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Practitioner's Perspective

Seizing the Opportunity: Realizing the Full Benefits of Drainage Water Management

Charles Schafer, Dave White, Alex Echols, and Thomas W. Christensen

Drainage water management (DWM) offers great promise to improve environmental performance and farm economic viability on tile-drained cropland. The new availability of innovative automation features eliminates or mitigates many of the long-standing barriers to farmer adoption of DWM. On-farm research and field experience demonstrate that crop production and nutrient loading reductions can be compatible goals with DWM applied in a conservation systems approach. Millions of cropland acres in the Great Lakes and Upper Mississippi River Basins are suitable for the adoption of this approach. It will take a concerted private-public partnership effort that provides educational, technical, and financial assistance to farmers and furthers research and outcome assessment work to aid their adoption. The potential for crop yield increases could help offset DWM implementation, management, and maintenance costs not covered by conservation programs. Partners should focus their efforts in priority small watersheds with a preponderance of tile drainage and compelling nutrient loading concerns. These small watersheds are the best opportunity to efficiently and effectively grow farmer adoption. Success in initial watersheds will create momentum, facilitate sharing of lessons learned, and foster the partner commitment needed to "scale up" efforts across the cropland suitable for DWM.

Charles Schafer is president of Agri Drain Corporation, Adair, Iowa. **Dave White** is president of Ecosystem Services Exchange, Barboursville, Virginia. **Alex Echols** is executive vice president of Ecosystem Services Exchange, Alexandria, Virginia. **Thomas W. Christensen** is project manager at Ecosystem Services Exchange, Leesburg, Virginia.

The Setting for Drainage Water Management

Agricultural land drainage has been a key to developing the viability and profitability of US agriculture since the early days of settlement. Surface and subsurface tile drainage enable farmers to remove excess water from poorly drained soils to improve workability and increase crop production and farm profitability. Tile drainage, first introduced to US agriculture in 1835 near Geneva, New York, now underlies 22.7 million ha (56 million ac) of the 129 million ha (320 million ac) of harvested cropland in the nation (USDA ERS 1987; USDA NASS 2017).

Federal legislation, through the 1962 Drainage Referral Act, first began to constrain the new application of agricultural drainage because of impacts to wildlife (USDA ERS 1987). In 1973, and strengthened in 1975, the US Department of Agriculture (USDA) Soil Conservation Service discontinued technical assistance for draining certain types of wetlands (Christensen 2020b). Presidential Executive Order 11990 (Protection of Wetlands) in 1977 further required avoidance of the destruction or modification of wetlands (USDA ERS 1987). The 1985 Farm Bill denied program benefits to farmers who grew annual crops on wetlands drained after December of 1985. Because of today's statutory and public policy setting, and better scientific understanding, subsurface tile drainage work is now largely focused on replacing and/or improving aged tile systems, installing new systems in soils where wetlands are not threatened, and retrofitting existing systems to enable farmer's adoption of manual or automated DWM.

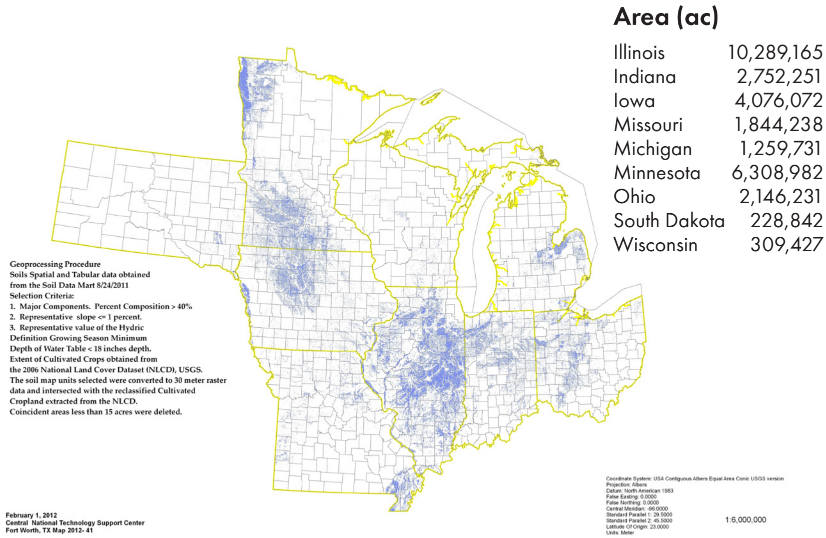
Despite its agricultural production benefits, tile drainage provides a direct conduit for nutrient transport to water bodies and poses environmental concerns. Without voluntary action by farmers to actively manage these tile systems for both production and conservation, water quality improvement goals are impeded. DWM, in combination with other conservation practices, offers great promise to improve both environmental performance and farm economic viability in tile-drained landscapes.

The Opportunity and Challenge

DWM uses adjustable, flow-retarding water control structures placed in a tile system that allow the soil water table elevation to be adjusted. Automated management of drainage water is an innovative, cost-effective tool to better control the rate and timing of water discharge and may be operated remotely. Automation employs two-way telemetry to greatly reduce the labor burden for farmers and provide real-time data to automatically manage water levels and flow rates in tile drained fields.

Figure 1

Tile-drained cropland in the US Midwest suitable for drainage water management. Map courtesy of US Department of Agriculture Natural Resources Conservation Service, 2012.



In 2012, USDA Natural Resources Conservation Service (NRCS) estimated 11.8 million ha (29.2 million ac) of cropland in just nine Great Lakes and Upper Mississippi River Basin states were suitable for DWM (figure 1). The absence of DWM is a lost opportunity for farmers and the environment. The evidence from over three decades of experience and research is compelling—every suitable cropland acre where DWM is not applied results in environmental benefits, farm income potential, and agricultural resilience forgone.

On-farm experience and research confirm crop production and nutrient loading reduction can be compatible goals through proper DWM. Research results report reduced nutrient loading ranging from 10% to 80% for dissolved phosphorus and 8% to 94% for nitrates, depending on site-specific conditions and the water management regime (Christensen 2020a). Phosphorus-focused research has not been as robust compared to nitrogen, but the consensus conclusion is that DWM is directionally correct for reducing nutrient loading from tile drainage (King et al. 2015).

In-field research on the crop yield effects of DWM has been limited, site-specific, and variable. Tile spacing and depth, water control system design, management regime, and weather conditions impact yield effects on a site-specific basis. Further studies and synthesis of findings will be needed to better characterize the impact of DWM on long-term yields so that farmers have access to decision-making guidance and tools.

Yield increases from one field study showed sites with corn and soybean yield increases ranging from 1% to 19%, but also an equal number of sites showing no yield increases (Skaggs et al. 2012). Computer modeling has shown long-term yield benefits of up to 5% are possible in the Midwest, but not every year (Christianson et al. 2016). Multiple studies indicate DWM is likely to increase crop yields when plants are stressed and tile flow is managed to improve soil water availability. In contrast, DWM is less likely to influence yield when precipitation keeps soil water available to meet plant demands.

Ghane et al. 2012, evaluated crop yields under DWM over multiple settings in northwest Ohio and concluded a yield advantage for corn, popcorn, and soybeans over free tile drainage. These researchers concluded the yield advantages of DWM can provide financial incentives for farmers to adopt this practice (Allerhand et al. 2013).

Previous yield studies were done without the benefit of real-time, "24/7" automatic management of water level control structures. We hypothesize that intensive soil moisture monitoring and automated real-time water level and flow rate management should result in increased yields, depending on precipitation amounts and timing.

The challenge is bringing site-specific planning and adoption of DWM and companion conservation practices to scale, first in priority small watersheds and then across the suitable cropland. The opportunity to realize and optimize both crop production and environmental benefits is present, and farmers should seize it now with assistance from agricultural and conservation partners.

Producers' Adoption of Drainage Water Management

Producer adoption of DWM has lagged far behind its potential despite its benefits and the financial assistance provided by conservation agencies to cover much of the cost of adoption. A review of NRCS Environmental Quality Incentives Program (EQIP) data (USDA NRCS 2020) shows that financial assistance for DWM (NRCS practice code 554) in fiscal year (FY) 2019 resulted in 259 completions with 3,242 ha (8,010 ac) benefitted. EQIP code 554 data from FY2009 forward also show the peak adoption was in FY2013, with 301 completions and 6,946 ha (17,163 ac) benefitted. For FY2009 through FY2019 combined, the data show a total of 2,340 completions and 39,798 ha (98,344 ac) benefitted. Certainly not all DWM applied involves NRCS financial assistance, but these data clearly indicate that DWM has not been adopted at anywhere near the coverage needed to achieve its full production and environmental benefits.

Overcoming barriers to farmer adoption is essential if this conservation practice is to see widespread use consistent with the multimillion acre need. Promise exists to overcome these barriers with the new, data-assisted automated DWM. Both manual and innovative automated DWM afford many benefits for farmers and downstream communities, including

- increased crop production, resilience, and reduced risk of crop losses during weather extremes, such as drought;
- potential for reduced cost of federal crop insurance;
- potential reduced input costs;
- potential to apply subsurface irrigation management for greater conservation and production benefits;
- opportunities for improved farm income by trading on-farm conservation-system generated water quality credits with regulated point sources;
- seasonal flooding benefits for migratory waterfowl;
- potential flood reduction benefits by storing more water in the soil profile; and
- reduced nutrient loading, principally through flow volume reductions.

Automated DWM addresses many of the long-standing barriers to adoption. This technology operates by two-way telemetry to reduce the labor burden and provide real-time data to automatically manage soil water levels and tile flow rates. Automation also facilitates the implementation and management of subirrigation. On average, the all-inclusive cost to retrofit an existing tile system to implement automated DWM is about \$618 ha^{-1} (\$250 ac^{-1}), much of which can be offset by financial assistance through conservation programs and typical crop yield increases.

What Needs to Happen?

There is no single solution nor prescription to improve tile drainage water quality associated with almost 12.1 million ha (30 million ac) of suitable cropland in the Great Lakes and Upper Mississippi River Basins. However, a site-specific system of in-field and edge-of-field conservation practices including DWM has been demonstrated to be a cost-effective, efficient solution to reduce nutrient loss from tile drained fields and provide crop production and other benefits. Automated DWM greatly improves the ability of farmers to manage more efficiently, with less labor, and with more effective results.

Priority small watersheds, such as 12-digit HUCs (typically 4,047 to 16,187 ha [10,000 to 40,000 ac] in size), with a preponderance of tile drainage and compelling nutrient loading concerns present the best opportunity to grow farmer adoption of DWM. This "working" watershed level provides enough consistency in physiography and types of farming operations to more effectively evaluate results, gain lessons learned, and apply continuous improvements and adaptive management timely and effectively.

More specifically, emphasizing focused partnership action at the small watershed level will

- optimize efficient use of technical and financial assistance and target highly suitable cropland that can have an aggregated water quality improvement;
- facilitate coordinated monitoring and assessment at the field, farm, and small watershed scales;
- create opportunity for greater collaboration and synergy among partners;
- provide farmers and partners with a clear "line-of-sight" between water quality results and DWM actions; and
- supply more extensive, richer data for modeling and for use with continuous improvement and adaptive management.

The objective of this focused approach is to achieve concentrated DWM in a small watershed to further identify and pursue approaches to overcome barriers to adoption, create adequate water flow and quality monitoring data for modeling and assessment, and develop site-specific decision support tools to validate efficacy and transportability to other sites. Success in multiple small watersheds should create momentum, facilitate sharing of lessons learned, and the foster opportunity for scaling up. From this foundation, adoption of DWM can be achieved in larger watersheds and eventually across the preponderance of suitable cropland. Private-public partnerships will foster such small watershed projects. It will take dedicated partners each playing a role(s) and contributing resources, capabilities, and available resources. The effect of these partnerships will be greater than the additive sum of their parts.

Scope of the Private/Public Investment Needed

The costs of implementing DWM vary based on site-specific characteristics, drainage system design, and the type of control system installed. Using the 2012 NRCS assessment of 11.8 million ha (29.2 million ac) in the nine Great Lakes and Upper Mississippi River Basin states where DWM can be easily applied provides a basis to examine the large-scale investment needed.

Cooke (2005) estimated \$49 to \$99 ha^{-1} (\$20 to \$40 ac^{-1}) to retrofit a tile system to install control structures for manual DWM, and \$220 ha^{-1} (\$89 ac^{-1}) for a new system in complex topography. Ecosystem Services Exchange has estimated the cost to retrofit tile drainage to implement the more efficient, effective, and innovative automated DWM at \$618 ha^{-1} (\$250 ac^{-1}), including annual data transmission and management fees. Thus, using a conservative \$99 ha^{-1} to retrofit tile drainage for manual DWM and \$618 ha^{-1} for the all-inclusive automated system, and applying that to 11.8 million ha (29.2 million ac), the gross costs could range from a high of \$7.3 billion to a low of \$1.2 billion. While neither figure is realistic because (1) not every farmer will adopt DWM, (2) installations will be a combination of retrofit and new systems and manual and automated systems, and (3) the practice already has been adopted on some acres, it does provide a view of the private-public sector investment needed to achieve successful adoption of DWM across this landscape.

Financial assistance from conservation agencies offsets many of the costs of planning and implementing DWM and companion conservation practices, such as denitrifying bioreactors and saturated buffers. Costs should be further offset by yield increases beyond typical crop production responses from free-flowing drainage. With real-time monitoring and water flow/quality data from automated DWM, the income opportunity for farmers is even greater because they will be positioned to trade water quality credits for payments with regulated point sources. However, it will take continued innovation to reduce the costs of implementation/management further if systems are to be applied, managed, and maintained across the cropland acres of opportunity.

Keys to Successfully Seizing the Opportunity

There are many keys to a successfully focused, lasting effort to foster adoption of DWM across the nine states identified in the NRCS 2012 assessment of suitable cropland. These keys to success include the following:

- Development of robust private-public partnerships with shared objectives/commitments consistent with each partner's mission, capabilities, and resources to lead efforts in each small watershed project.
- Small watersheds that have the key physical attributes for successful DWM, willing farmers, engaged local partners, and external drivers, such as downstream water quality concerns.
- Use of a conservation systems approach, with DWM supported by companion in-field and edge-of-field conservation practices.
- Quality technical assistance of sufficient quantity from both the private and public sectors, working in cooperation in each small watershed.
- An ambitious project timeline for each small watershed that strives to create momentum by sharing results from early adopters with other farmers.
- Concurrent research and development that take advantage of widespread adoption in a small watershed to grow the knowledge base for continuous improvement, adaptive management, and the science basis for decision-support tools.

- Partnership efforts that drive outcome assessment, not just in physical terms such as nutrient load reductions and crop productivity, but also regarding on-farm economics.
- Financial assistance for farmers that places value on off-site benefits, not just the costs incurred or income forgone in adopting DWM.
- Outreach and education across all farmers, partners, and stakeholders that is robust and maintains core consistency but is adapted to each small watershed and the uniqueness of its partnership.

Conclusion

Farmers own or use the cropland where DWM can be applied, are the decision makers for their operations, bear the risks and consequences of their decisions, and are the ones that can adopt and improve this practice applied in a conservation systems approach. Their success individually and collectively in small watersheds can create the foundation, synergy, and momentum to achieve the adoption of DWM across the many million cropland acres of opportunity in the Great Lakes and Upper Mississippi River Basins. The introduction of innovative automated DWM removes many of the historic barriers to farmer adoption and will provide improved management and assessment of outcomes.

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