municipal water supplies.

The impacts of various agricultural drainage system designs on the transport of nitrate nitrogen from agricultural land and its conveyance to streams and rivers, are being examined. This project focused on the effects of drainage pipe depth and spacing, as well as the use of water control structures to manage the water table level. In several regions it has been shown that managed drainage has the potential to reduce the amount of water and the amount of nitrate removed through subsurface drainage.

It has been shown in some regions that installing drainage pipe at a depth of 3 feet could result in similar benefits to managed drainage without the expense of installing and adjusting water control structures. By draining the soil to a depth of 3 feet rather than 4 feet, potentially less water and therefore less nitrate is removed.

Methods

Site selection and description

Sites for the demonstrations were selected that were fairly uniform, located in areas where subsurface drainage systems are being improved, and local cooperators were available. One site was located in Mower County and the other in Nicollet County. Soils and tile maps are on page 5.

Conventional Drainage - CvD

Two conventional drainage plots were developed at each site. The drainage lines were installed to a depth of 4 feet, and the lines were spaced at 80 feet. This drainage design of depth and spacing is commonly referred to as "pattern-tiled."

Shallow Drainage - ShD

Two shallow drainage plots were developed at each site. The drainage lines were installed to a depth of three feet, and spaced at 50 feet. Most commonly installed where the outlet to the ditch requires shallow drainage system.

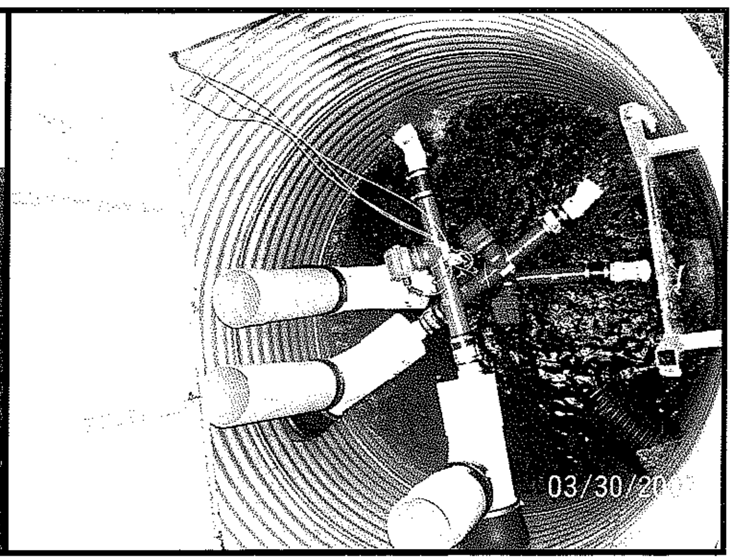
Managed Drainage - MnD

Two managed drainage plots were developed at each site. Drainage lines were installed to a depth of 4 feet, and the lines were spaced at 50 feet. Inline control structures were installed as needed at each plot. Control structures use 5 and 7-inch plastic "logs" and are manually inserted and removed as needed.

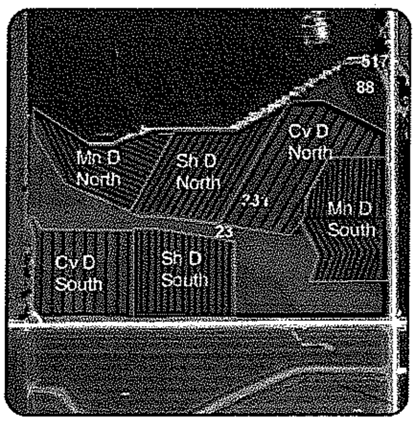
The function of the control structure is to vary the depth of the water table within the crop field. The water table can be raised after harvest to hold back water and reduce flows during the late fall, winter and early spring. In the spring, the water table is lowered as needed for tillage and planting, and before harvesting in the fall. The water table is raised to within 2 feet of the soil surface after planting and spraying in the spring, storing water for crop use (Frankenberger etal, Purdue, August, 2006). When early spring rainfall is below normal, the water control "logs" may be left in a higher position in order to store water in the profile for use by the crop. This was done in spring 2009.

Measurements

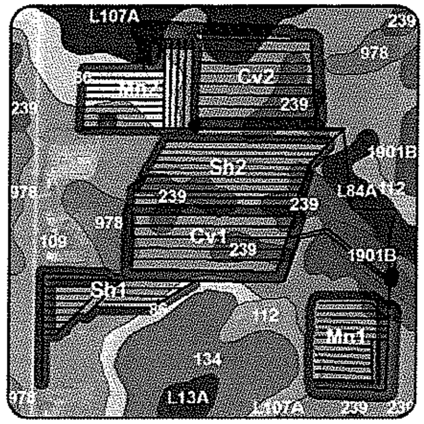
For each plot, equipment was installed to measure the flow of subsurface drainage water. The drainage line coming from each plot was directed to a vertically installed 5-foot diameter culvert (see picture below). An electromagnetic flow meter was installed on each drainage line and connected to a datalogger. Flow measurements were recorded every 15 minutes. Water samples were collected when flow occurred from each plot weekly and were analyzed for nitrate concentrations. Crop yields were measured by combine yield monitor. Crops were either corn or soybean. Rainfall was measured by means of a tipping bucket rain gauge. Data was collected every 15 minutes.



Mower Tile & Soils



Nicollet Tile & Soils



Results

Project results 2007 and 2008: Two cropping seasons were climatic opposites. The 2007 season started very dry, spring through summer, then from mid summer to November it was very wet. The 2008 cropping season started late with the thaw of a very deep frost. This was followed by a wet and cool spring, then drier conditions mid-summer through fall reflecting a more normal trend.

Nicollet County Site

Annual flows from each of the drainage plots at Nicollet County site are shown in the table below. Annual water flows in all the plots ranged from 1.0 inches to 6.9 inches of flow. Equipment failure in 2008, in one of the conventional drainage plots resulted in erroneously low measurements. The water table in Site 2 of the managed drainage plots was not able to be managed as the water table would rapidly fall below the desired level. Therefore this plot gave abnormally low annual flows.

Nitrate nitrogen losses corresponded closely to the amount of drainage flow and is typical for this cropping management system. The losses nitrate nitrogen from the normally functioning managed plot ranged from 16.8 to 22.2 lb/acre while the range of the conventional and shallow plots was from 20.4 to 30.4 lb/acre.

The peak daily flows from the shallow and managed drainage designs showed that the plots were able to flow at the drainage coefficient level of 0.5 inches per day. Daily flows from the conventional drainage plots did not exceed 0.375 inches per day.

Mower County Site

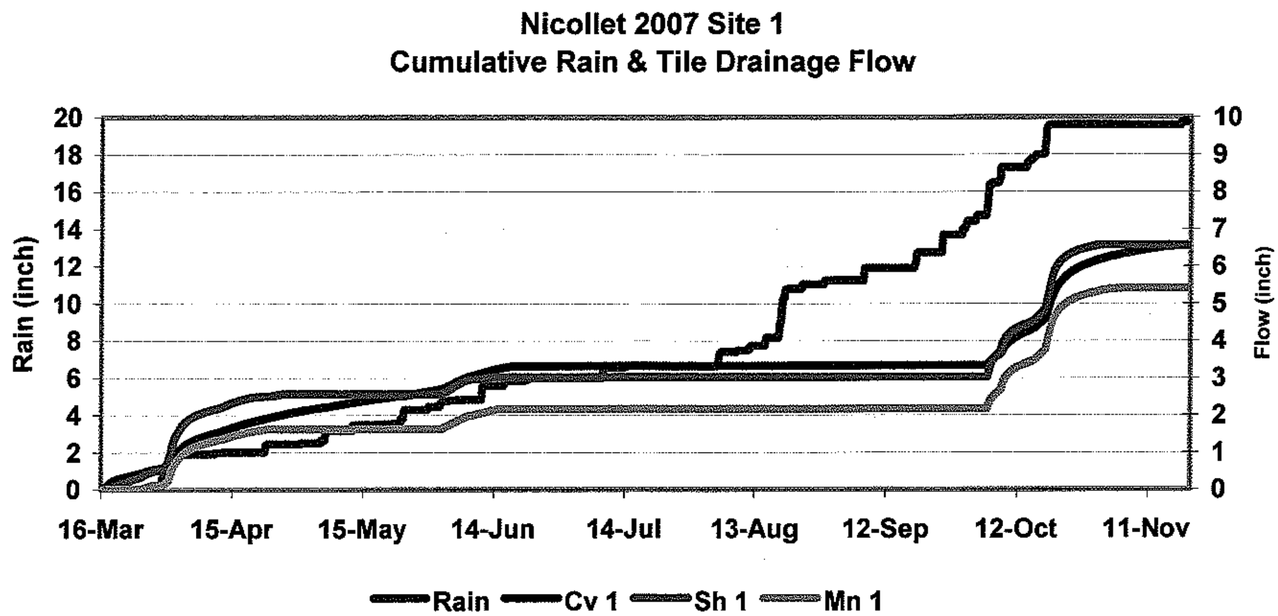
Annual drainage flows ranged from 4.8 to 14.5 inches, 6.6 to 19.9 inches, and 5.1 to 11.3 inches for conventional, shallow, and managed drainage system designs, respectively. Daily peak flows for all design approached the drainage coefficient level of 0.5 inches per day.

Nitrate nitrogen losses for this site were very low from all plots because of the nutrient management strategies used by the producer. Annual nitrogen losses were less than 7.0 lb/acre for all the plots, with losses from managed drainage plots never exceeding 5.3 lb/acre.

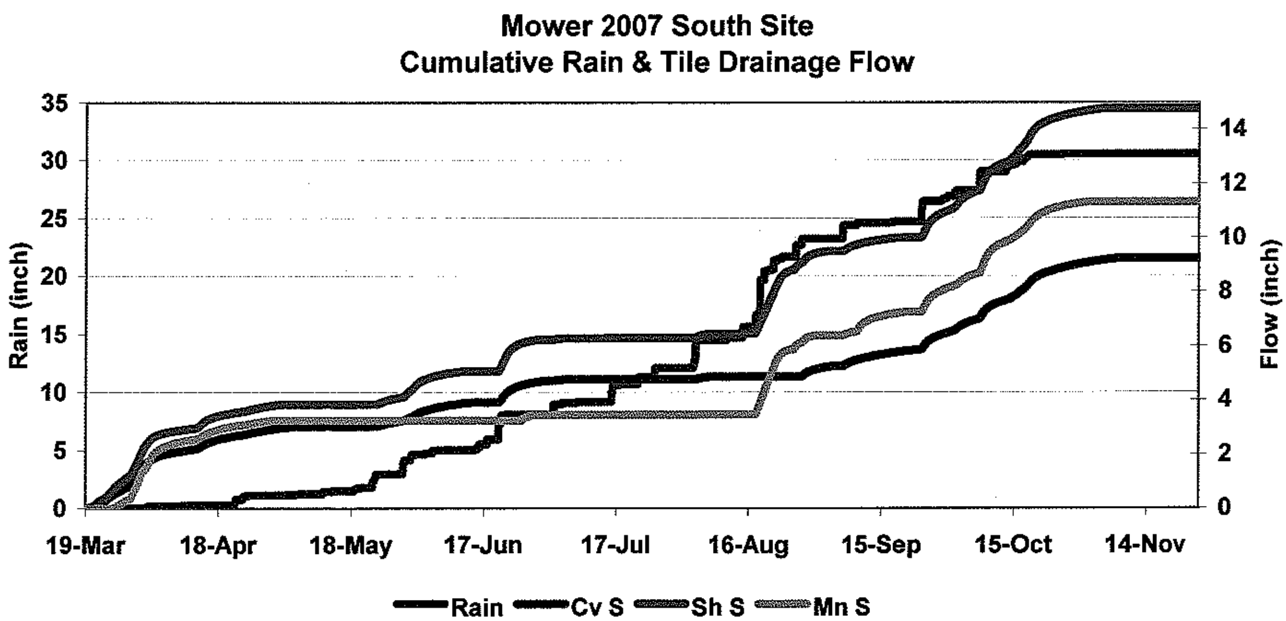
Annual Drainage Volume and Nitrate-Nitrogen Loss
Conservation Drainage Plots in Nicollet and Mower Counties

		Conventional*		Shallow*		Managed*	
		2007	2008	2007	2008	2007	2008
Nicollet County Site	Drainage (inches)	6.6	4.7***	6.6	5.5	5.4	4.9
		6.0	6.9	1.5	2.0	1.0**	1.2**
	NO3-N loss (lb/acre)	26.4	20.4	25.8	30.4	16.8	22.2
		19.7	23.7	2.8	8.5	8.1	6.6
Mower County Site	Drainage (inches)	14.5	5.7	19.9	8.7	10.4	5.8
		9.2	4.8	14.8	6.6	11.3	5.1
	NO3-N loss (lb/acre)	6.0	6.7	5.4	7.0	4.4	5.3
		4.9	4.1	4.1	5.4	4.4	4.5

*Top and bottom values in each cell result from Nicollet County 1 and 2, respectively.
*Top and bottom values in each cell result from Mower County N. and S. respectively.
**Due to unknown factors, the water table was not effectively maintained.
***Equipment failure caused considerable loss of water flow data.



Graph 1 Flow from drainage systems and rainfall are expressed in inches. During the 2007 season there was nearly 20 inches of rain at this site. From 5 inches to 7 inches of water went through the soil into the subsurface drainage system for managed drainage



Graph 2 Flow from drainage systems and rainfall are expressed in inches. During the 2007 season there was over 30 inches of rain at this site. From 10 inches to 15 inches of water went through the soil into the subsurface drainage system for managed drainage

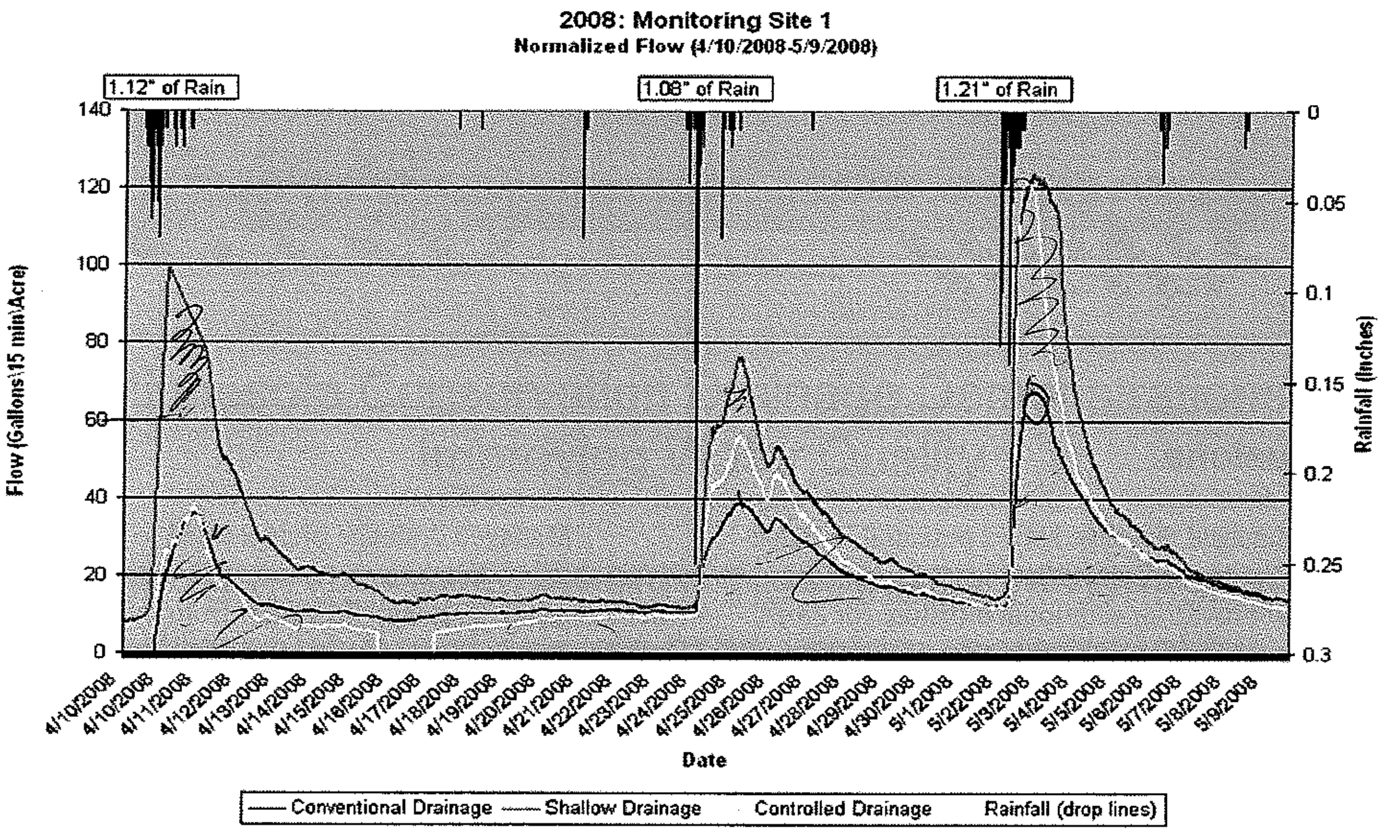
Impact on Flow from Storm Events

Shallow drainage (3ft deep by 50 ft spacing) starts flowing, and stops flowing water sooner than conventional drainage (4ft deep by 80 ft spacing).

The shallow drainage has remarkably different response rates than managed or conventional drainage as displayed in the following graphs. Note the differences in the start, peak, and the end of the flow for the red line (shallow), and its relative response rate, to the yellow line (managed), and the blue line (conventional). Three sequential rain events in the spring 2008 are provided as comparisons.

The shallow drainage system presents challenges to goals of dampening the hydrograph. Shallow drainage system increased peak flows and may not benefit stream geomorphology.

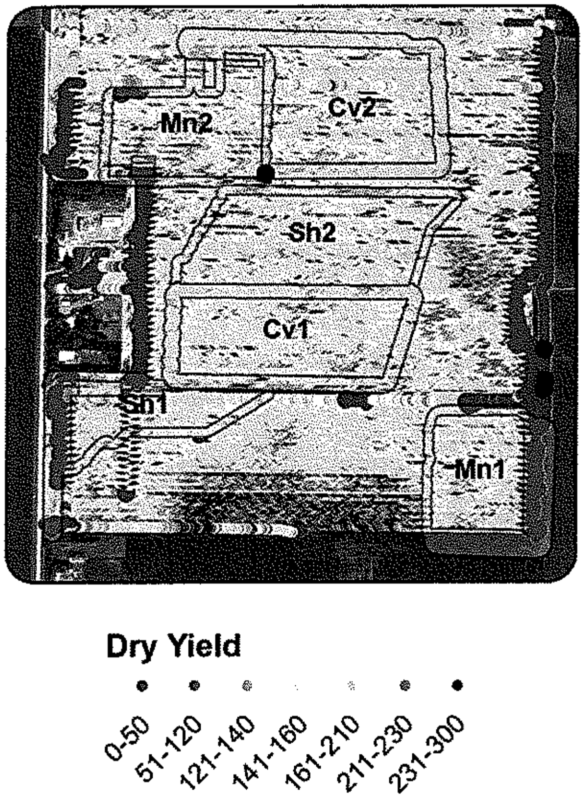
Conventional drainage system in these plots lowered the hydrologic pulses to the receiving downstream water bodies, however, delivers more total flows and total nitrates in a long, sustained pulse.



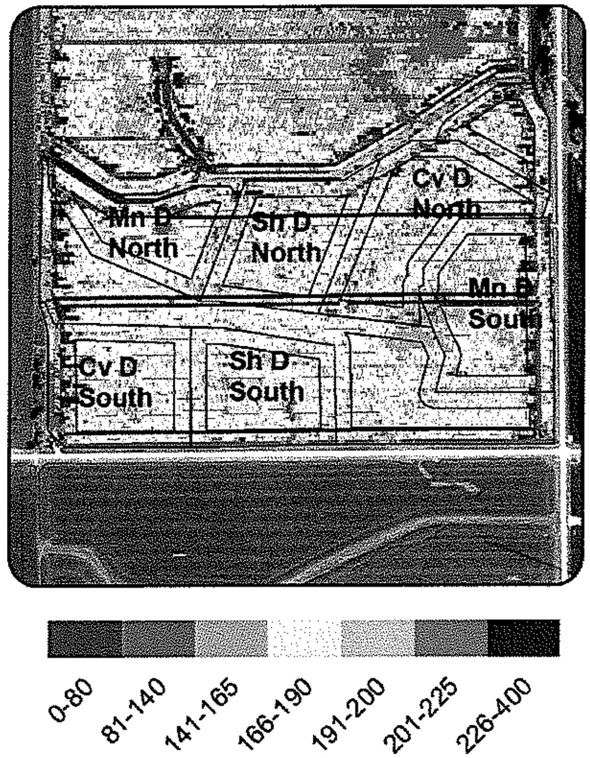
Crop Yield Response

Yields were quite uniform across both sites for 2008. Significant differences in crop yields were not observed in this study.

Nicollet County Site



Mower County Site



Conclusions

Managed drainage shows potential in reducing drainage water flow, nitrate loses in drainage water, and providing additional moisture for crops. However, it requires additional planning, design, and management, and is usually difficult to retrofit onto existing systems. Its use is currently restricted to areas appropriate for installation (less than 1% slope). In response to this limitation there are new plans and designs being developed to address the current limitations of managed drainage.

Managed drainage exported less water and had lower nitrogen concentrations in the drainage water, resulting in lower nitrogen losses. There was approximately a 25% or more reduction in flow and in nitrate ~~concentration in~~ in these plots.

Volume

Managed drainage plots reacted to rain similarly to shallow drainage plots when the water table was not managed. Drainage flow rates from the shallow and the managed were greater than from conventional drainage when water table was not managed.

Southern Minnesota usually receives significant moisture through snowmelt and rainfall in April, May and June, but often inadequate soil moisture later in the growing season. Holding some water in the soil profile may help increase crop yields in certain years.