USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

Tools to Inform and Transform Drainage

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INTRODUCTION

Subsurface (tile) drainage of naturally poorly drained soils is widespread across the U.S. Midwest. Planning, designing, and installing individual subsurface drainage systems should be site-specific, taking into consideration unique factors such as soil, topography, climate, and crop management. Tools can inform drainage design and implementation by giving decision-makers access to actionable information and ability to quickly calculate the impact of water management decisions on the farm.

Tools are also needed to transform the way subsurface drainage is implemented on the farm. Innovative new drainage practices, such as controlled drainage, drainage water recycling, and others (Figure 1), provide the benefits of drainage while reducing nutrient loss and potentially increasing crop yields. When designed and implemented correctly, these practices have great potential to improve water quality. Yet making decisions about selecting, designing, and implementing these new practices adds complexity, and the information needed is often not readily available. Tools can help collect, analyze, and communicate information to decision-makers and thereby advance the adoption of these new drainage practices.

This publication describes eight tools that support decision-making for subsurface drainage systems. The tools provide easily accessible information on soils, weather, and drainage systems, and they estimate the suitability and potential benefits of drainage practices. The first three tools help inform planning and design of conventional subsurface drainage systems. The next three are relevant to transform from the conventional approach to subsurface drainage and water management to newer practices. The final two tools relate to conducting water quality measurements and understanding data.

Together, these tools will help when planning and evaluating drainage systems to improve water management in subsurface-drained landscapes. All tools presented here are available at no cost and without creating an account. You'll find them at the Transforming Drainage website (https://transformingdrainage.org/tools/). They vary in complexity as they are designed for a variety of users who have different backgrounds and needs.

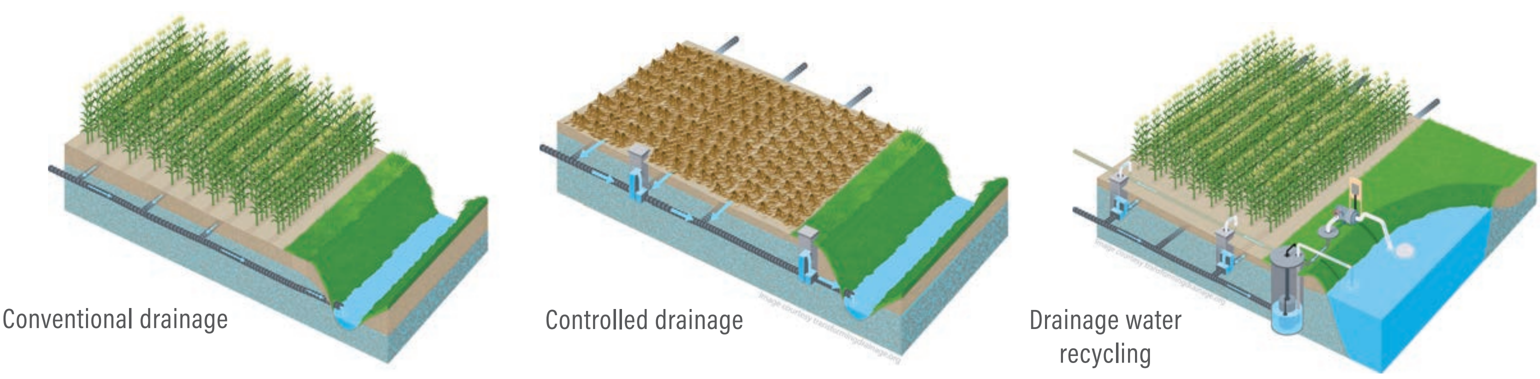


Figure 1. *Tools in this publication inform the design of conventional drainage (left) as well as conservation drainage practices such as controlled drainage (center) and drainage water recycling (right).*

LIST OF DRAINAGE TOOLS

TOOL USERS AND APPLICATIONS

The tools can help answer a range of drainage questions for a variety of users. Seven different types of tool users are described below, along with examples of how each user can benefit from the tools.

Farmers and landowners wear many hats and are often involved in multiple levels of decision-making, including where certain drainage practices may be most suitable on their farm, how practices should be installed, and evaluating whether or not to adopt practices based on the potential benefits.

Drainage contractors are involved in the planning and design of drainage practices and often act as advisors to farmers and landowners during their decision-making process. Much of their focus is on evaluating the suitability of practices at a certain site and how certain site characteristics impact the design and installation of drainage systems.

Drainage engineers are technical experts involved in evaluating the suitability, feasibility, and impact of various drainage practices and designs. Their work requires detailed information about site characteristics, such as soil properties, crop management, topography, climate, and drainage patterns, as well as tools to evaluate various management decisions related to the drainage system.

Drainage researchers include those who develop, evaluate, and research the effectiveness and impact of drainage practices. This group of users can benefit from tools that allow for the evaluation of practices across broad regions, or those that support evaluation across long time periods, to study how certain site characteristics or management decisions impact the benefits received from drainage practices.

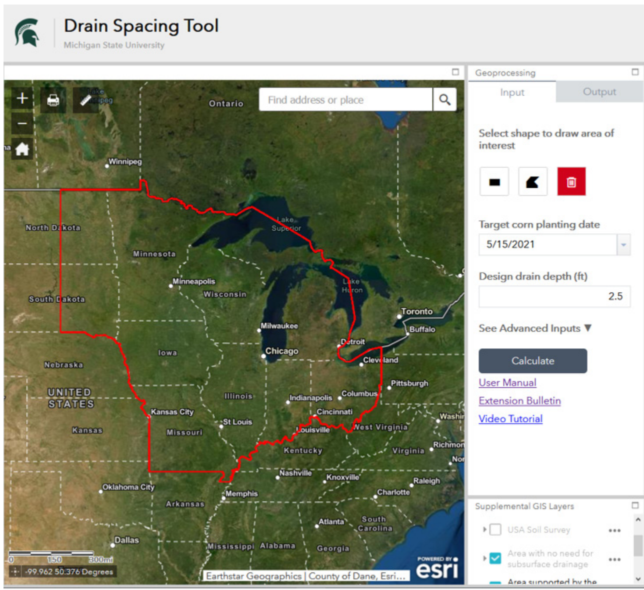
Crop advisors include users such as crop consultants and farm managers. This group of users often interact directly with farmers to assist in initial planning when evaluating drainage options relative to cropping system needs and may provide resources to the farmer that can be used for their decision-making.

Conservation professionals include local, state, and federal agency staff, as well as various non-governmental organization staff, who develop and implement programs to improve water quality on drained agricultural land. These users are often interested in tools that can help quantify the environmental benefits resulting from conservation drainage practices and identify where these practices are best suited.

Educators are those who train or teach others about drainage practices or concepts of design. They may be educating students in classrooms or farmers and others through Extension programs. Tools help educators by providing valuable teaching aids that can be used to develop educational activities for the classroom, lab, or online.

DRAIN SPACING TOOL

https://transformingdrainage.org/tools/drain-spacing/



User interface for the Drain Spacing Tool. Users can navigate to a specific field location using the geographical interface and determine the optimum drain spacing that maximizes economic return on investment in the drainage system.

OVERVIEW

The Drain Spacing Tool estimates the optimum drain spacing that maximizes economic return on investment in the drainage system.

If your soil needs subsurface drainage, use this tool to estimate the optimum drain spacing for any rotation of corn and soybeans.

This tool covers the states shown with a red boundary in the tool screenshot above. When you navigate to the field of interest, well-drained areas where drainage may not be beneficial will show as a shaded area.

HOW IT WORKS

The Drain Spacing Tool has a geographical user-interface that allows the user to zoom in to a specific field and draw a polygon around the area of interest. This tool requires manual inputs for the selected area of interest.

WHAT USERS PROVIDE

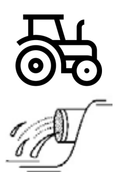
- Location and field boundary
- Design drain depth (ft)
- Target corn planting date
- Other advanced inputs

WHAT THE TOOL PROVIDES

- Optimum drain spacing (ft)
- Drainage intensity (in/day)
- Estimated length of 4-inch lateral drain pipe (ft)
- Estimated initial cost of system ($)
- Drained-field area (ac)
- Other advanced outputs

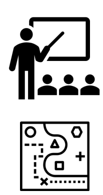
HOW THE TOOL CAN BE USED

After confirming the need for subsurface drainage outside of the tool, the Drain Spacing Tool can be used by a variety of users to answer a range of different questions, for example:



Farmers, landowners, and drainage contractors can use the Drain Spacing Tool to estimate the optimum drain spacing for their drainage design and estimate the cost of the drainage system.

Drainage engineers can use it to determine the effect of drain depth and soil properties on drain spacing.



Educators and crop advisors can use it to educate people how to properly estimate the optimum drain spacing and avoid over-design of the system that leads to excess nutrient loss.

For More Information

This tool, and associated documentation, is freely available at https://www.egr.msu.edu/bae/water/drainage/drain-spacing-tool

Author: Ehsan Ghane, Michigan State University

DRAINAGE RATE CALCULATOR

https://transformingdrainage.org/tools/drainage-rate/

OVERVIEW

This tool calculates the three standard coefficients (drainage rates) recommended by Skaggs (2017) for characterizing hydraulic properties of subsurface drainage systems.

Drainage Intensity represents the steady state drainage rate when the water table midway between parallel drains is at the soil surface. It is a measure of the rate at which water can move through the soil to the drains.

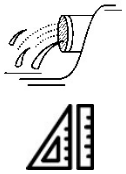
Drainage Coefficient quantifies the hydraulic capacity of the drainage system. This value is the rate that the outlet works can remove water from the site.

Kirkham Coefficient is the steady subsurface drainage rate corresponding to a saturated soil profile with a shallow ponded surface. This is when the subsurface drainage rate is at a maximum in most cases because water can freely move across the surface toward the drains.

Skaggs, R.W., 2017. Coefficients for quantifying subsurface drainage rates. Applied Engineering in Agriculture, 33(6), pp.793-799.

HOW THE TOOL CAN BE USED

The tool can be used by a variety of users to answer a range of different questions, for example:



Drainage contractors and engineers can use the tool when designing and evaluating drainage systems to match drainage coefficients with drainage intensities.

Drainage researchers can use it to quantify key subsurface drainage rates for reporting drainage system hydraulic characteristics of study sites in a standard way.

Educators can use it with students to calculate drainage rates for different conditions to explore the impacts of soils, hydraulics, and drainage system characteristics on drainage rates.

For More Information

This tool, and associated documentation, is freely available at https://analytics.iasoybeans.com/cool-apps/TD_DrainageCalculators/.

Author: Chris Hay, Iowa Soybean Association

HOW IT WORKS

Drainage Intensity (in/day or cm/day) is calculated using the Hooghoudt equation and is dependent on the effective saturated hydraulic conductivity of the soil profile, drain depth and spacing, effective radius of the drain, and equivalent depth to the restrictive layer.

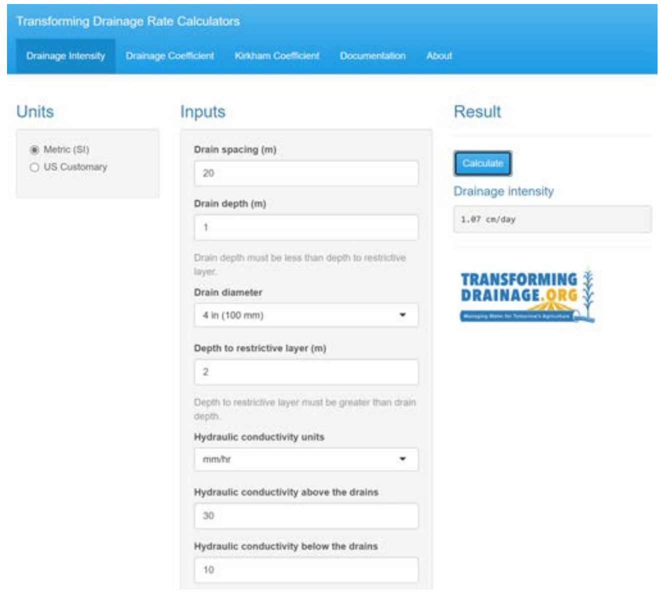
- Inputs: Drain spacing, depth, and diameter; Depth to restrictive layer; Hydraulic conductivity above and below the drains
- Output: Drainage intensity

Drainage Coefficient (in/day or cm/day) is calculated by Manning's equation and is dependent on the size, slope, and hydraulic roughness of the drains (and where pumped outlets are used, the pumping capacity).

- Inputs: Drainage area, grade, diameter, and material
- Output: Drainage coefficient

Kirkham Coefficient (in/day or cm/day)

- Inputs: Drain spacing, depth, and diameter; Depth to restrictive layer; Ponded water depth; Hydraulic conductivity
- Output: Kirkham coefficient



User interface for the Drainage Rate Calculator. Users can determine three standard coefficients for characterizing the hydraulics of subsurface drainage systems.

LIKELY EXTENT OF AGRICULTURAL DRAINAGE TOOL

https://transformingdrainage.org/tools/drained-area-tool/

OVERVIEW

This tool identifies agricultural areas that are likely to have been drained for crop production, usually through subsurface tile drainage, in the Midwestern USA. Land used for cropland or pasture/hay is selected, and likely extent is based on soil drainage class as follows:

Very poorly to poorly drained soils are assumed to have at least some form of artificial drainage installed to support agricultural land use, and therefore classified as "likely to be drained".

Somewhat poorly drained soils are classified as "potentially drained", as these soils are often included whenever drainage improvements or upgrades are made in the field.

Moderately well drained to excessively drained soils are classified as "unlikely to be drained" as these soils are not likely to suffer from excess soil water conditions, and therefore not likely to be artificially drained.

HOW IT WORKS

The tool is in the form of an online map of the entire Midwestern USA, displaying areas that are likely, potentially, or unlikely to be drained. The data can also be downloaded for use in a GIS analysis. The data sources are the United States Department of Agriculture: 2018 gSSURGO data from the USDA Natural Resources Conservation Service. Only agricultural land is included, based on the 2011 National Land Cover Database.

For More Information

This tool, and associated documentation, is freely available at the https://transformingdrainage.org/tools/drained-area-tool/.

Authors: Jane Frankenberger, Benjamin Reinhart, Ben Hancock, Agricultural & Biological Engineering, Purdue University

HOW THE TOOL CAN BE USED

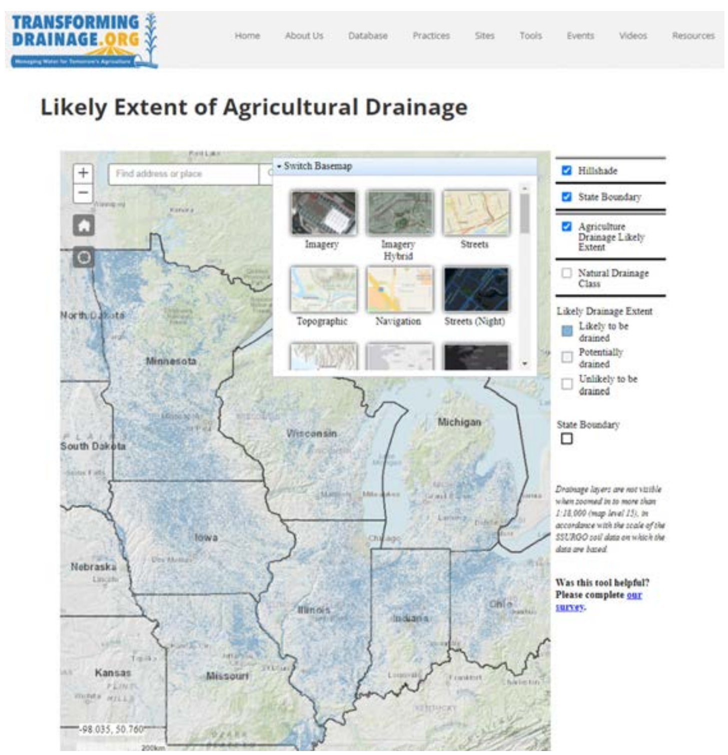
The tool can be used by a variety of users to answer a range of different questions, for example:

Farmers and landowners can use the tool to estimate whether land they are interested in is likely drained. These users, as well as drainage contractors, can use it to learn where poorly drained areas are located.

Drainage researchers can download the data and use it in GIS analyses to evaluate the potential for drainage and nutrient reduction benefits at specific experimental sites, or across variable site and climate conditions.

Crop advisors and conservation professionals can use it to estimate where water quality impacts are primarily associated with tile drainage and make decisions about practices to offer.

Educators can use it in helping others understand the prevalence and role of drainage, and where poorly drained soils occur in the landscape.



User interface for the Likely Extent of Ag Drainage Tool. Users can identify agricultural areas that are likely to have been drained for crop production.

CONTROLLED DRAINAGE SUITABILITY TOOL

https://transformingdrainage.org/tools/cd-suitability/

OVERVIEW

Controlled drainage, also known as drainage water management, is the practice of using a water control structure to raise the depth of the drainage outlet, holding water in the field during periods when drainage is not needed.

The Controlled Drainage Suitability Tool identifies land in the Midwestern USA that has a high probability of being suitable for controlled drainage (CD). The soils have been identified as likely to be or have been drained for crop production, and for economic feasibility, the identified land has slope less than 1% to maximize the spatial area controlled by each water control structure.

This map is designed to give a broad picture of the locations in the region that are likely to be suitable for CD activities, but it does not consider property boundaries and the fact that landowners and managers on neighboring properties may have different goals and objectives that may not include CD.

HOW IT WORKS

The tool is in the form of an online map of the entire Midwestern USA, displaying areas that are suitable for controlled drainage. The data sources are the United States Department of Agriculture: 2017 gSSURGO data from the Natural Resources Conservation Service (USDA-NRCS) and the 2015 Cropland Data Layer from the National Agricultural Statistics Service (USDA-NASS).

For More Information

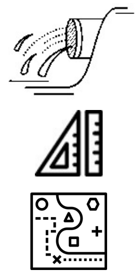
This tool, and associated documentation, is freely available at https://transformingdrainage.org/tools/cd-suitability/.

Authors: This tool was developed in collaboration with Ruth Book and soil survey staff of NRCS, Benjamin Reinhart, Jane Frankenberger, Agricultural and Biological Engineering, Purdue University

HOW THE TOOL CAN BE USED

The tool can be used by a variety of users to answer a range of different questions, for example:

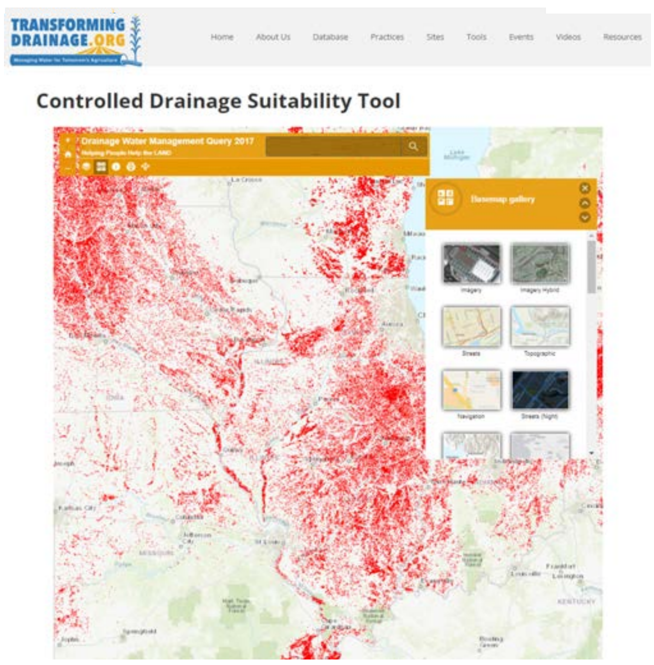
Farmers and landowners can view which of their fields may be suitable for controlled drainage and seek advice for investigating further.



Drainage contractors, engineers, and crop advisors can quickly explore opportunities with farmers and landowners to implement controlled drainage, and if the farmer is interested, prioritize areas to conduct onsite investigation.

Drainage researchers and conservation professionals can download the data to conduct regional or watershed GIS analyses, and estimate potential for CD implementation in watershed planning.

Educators can use it to help students understand soil properties required for effective implementation of controlled drainage.



User interface for the Controlled Drainage Suitability Tool. Users can identify land that has a high probability of being suitable for controlled drainage.

SUBIRRIGATION SUITABILITY TOOL

https://transformingdrainage.org/tools/subirrigation-suitability-tool/

OVERVIEW

Subirrigation utilizes subsurface tile drains to deliver irrigation water to a field by raising the water table. In locations that are suitable for this practice, it can provide an efficient and low-cost means of irrigation provided the drains are close enough to achieve uniform distribution.

The Subirrigation Suitability Tool identifies potential suitability for subirrigation of land in the U.S. Midwest. Suitable areas consist of agricultural land that is likely to be drained and has a restricting layer that causes the water table to rise, permeable soil above the restricting layer that allows the water to move horizontally between the tile drains, and slope less than 1%-2% that allows economical systems. While a field assessment of any site is needed to evaluate a potential project, the tool can help prioritize locations to conduct an onsite assessment.

HOW IT WORKS

The tool is in the form of an online map of the entire Midwestern USA, displaying layers that can be turned on or off and also downloaded. For any point, the tool displays the subirrigation potential suitability (high, medium, low, or not suitable) and a popup dialog displays the most limiting criterion. The tool also provides individual layers that describe the rating and values for each of the three criteria used in the suitability rating (hydraulic conductivity, slope, and drainage class).

HOW THE TOOL CAN BE USED

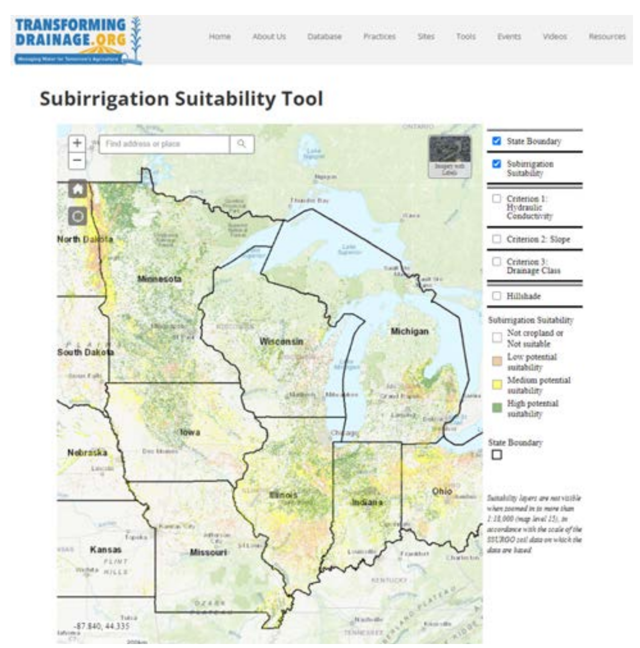
The tool can be used to address questions and explore opportunities by many users, for example:

Farmers and landowners can view which of their fields are potentially suitable and merit further investigation for subirrigation.

Drainage contractors, engineers, and crop advisors can quickly explore opportunities with farmers and landowners to implement subirrigation, and if the farmer is interested, prioritize areas for onsite investigation.

Drainage researchers and conservation professionals can download the data to conduct regional or watershed GIS analyses.

Educators can use it to help students understand soil properties required for effective subirrigation and teach how limiting factors influence subirrigation design.



User interface for the Controlled Drainage Suitability Tool. Users can identify land that has a high probability of being suitable for controlled drainage.

For More Information

The tool, and associated documentation, is freely available at https://transformingdrainage.org/tools/subirrigation-suitability-tool/. Data are also available for download or as a REST web service that can be streamed into other GIS-based applications.

Authors: Jane Frankenberger, Benjamin Reinhart, Agricultural & Biological Engineering; Jason Ackerson, Agronomy; Purdue University

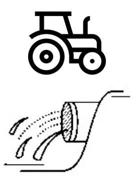
EVALUATING DRAINAGE WATER RECYCLING DECISIONS (EDWRD)

https://transformingdrainage.org/tools/edwrd/

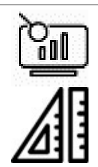
OVERVIEW

Drainage water recycling is the practice of capturing drained agricultural water in various sizes of water storage reservoirs for reuse as irrigation. The "Evaluating Drainage Water Recycling Decisions" (EDWRD) tool provides an estimate of the potential irrigation and water quality benefits that result from drainage water recycling across multiple reservoir sizes.

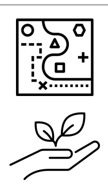
HOW THE TOOL CAN BE USED



Farmers, landowners and drainage contractors can estimate how large of a reservoir is needed to irrigate a field. If only a certain amount of land is available for the reservoir footprint, they can determine how many acres can be irrigated from a particular reservoir size.



Drainage researchers and engineers can run long-term simulations to determine how often certain irrigation or water quality outcomes are achieved under a set of soil, weather, crop, and reservoir conditions.



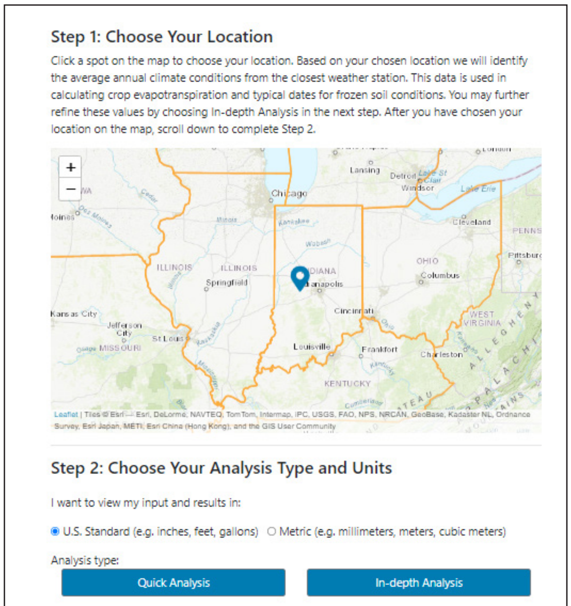
Crop advisors and conservation professionals can work with farmers and landowners to evaluate how irrigation management decisions (e.g., application depth and timing), crop rotation, and differences in soil types and weather influence the amount of irrigation and water quality benefits.

HOW IT WORKS

The tool integrates water balances for a subsurface-drained field and reservoir to estimate how much water can be captured, stored, and reused for irrigation. Crop evapotranspiration is calculated following the FAO-56 dual crop coefficient approach. Irrigation benefits are quantified by applied irrigation and its relation to the irrigation demand, while water quality benefits are quantified by the amount and percentage of tile drain flow captured by the reservoir.

WHAT USERS PROVIDE

Users provide their field and soil properties, reservoir sizes to assess, and daily weather and drain flow inputs. Default values are provided based on a user's selected location, and example datasets are available.



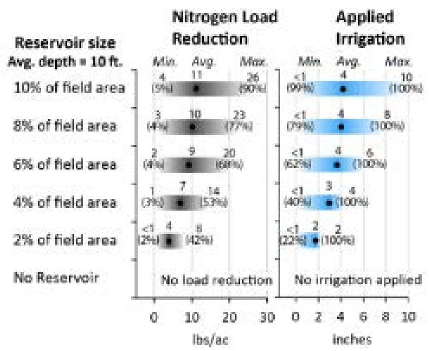
User interface for the Evaluating Drainage Water Recycling Decisions Tool (EDWRD). Users can estimate potential irrigation and water quality benefits for different sizes of reservoir.

WHAT THE TOOL PROVIDES

EDWRD provides users with annual, monthly, and daily estimates of the soil and reservoir water balance components and annual metrics. For each reservoir size, outputs include:

Irrigation metrics: Annual applied irrigation, annual relative irrigation supply

Water quality metrics: Tile drain flow reduction, tile drain nutrient load reduction



Example of irrigation and water quality outputs based on reservoir size.

For More Information

This tool, and associated documentation, is freely available at https://transformingdrainage.org/tools/edwrd/. Source code is available on GitHub at https://github.com/TransformingDrainageProject/edwrd.

Authors: Benjamin Reinhart, Jane Frankenberger, Ben Hancock, Agricultural & Biological Engineering, Purdue University

FIELD NUTRIENT LOSS APP

https://transformingdrainage.org/tools/nutrient-loss-app/

OVERVIEW

The Field Nutrient Loss App allows users to estimate nutrient loss from field measurements.

Farmers are often interested in determining how much nitrogen (N) is leaving through their field tile. Determining the loss in pounds requires measuring:

(1) drain flow rate (usually in gallons per minute, abbreviated as gpm) and

(2) the concentration of nitrogen in the water (usually in mg/L or parts per million, abbreviated as ppm).

Together these can be used to estimate the mass of N lost at the time that the measurements are taken. The lost nitrogen has monetary value, which can be calculated based on the pounds of N lost per day and the value of the fertilizer. This user-friendly tool is available to estimate this in the field, so the user can roughly see how much nitrogen is being lost without dealing with cumbersome calculations.

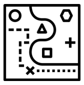
HOW IT WORKS

A farmer inputs the type of pipe and three values based on measurements at the drain outlet: the depth of flow, the pipe diameter, and slope. The tool uses these values in a standard hydraulic formula (Manning's equation) to calculate the flow rate. The farmer also inputs the concentration of nitrogen, measured using paper test strips or a laboratory analysis of a tile water sample.

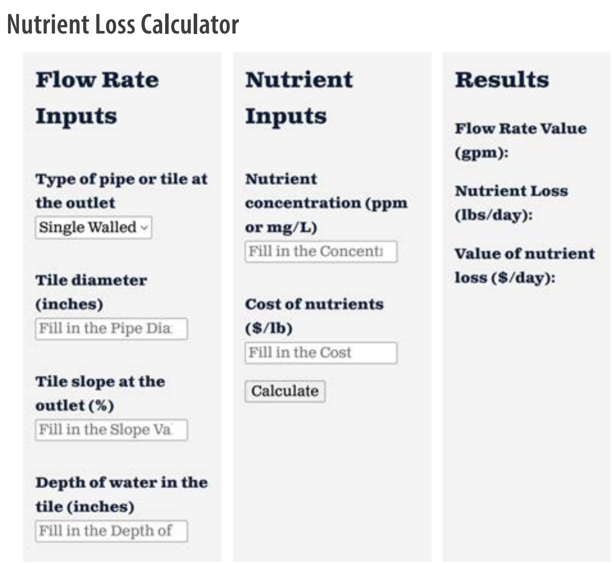
HOW THE TOOL CAN BE USED

The tool can be used by a variety of users to answer a range of different questions, for example:

Farmers and landowners can use the tool to quantify nutrient losses under current management approaches (crop type, fertilizer rate, application, and timing).



Crop advisors and conservation professionals can use it to quickly explore opportunities with farmers and landowners to implement management practices that reduce nutrient loss. Watershed coordinators can use the tool within a monitoring program to determine where edge-of-field practices would have the highest impact.



User interface for the Field Nutrient Loss App. Users can estimate flow rate, nutrient loss and its value on their phone or computer.

For More Information

This tool, and associated documentation, is freely available at https://extension.sdstate.edu/nutrient-loss-calculator

Author: John McMaine, South Dakota State University

TRANSFORMING DRAINAGE DATA VISUALIZATION TOOL

https://transformingdrainage.org/tools/data-visualization/

OVERVIEW

This interactive tool provides high-resolution visualization interfaces for users to explore data from 39 research sites studying conservation drainage practices. These sites have controlled drainage, saturated buffers, or drainage water recycling infrastructure installed in comparison to free (non-managed) drainage. Drain flow and water quality were measured on a daily basis and can be visualized at different time scales including daily, monthly, and annual. In addition, agronomic and soil parameters were measured to illustrate how the agricultural system changes with differing conservation drainage practices.

Visualization tools like this aid in user comprehension of differences across sites and years in terms of variability across and within seasons. The tool allows users to download their custom figures for use in presentations or publications.

WHAT THE TOOL PROVIDES

This dynamic and interactive tool allows users to select the practice, site, year, and measurement of interest.

Download customized figures for:

- Drain Flow
- Nitrate Load
- Water Table Depth
- Water Quality
- Soil Moisture

Two-page research site summaries are available as supplementary information.

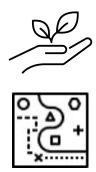
Access to research data via hyperlink to Transforming Drainage research data website.

User interface of the Transforming Drainage Data Visualization Tool. Users can explore data from 39 research sites studying conservation drainage practices.

HOW THE TOOL CAN BE USED

The tool can be used to address questions and explore opportunities by many users, for example:

Drainage researchers can use it to understand and visualize variation across sites and years in water quality measurements. Data can be downloaded through a linked interface for regional or watershed analyses.

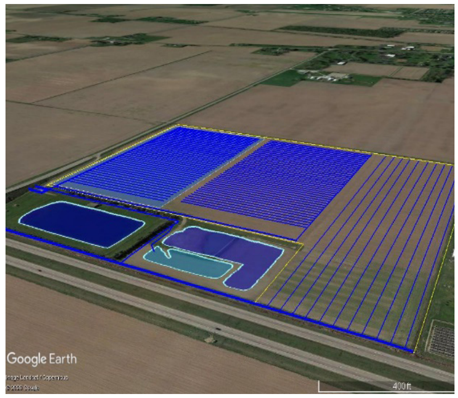


Conservation professionals and drainage engineers can use this tool to establish benchmarks for suitability of conservation practices.

Educators can use the interface with students or workshop participants to highlight the challenges and opportunities when managing agricultural systems for improved water quality.

For More information

This tool, and associated documentation, is freely available at http://drainagedata.org/.



AUTHORS

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Other drainage tools and resources can be found at https://conservationdrainage.net/resources/general-drainage-tools/.

This publication is part of the Transforming Drainage project. An 8-state project led by a core group of 15 leading agricultural engineers, soil scientists, agronomists, economists, social scientists, and database and GIS specialists with a common vision — to transform the way drainage is implemented across the agricultural landscape. Find out more at www.transformingdrainage.org

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USDA United States Department of Agriculture National Institute of Food and Agriculture