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Agricultural Conservation Planning Framework: Watershed applications, research opportunities, and training resources

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Abstract: The Agricultural Conservation Planning Framework (ACPF) is an approach to precision conservation for agricultural watershed planning, which is supported by high-resolution watershed data providing spatial detail on land use, soil survey, and topography, which, in turn, are analyzed using an ArcGIS toolbox to identify conservation practice placement options for water quality improvement. A variety of conservation practice placements are identified by the software and can be presented as planning options to engage farmers and watershed stakeholders in local conservation efforts. This special section comprises three research articles, two features, a research editorial, and this overview article. These papers describe new features in ACPF version 3, released in late 2018, describe research from multiwatershed ACPF analyses, discuss watershed planning approaches that have utilized the ACPF, and evaluate farmer perceptions of ACPF results for their farms. This overview article describes the history and development of the ACPF, its role in a watershed approach to agricultural conservation, training and support for the ACPF, and future challenges anticipated as the ACPF is trialed outside the upper Midwest. Several watershed case studies are presented that were part of a symposium during the Soil and Water Conservation Society Annual Conference in 2017. The ACPF was developed by the USDA Agricultural Research Service with support from the Natural Resources Conservation Service, is in the public domain, and is available, along with support and training resources, through https://acpf4watersheds.org. Broader adaptation in using the ACPF as a platform for watershed planning, modeling, and research is encouraged.

Key words: conservation planning—decision support tools—precision conservation—watershed analysis

The Agricultural Conservation Planning Framework (ACPF) is a tool that uniquely supports small watershed conservation planning. The Framework has three legs: a conceptual approach for implementing conservation across small watersheds; an ArcGIS-based toolbox to facilitate terrain analysis for identifying suitable sites for major conservation practices; and a set of geographic information system (GIS)-ready databases designed for conservation applications.

The goals of this article are to review the origin and purpose of the ACPF, explain its role in a watershed approach to agricultural conservation, describe training and support available, and discuss the future of the ACPF, making a case for broader adaptation and adoption of the tool in watershed planning, modeling, and research.

The ACPF originated from the need for a bridge between state/regional planning and farm-level implementation. A tool was needed to understand the watershed context of individual practices so implementation could more effectively impact water resources. The ACPF was developed to help watershed planners bridge this gap as they work towards state nutrient reduction targets while preserving agricultural productivity.

The ACPF was designed to provide practical decision-making support in a form that was useful and accessible to local small-watershed planners. Such support would need to be consistent with several principles: (1) every farm and watershed is unique so any tool must be customizable for diverse landscapes and incorporate local knowledge; (2) at the same time, the design and inputs must be straightforward and accessible to users without specialized modeling skills; (3) the outputs must be scientifically consistent, accounting for upstream-downstream watershed impacts in a variety of landscapes; (4) conservation is achieved by a mix of practices, so a tool must support implementation of a variety of practices defined by conservation programs; (5) to support voluntary participation and sound solutions, practice siting decisions should not be prescribed, but must be flexible and locally controlled; and (6) watershed conservation begins with soil practices that build soil health, control erosion, and employ 4R (right source, right rate, right time, and right place) nutrient management (Tomer et al. 2013).

The conceptual framework of the ACPF is to implement farm-scale practices in a watershed context through a chain of water management practices from in-field soil and nutrient best practices, to drainage management, edge-of-field practices, and riparian practices (figure 1). In addition to putting individual practices into their watershed context, the Framework provides a way to empower stakeholders to engage and participate in solution building.

The ArcGIS toolbox for siting conservation practices requires several input databases, which have been developed for over 11,000 12-digit hydrologic unit code (HUC-12)

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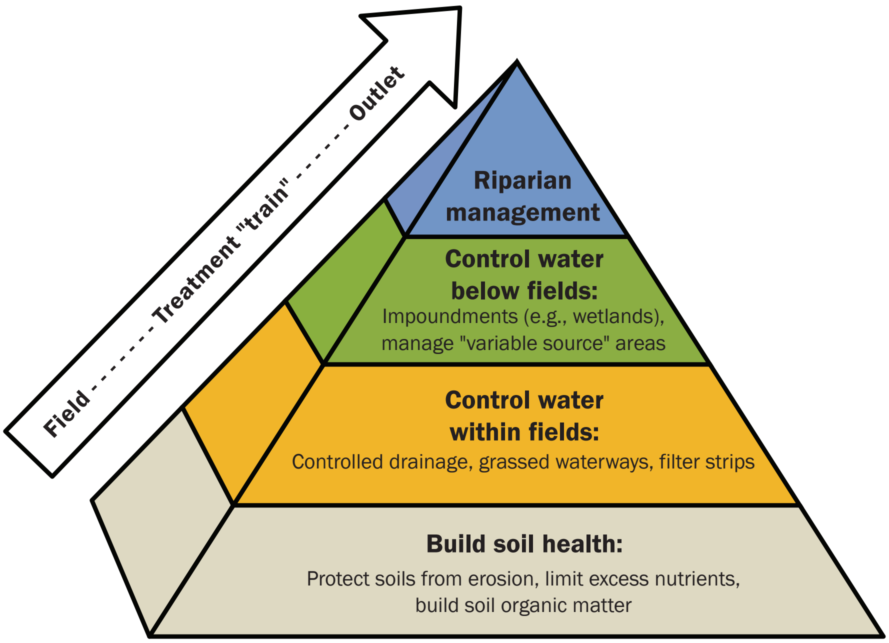
Figure 1

Conservation pyramid as a conceptual basis for the Agricultural Conservation Planning Framework. Broad-based efforts to improve soils, structural practices within and below fields, and riparian management practices provide a sequence of conservation opportunities to tailor agricultural watershed management to each watershed's landscapes using high resolution data and can enable stakeholder participation in planning (adapted from Tomer et al. [2013]).



watersheds across the Midwest (figure 2). The four essential inputs are (1) a subset of soils information obtained from USDA Soil Survey (gSSURGO) databases; (2) field boundaries to allow for analysis at the unit of land management; (3) cropping and land use history, by field, for the past six years; and (4) high resolution digital elevation model (DEM) data (2 to 3 m [6.5 to 9.8 ft] grid resolution is recommended). The DEM layer must be acquired by the user from a source that varies by state. The other three layers are available for easy download by watershed from a single interface available from the ACPF website. The soils, field boundaries, and land use history are used for additional applications, including Iowa's Daily Erosion Project (Tomer et al. 2017).

Development of the ACPF ArcGIS toolset and input databases began in 2011 at the USDA Agricultural Research Service National Laboratory for Agriculture and the Environment at Ames, Iowa (Tomer et al. 2013). Initial funding was from a USDA Natural Resources Conservation Service (NRCS) Conservation Innovation Grant awarded to the Environmental Defense Fund. Version 1 was released in October of 2015. Over the years, the extent of the databases was expanded, the number of practices increased, programming improved, and training was delivered in Iowa, Minnesota, Wisconsin, Indiana, Nebraska, and Ohio. Version 3 was released in September of 2018. The website acpf4watersheds.org, hosted by the North Central Region Water Network, launched in 2018. The focus so far has been centered on the upper Midwest.

The ACPF ArcGIS toolbox facilitates hydromodification of DEMs, definition of flow networks, digital terrain analysis, characterization of farm fields, identification of potential sites for about 10 common conservation practices, and characterization of riparian corridors (Tomer et al. 2015a, 2015b). The riparian analyses tools, as revised in version 3, delineate the land area contributing to each stream segment (Tomer et al. 2020a). The processes are not deterministic, and the outputs are not prescriptive. The tools do not include economic analyses or pollutant load estimates, but tabulated outputs for each practice can help planners and land managers identify high-priority fields and define the practical potential and appropriateness of conservation practices. The siting of conservation practices is largely based on terrain analysis. While the toolbox was designed for addressing nutrient and sediment concerns, the results may also be relevant to other water quality and quantity concerns, to the extent they are driven by hydrology.

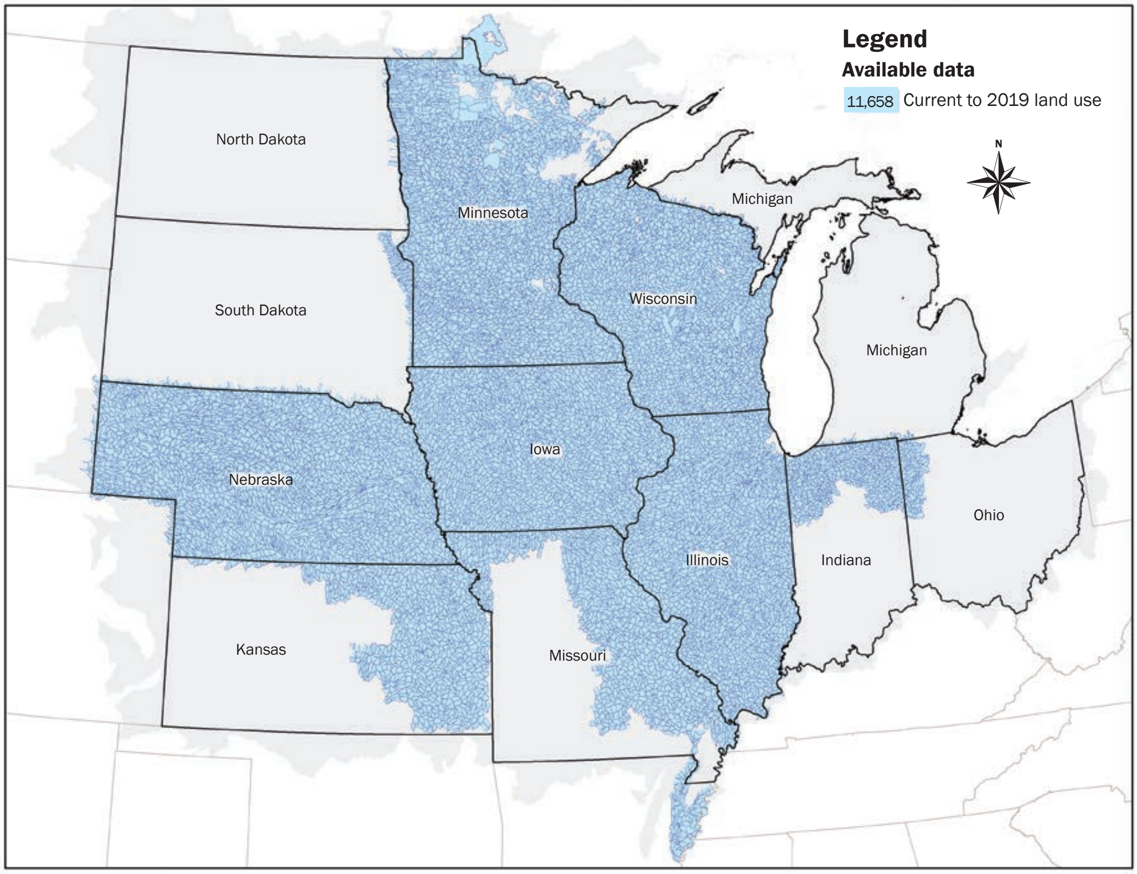
Many county or regional conservation offices have the expertise and resources needed to run the ACPF (Lewandowski 2016). Running the toolbox requires moderate proficiency in ArcGIS and knowledge of local landscapes and practices. Once trained, a GIS technician working on a single small watershed (e.g., 4,000 to 20,000 ha [9,884 to 49,421 ac]) can hydromodify a DEM and define flow networks in at most two days and then apply the tools to site conservation practices in less than a day. The toolbox runs using an advanced license of recent versions of ArcGIS (10.3 to 10.6 and Pro).

Agricultural Conservation Planning Framework as Part of Watershed-Based Conservation

Water resource management in agricultural regions is generally a process of planning and implementing land use and land management practices to improve the quality or quantity of surface and groundwater. It is a local, iterative, adaptive management process, accounting for interactions among physical practices, environmental conditions, and social interactions and systems—components that come together uniquely at a place. These components also interact across scale, with large-scale processes (federal and state policies, markets, and weather systems) interacting with medium and small-scale processes (e.g., community dynamics and farm field hydrology). Discerning the optimal scale for managing these interactions is important to effective planning and implementation (Konopacky and Ristino 2017; McLellan et al. 2018; Rao and Powers 2019). These authors argue that watersheds of 4,000 to 16,000 ha (9,884 to 39,537 ac)—the size of a HUC-12 watershed—are the right size for understanding and acting upon hydrologic and social features to change land use and management practices in support of water quality. (They acknowledge the optimal watershed size may be larger or smaller than a HUC-12, depending on the population density and existing opportunities for organizing, collaborating, and funding.)

Figure 2

Extent of the Agricultural Conservation Planning Framework database, available for download at the hydrologic unit code 12 scale, through acpf4watersheds.org.



These small scales are optimal because one or a few staff can establish relationships with all the landowners and engage most of the stakeholders; hydrologic processes can be described and used to prioritize practices and sites; and conservation activities can have measurable impacts on water and social characteristics. While strategic planning and monitoring at larger scales is valuable to ensure statewide coverage, prioritize small watersheds, and inform small watershed planning; these larger scale plans typically lack the detail needed to prioritize new practices for implementation and to maintain local support.

ACPF is a unique tool in efficiently identifying specific sites appropriate for the major suite of conservation practices. The ACPF is best applied at the HUC-12 scale. It is less effective at large scales where only general locations for practices are needed, or at small (field) scales that cannot consider landscape-scale hydrologic processes. Thus, ACPF is only useful to managers taking a small watershed approach to conservation, in contrast to either an entirely farm-based or major watershed (HUC-8) approach to planning.

ACPF outputs have been used in a variety of ways to support watershed-scale conservation. Ranjan et al. (2019) describe a typology of producer engagement strategies including using the ACPF as background information to make field visits more effective, integrating priorities based on ACPF terrain analysis with priorities based on farmer preferences, soliciting help with field validation of ACPF outputs, and informing discussions in group settings. Other articles in this issue describe examples of ACPF applications: Gesch et al. (2020) share the process used in Iowa to develop watershed plans. Tomer and Nelson (2020) combine analyses from several watersheds to support larger scale planning, and assess how ACPF data on distributed, landscape-based water detention practices may inform strategies for recruiting landowners to implement those practices, which can attenuate peak runoff rates.

In any application of ACPF, effective soil and water resource management relies on the quality of relationships between farmers and local conservation partners. Conservationists influence these relationships in the way they present ACPF outputs. Ranjan et al. (2020) explore in detail how the process and medium of discussing precision conservation options affect how farmers receive conservation targeting efforts.

Case Studies

The following examples illustrate three types of applications of the ACPF. The first begins with ACPF analyses as the basis for watershed plans and funding proposals to provide a science-based justification for conservation strategies. The second used ACPF output to support producer engagement by giving landowners the information they needed to engage meaningfully in watershed decision-making. The third example used ACPF to support implementation by identifying practice sites only after stakeholders had prioritized practices. These case studies were presented during an ACPF symposium at the 2017 Soil and Water Conservation Society Annual Conference in Madison, Wisconsin.

Agricultural Conservation Planning Framework to Justify Conservation Strategies. HeartLands Conservancy (HLC) began using the ACPF in 2014 as part of the watershed planning process for the Upper Silver Creek watershed in southwestern Illinois after they received a US Environmental Protection Agency (USEPA) 604b watershed-based planning grant from the Illinois Environmental Protection Agency (IEPA). The Upper Silver Creek watershed, located primarily in Madison County, Illinois, covers 486 km^2 (120,091 ac) and includes several areas that were historically wetlands but are now cultivated farmland. The ACPF's Nutrient Removal Wetlands tool output was used to identify critical wetland areas—areas of highest priority for wetland restoration. The ACPF results were used by the watershed planning team to estimate the highest possible implementation of nutrient removal wetlands. For example, if the ACPF Nutrient Removal Wetlands tool returned 80 ha (198 ac) of nutrient removal wetlands, the team would look at the watershed map and consider the feasibility of restoring 10%, 20%, or 50% of those sites, and then calculate the reduction in nutrient pollutant loads associated with doing so. This made it possible to set ambitious but feasible pollutant reduction targets for the whole watershed. In this way, HLC completed a comprehensive watershed-based management plan for the Upper Silver Creek that was informed by output from the ACPF. Once the Upper Silver Creek Watershed Plan was completed and approved by the IEPA, HLC applied for and received a USEPA 319h grant from IEPA to assist in implementing practices that prevent nonpoint source pollution in the watershed. Landowners with areas that were highly ranked for wetland restoration potential who had previously expressed interest in wetland restoration were the first to receive information about cost-share funding provided by the 319h grant.

Based on their success in the Upper Silver Creek watershed, the IEPA awarded HLC a second 604b planning grant in 2016 to develop a watershed-based management plan for the Lower Silver Creek watershed—the southern half of the 988 km^2 (244,255 ac) Silver Creek watershed. HLC along with its partners, including the National Great Rivers Research and Education Center and Midwest Streams, developed a watershed-based management plan for the Lower Silver Creek watershed using output from the ACPF to identity effective best management practices (BMPs). The plan was approved by IEPA in 2018 (HeartLands Conservancy 2018).

HLC ran ACPF analyses as the basis for the Canteen Creek-Cahokia Creek and the Indian Creek-Cahokia Creek Watershed Plans, currently in progress. Additional 604b planning grant proposals are pending with the IEPA to continue developing watershed-based management plans for other watersheds in southwestern Illinois. The ACPF will continue to be an integral part of their process for developing watershed-based plans.

Agricultural Conservation Planning Framework to Support Producer Engagement. The Wilson Creek watershed in western Wisconsin was selected for a concerted water quality improvement project by county land conservation and USDA NRCS staff in 2015. This watershed was selected due to its improvement potential, support from partners including Wisconsin Department of Natural Resources and Trout Unlimited, and participatory interest shown by resident landowners to implement conservation in the watershed. Located at the northern extent of the unglaciated Driftless Area, Wilson Creek is a class II trout stream that forms its headwaters in eastern St. Croix County and flows east into Dunn County to its confluence with Lake Menomin, a reservoir on the Red Cedar River. The watershed encompasses 135 km^2 (33,280 ac), of which over 55% is agricultural land use. Wilson Creek, as well as most of its tributaries, is listed on the federal Impaired Waters List (303[d] List) for pollution due to excessive phosphorus (P). The goal of this project is to improve water quality to the extent that the waters can be removed from the 303(d) List.

Community engagement is an important aspect of addressing water quality problems (Beckworth and Paulson 2015; Thompson et al. 2015). For any watershed-scale project to be successful, it is important that residents have an understanding of the problem and are part of the process of identifying solutions. At the start of this project, a citizen-led group comprised primarily of watershed residents was formed to guide project implementation. The group selected the name Wilson and Annis Creek Watershed Partnership (WACWP). An initial task of WACWP was to set goals and prioritize BMPs that would be the focus of the conservation efforts, providing guidance to agency staff on how to spend project funds. To aid in this decision-making, Dunn County Land and Water Conservation Division staff performed an ACPF analysis of the watershed to illustrate to stakeholders where and which BMPs might be best suited within the watershed. Using the ACPF results, stakeholders were able to identify BMP options that would help meet water quality goals while complementing their own conservation and farming interests.

The precision conservation siting and riparian assessment tools in ACPF were used to identify ideal BMP locations and evaluate riparian function in the watershed. Many WACWP members expressed concern about gullies and erosion issues on their fields, and grassed waterways and riparian buffers were determined to be two practices that would have the greatest potential in reducing sediment and associated nutrient loading into Wilson Creek. Results of the analysis were used to develop landowner mailing lists to target potential project locations.

Many funding sources came together to implement the conservation projects identified, including the NRCS Environmental Quality Incentives Program under the National Water Quality Initiative subprogram. Wisconsin Department of Natural Resources contributed funds and staff time to restore segments of stream and associated riparian zones, while Trout Unlimited contributed labor and additional funds towards those projects. By 2019, the Wilson Creek project, through the efforts of the citizen-led WACWP, led to over 1,000 m (3,500 ft) of grassed waterways installed and about 6 km (4 mi) of riparian corridor protection and trout stream restoration, among other BMPs.

Agricultural Conservation Planning Framework to Support Implementation. The last example of incorporating ACPF into water planning and implementation is detailed by Gesch et al. (2020). The Iowa Soybean Association develops watershed plans by first working with landowners to identify priority issues and practices. Then, water quality modeling and the stakeholders' goals are used to set specific implementation goals for the practices. Finally, the ACPF is employed to identify specific locations for siting practices.

Agricultural Conservation Planning Framework for Research and Regional Planning

While the ACPF was designed to support local planning and implementation, it has also been used for research and for larger scale planning. For example, Tomer et al. (2020c) used the ACPF to compare practice placements among 32 Iowa watersheds for their impact on runoff mitigation and controlled drainage. This research showed that the Stream Power Index threshold used to site grassed waterways was not sensitive to landscape steepness and stream dissection. A procedure to place grassed waterways at a defined density (length of waterways per unit area of cropland in the watershed) was derived from this research to help planners be more specific about ACPF-based grassed waterway placements. In a related study, Tomer (2020b) conducted a multiwatershed analysis of the same 32 watersheds to examine regional opportunities for placement of saturated buffers, a practice that diverts tile drainage water into riparian soils to reduce nitrate (NO_3^-) loads. Suitable sites for saturated buffers were found along 30% to 70% of streambank lengths. Analysis of riparian catchments above these suitable sites showed that tile drainage from 15% to 40% of these watersheds could be treated using saturated buffers. However, watersheds with large headwater catchments above stream initiation points (i.e. watersheds with low stream density) have little or no opportunity for riparian treatment. Such watersheds are found in the Des Moines Lobe (Major Land Resource Area 103), a region of intensive row crop agriculture and artificial drainage. Drainage management and edge-of-field practices (e.g., bioreactors) become more important for improving quality of tile drainage where riparian opportunities are sparse.

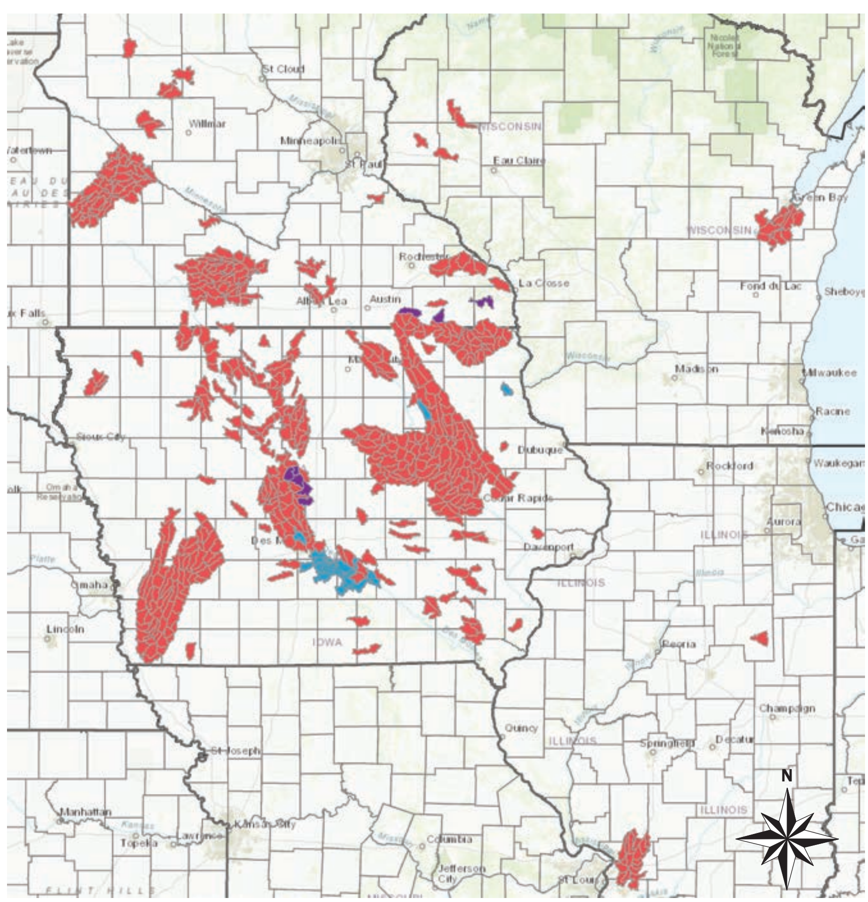
Multiwatershed research using the ACPF can address a variety of questions that could be applied to sensitivity analyses and other hypotheses. Some examples of other research and planning questions that could be addressed include the following: Where edge-of-field monitoring is being conducted, what is the extent of sites in the watershed with similar characteristics to the monitored site? For regional planning, how does the extent of locations suited to a specific practice vary among watersheds and landform regions? Can this information help budget conservation expenditures and prioritize research/demonstration efforts? What are the opportunities to combine in-field and edge-of-field practices across a watershed to increase impact from the individual practices?

Agricultural Conservation Planning Framework Training and Support

Training and support are required to use the ACPF correctly and effectively. The level of complexity of any model is a tradeoff between enough detail to provide meaningful information and enough simplicity that it can be run affordably to support decision-making. That balance point depends on what decisions need to be made and who needs to make them. The ACPF is designed to support local conservation planners identifying specific sites for conservation practices. Thus, it is not limited to expert users or researchers, but it does require training to use correctly and effectively. The NRCS and USEPA have funded development of training and support resources to encourage use and applications of the ACPF. ACPF resources are hosted by the North Central Region Water Network at acpf4watersheds.org.

Training and support are targeted at two skill sets: technical use of the ArcGIS toolkit and integration of the ACPF outputs into conservation planning and implementation. Using the ACPF requires the integrated work of GIS specialists who have midlevel ArcGIS skills alongside conservationists or watershed managers who understand the local landscape and land uses. A self-study program is available for GIS users to learn the technical details of using the ACPF toolset effectively. To use the toolset correctly, GIS

Figure 3
Watersheds analyzed using the Agricultural Conservation Planning Framework (ACPF) toolbox. A current map including contact information for each watershed is available from the ACPF website. Colors represent different levels of completion applying the ACPF.



specialists should allow about two full days of study—either at a face-to-face workshop or through self-study with training videos. For watershed coordinators who may not have GIS skills, a face-to-face workshop has been developed to discuss how to integrate ACPF into stakeholder engagement, planning, and implementation activities. Additional workshops and online resources are planned.

In addition to training, the acpf4watersheds.org website provides support resources, including a discussion forum for troubleshooting technical issues, the user guide, a map of completed watersheds including contact information, links for downloading, a list of publications, and examples of applications of the ACPF.

Future Development and Expansion

Within six years of first being proposed (Tomer et al. 2013), the ACPF has been shown useful in hundreds of watersheds across the Midwest (figure 3). Now, ACPF work is shifting from development and deployment to a new phase—one of establishing a system for long-term maintenance and user support, integrating the ACPF into conservation planning and implementation processes, and expanding its use to other regions.

The ACPF was developed within and has been used across the US Midwest in areas of expansive corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.) production. Subsurface drainage is common in these areas, and several of the ACPF conservation practice placement tools are aimed at managing tile drainage and associated nutrient loads. The ACPF has been successfully applied for watershed planning across a variety of landform regions, including glacial landscapes of varying age and stages of geomorphic development, and karst terrain. Based on the diversity of applications so far, the developers are optimistic that the ACPF can be expanded to other agricultural regions, landscapes, and cropping systems, pending testing and validation in places representing a wider geography. Transporting the ACPF to new areas will require adaptation and will present challenges, but the utility of the ACPF planning concept and database will remain applicable. The challenge will be ensuring the output conservation options are realistic in the new landscapes by allowing for customizations and providing placement options for new (and novel) practices that are relevant to wider landscape and land use settings. Among these challenges will be the following: (1) identifying relevance of ACPF analyses for conservation planning in very flat terrain, including lacustrine and alluvial plain landscapes; (2) adaptations for conservation planning in irrigated croplands; (3) adaptations for surface drainage systems (ditches carrying ephemeral runoff, field-border dikes); and (4) addressing watersheds dominated by small (<8 ha [20 ac]) fields with mixed agricultural and perennial land cover (common in the eastern United States). The ACPF needs to be piloted in watersheds with these challenges to demonstrate where and how the Framework can be expanded, stepwise, to a national scale. We encourage a measured approach to determine how the ACPF can be adapted among agricultural landscapes nationally.

In addition to ongoing training and resources, users in new regions will need access to input databases. The databases will no longer be centrally generated; however, the database developers have created tools to facilitate building of databases so states or even local offices can generate their own.

Two of the articles in this special section describe a new watershed discretization approach called riparian catchments, which is part of ACPF version 3. The riparian catchments approach is intended to synergize conservation efforts at landscape scale by identifying and linking conservation options in upland and riparian settings through a precision approach. The hope is to enable whole-watershed riparian analyses and clearer identification of conservation priorities for implementing new practices in uplands and riparian zones. Single watershed and cross-watershed analyses using riparian catchments are demonstrated in these two articles (Tomer et al. 2020a, 2020b).

Conservation decisions must be made to achieve economic as well as environmental efficiencies. Incorporating predictive technologies that allow planners to evaluate costs and benefits of precision conservation options will improve planning outcomes. Efforts are underway to enable conservation practice implementation and opportunity costs to be incorporated into the development of ACPF planning options. Watershed models (e.g., Soil and Water Assessment Tool) are also important to predict conservation outcomes, and these models are improving in terms of spatial precision. We encourage watershed modelers to explore use of the ACPF as a spatial platform for modeling and as an approach to develop watershed planning scenarios for testing using watershed simulation models.

We believe that the riparian catchments approach to watershed discretization, together with economic costing tools that are under development, will support wider use of the ACPF in the future. Contributions to continued development of the ACPF are welcomed across these challenges and technologies. Our goal is to establish ways to incorporate and credit broader contributions to facilitate expansion and continued testing and evaluation of the ACPF.

Disclaimer

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