doi:10.2489/jswc.2022.00138

Assessing the Agricultural Conservation Planning Framework toolbox in a Southern Piedmont landscape of the United States

Z.M. Respess, R. Austin, L. Gatiboni, and D. Osmond

Abstract: The Agricultural Conservation Planning Framework (ACPF) is a geospatial decision support tool that was developed and is used in many areas of the Midwest of the United States to help with the prioritization and placement of conservation practices within agricultural watersheds. We evaluated the utility and extensibility of ACPF in two US Geological Survey 12-digit scale hydrologic units in the Southern Piedmont of North Carolina. The Southern Piedmont consists of less row crop agriculture and more pasture systems than the Midwest and has generally lower pollutant loads. Also, agricultural fields are comparatively smaller, irregularly shaped, and more sparsely distributed. For this study, local conservation experts were interviewed about conservation practices and their appropriate locations in the landscape. Interviewees demonstrated an extensive working knowledge of the land and producers on over 90% of the farmland. Many of the conservation practices identified by the local experts were "soil health" practices, such as cover crops or nutrient management, and are assumed in use before running ACPF. Results revealed that many of the conservation practices output by ACPF were not identified by the local experts in the Southern Piedmont watersheds due to their limited use in pasture conservation, conservation priorities, and landscape characteristics. Row crop agriculture was sparsely distributed in each study watershed and comprised less than 2% of the total catchment area. Contour buffer strips and grassed waterways were the conservation practices most identified by ACPF and were sited in 75% of cropped fields. A greater number of crop-related conservation practices (48 versus 15) were identified by ACPF than by local experts; however 80% of the conservation practices identified by the experts were outside the scope of ACPF and were mainly nutrient management or soil health practices. To evaluate ACPF for broader utility in the Southern Piedmont, alternative interpretations for existing outputs were considered: (1) ACPF "proxies" were identified to compare locally accepted practices with ACPF outputs that perform a similar function (e.g., strip cropping rather than contour buffer strips) and, (2) placing locally used conservation practices (e.g., exclusion fencing) based on existing ACPF data layers (hydrologically enforced flow paths). Alternative uses and interpretations surrounding ACPF outputs and data layers may provide opportunities for conservation planning outside the scope and intended use of ACPF in the Southern Piedmont.

Key words: Agricultural Conservation Planning Framework—conservation practices—geographic information systems—Southern Piedmont

As early as 1977, the USDA and the US Environmental Protection Agency began agricultural watershed-scale studies to determine the effectiveness of conservation practices. Some of the largest of these studies have been the Rural Clean Water Management Project and different Conservation Effects Assessment Project initiatives (Gale et al. 1993; Tomer and Locke 2011; Osmond et al. 2012a, 2012b). Each project independently found that to influence water quality change, agricultural watershed management is essential, which includes identifying the pollutant(s) of concern, the source of the pollution, the critical source areas delivering the majority of the pollution, the appropriate conservation practice systems, and the goals and objectives that must be set in order to implement a well-developed plan and to measure success. To this end, in 2015, USDA Agricultural Research Service developed, in association with USDA Natural Resources Conservation Service (NRCS), the Agricultural Conservation Planning Framework (ACPF), a software to help watershed planners select and implement precision conservation practices that "control" (reduce within the field or at the edge of the field during transport) and "trap" (reduce at the field edge or in-stream) pollutants to reduce nutrient and sediment losses (Tomer et al. 2013; USDA NRCS 2021).

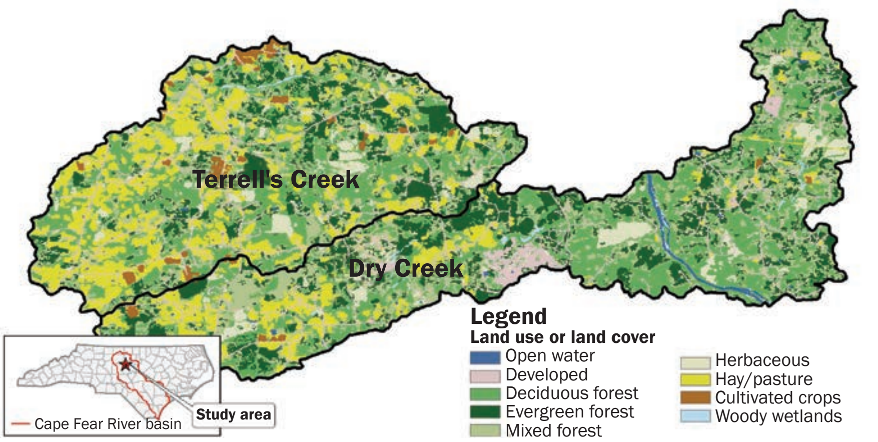
To site conservation practices, the ACPF software uses spatial data—soils, land use, elevation—to determine hydrologic flow pathways and hence locations for in-field (grassed waterways [NRCS Code 412], water and sediment control basins [WASCOBs, which are a series of embankments that store and slowly release runoff through underground outlets; NRCS Code 638], and contour buffer strips [NRCS Code 332]), edge-of-field (bioreactors [NRCS Code 605] and drainage water management [NRCS Code 554]), and below field (ponds [NRCS Code 378], riparian forest buffers [NRCS Code 398], herbaceous buffer [NRCS Code 390], and wetlands [NRCS Code 656/658]) conservation practices. The flexible nature of ACPF allows for the development of varied watershed-scale conservation planning scenarios to help meet pollutant reduction goals (Tomer et al. 2013, 2015). As ACPF has progressed, an ArcGIS (ESRI 2019) toolbox has been incorporated along with riparian analysis and a graphical user interface to help identify conservation practice placement options for improved water quality (Lewandowski et al. 2020). The assumption of the tool, before siting

Zachary Respess is an extension associate, **Robert Austin** is a research and extension specialist, **Luke Gatiboni** is an assistant professor and extension specialist, and **Deanna Osmond** is a professor and department extension leader in the Department of Crop and Soil Sciences, North Carolina State University in Raleigh, North Carolina.

Received September 9, 2021; Revised January 12, 2022; Accepted February 23, 2022;

Figure 1

Study watersheds located in the Upper Cape Fear River basin of North Carolina. Land cover is a mix of forest, pasture, and crop land typical of a Southern Piedmont landscape.



conservation practices, is that pollutants are best "avoided" by encouraging that all fields are using appropriate nutrient management and soil health practices (conservation tillage, cover crops, etc.). To site conservation practices ACPF uses "control" and "trap" strategies: control or treat the flow of water within and below fields and trap nutrients and sediment. Additionally, the use of ACPF in watershed planning in conjunction with farmer engagement may motivate precision selection and placement of conservation practices (Ranjan et al. 2020).

Agricultural conservation planners, not-for-profit organizations, and USDA NRCS are interested in utilizing ACPF beyond the regions where the tool was developed, intended, and tested (primarily cultivated cropland in the upper Midwest, Nebraska, and part of Kansas). In the Southern Piedmont, there has yet to be a study that compares ACPF results to recommendations produced by conservation professionals at the local level. We aim to provide this comparison to document the tool's utility and extendibility to other regions. To this end, we implemented ACPF in two, US Geological Survey 12-digit hydrologic unit code (HUC) watersheds in the Piedmont of North Carolina, which has a typical southern agricultural landscape consisting of mixtures of forest, pasture/hay, and cropland. The objective of this work was to determine the extendibility of ACPF into the Southern Piedmont by comparing conservation practices and resources concerns identified by ACPF to local-based knowledge.

Materials and Methods

Study Area. The study area, located in the Upper Cape Fear River Basin (i.e. Jordan Lake watershed), consists of two (Terrell's Creek and Dry Creek), 12-digit HUC watersheds (figure 1). Both HUC-12s contribute to the Haw River (HUC: 0303002) as it heads southeast and empties into the southern side of the multipurpose Jordan Lake reservoir. Jordan Lake's watershed is regulated for nutrients to protect the lake as a recreational and drinking water reservoir (NC DEQ 2021). A subset of stream reaches within Terrell's Creek and Dry Creek are on North Carolina's 303(d) list of impaired water due to benthos concerns. Dry Creek contains a collection of minor nonagricultural pollution permits including one for a golf course located in the middle of the HUC-12 and 0.5 km south of the main stem of Dry Creek. Reference the supplemental materials of this article for a description of the data development routines used for implementing the ACPF in the study area.

Model Parametrization and ACPF Outputs: Subsurface Drainage. Tile drains are not used in the study watersheds and are not identified within the ACPF tile drainage estimate due to the rolling landscape and well-drained soils. As such, the subsurface drainage practices supported by ACPF were not considered in this study. We assessed the remaining capabilities of the software, including the siting and placement of potential conservation practices, and the landscape and land use characterization of agricultural fields and riparian areas.

Model Parametrization and ACPF Outputs: ACPF Predicted Conservation Practices. The ACPF output was generated for the two watersheds by running a set of ACPF operations sequentially on data acquired and preprocessed for use in ACPF. To maintain consistency across conservation practices and between watersheds, the input parameters for each operation were held constant. The conservation practices sited by ACPF within the two study watersheds included grassed waterways, contour buffer strips, and impoundments (WASCOBs, ponds, and nutrient removal wetlands [NRWs]). Grassed waterways were sited using a stream power index value of 10.0. Contour buffer strips were developed using the ACPF default width of 4.5 m, although this parameter does not affect the placement of the conservation practice. ACPF sites contour buffer strips when areas within a field contain slopes between 4% and 15%. Their spacing is determined by slope, where the slope is divided into quartiles and the 3rd quartile of a field's slope determines the spacing. Slopes between 4% and 8%, 8% and 12%, and 12% and 15% correspond to uphill spacing of 76.2, 61, and 46 m, respectively. When presenting results, contour buffer strips in fields with a mean slope greater than 10% were symbolized to indicate potential locations for terraces as recommended in the ACPF user guide (Porter et al. 2018).

Impoundments are placed in the landscape by ACPF based on the upslope contributing drainage area, the size of the impoundment, and the landscape position. The different types of impoundments sited by ACPF, in order of increasing size and lower landscape position, include WASCOBs, ponds, and NRWs. Drainage areas between 0.8 and 20 ha are assessed for WASCOBs, 2 and 41 ha for farm ponds, and greater than 61 ha for NRW. The WASCOB and pond tools were used in this study because they best matched the size and location of existing impoundments in the study watersheds. These impoundments were sited in fields identified in pasture as well as row crop agriculture. The WASCOB tool was run using bank heights of 1.0, 1.5, and 4.5 m in order to capture a range of possible locations and impoundment sizes found in the region. We report the frequency of WASCOBs for all three bank heights, but the 1.0 m bank height was used to best compare practices identified by the local experts. Along steeper drainage and larger contributing areas, ACPF was used to site ponds rather than WASCOBs. Specifically, drainage areas between 2 and 41 ha are required for ACPF to site a pond, and slopes must range between 20% and 50%. Additionally, the ratio between the pond area and the upslope contributing drainage area must be between 0.25 and 8. Attempts were made to site NRW, but no wetlands were placed because we excluded NRW that (1) intersect existing impoundments, roads, and farms; (2) do not drain over 20% agricultural areas; or (3) are located on third order or higher National Hydrography Dataset medium resolution blue line streams.

Model Parametrization and ACPF Outputs: Field and Riparian Zone Characterization. Beyond siting of conservation practices, the ACPF toolkit gathers information for two discrete landscape units, fields and riparian zones, by calculating or associating characteristics (attributes) with these features. Both fields and riparian zones are represented by polygon features and can be used to quantify and rank conservation concerns or identify critical source areas. The riparian analysis includes polygons buffered on both sides at 90 m of the stream centerline. A nominal length of 250 m was used to divide streams into discrete segments and is the intermediate and default value in ACPF. Riparian and field runoff analyses provide additional information for conservation planners when they are developing a watershed plan.

Fields less than 2 ha are not included because ACPF does not site in-field conservation practices for fields that size. However, many fields in the Southern Piedmont are 2 ha or less. Given this, adjacent areas appearing to be the same land use were deliberately merged together if the sum of their areas would exceed the 2 ha threshold. Notably, merging was not conducted across features like roads and hedgerows visible in aerial imagery. Even with these measures, 11 (18%) row crop fields in Terrell's Creek and 4 (25%) row crop fields in Dry Creek were excluded due to the 2 ha threshold. Approximately 20% of pasture or mowed fields were excluded by the 2 ha threshold.

Comparing ACPF Output to Local Expert Knowledge – Double Blind Analysis. A double-blind analysis was performed to test and compare conservation practices identified by using ACPF and traditional conservation planning to identify practices in the study watersheds. Two regional conservation planners (e.g., local experts), with over 20 years of combined experience, were interviewed over two, four-hour sessions. The interviews were conducted by coauthors with minimal knowledge and experience running ACPF. Through the discussion that ensued, we obtained information relative to preferred conservation practices. The ACPF outputs were generated independently by the lead author with demonstrated experience and knowledge of ACPF.

During each interview, the local experts were presented with a large poster-size hardcopy map containing basemap imagery of the watershed and the HUC-12 watershed boundary. Additionally, a laptop was used with Google Maps to provide a more detailed inspection of fields when directed by the local experts. To protect the integrity of the double-blind study, no details were provided between the expert team and the ACPF technician. The experts were asked to identify all appropriate conservation practices in the respective watersheds by following the process they would normally use for conservation planning. Local experts were actively working with the local landowners at the time of the interview, had visited most of the farms, and had an understanding and knowledge about what conservation practices were necessary in each field. Interviewers recorded the location of conservation practices on the map and accompanying conservation concerns as experts identified them. After the meetings, notes were compared, and the results summarized into a standard format for comparison with ACPF.

To compare the identified conservation concerns between ACPF and that from the local experts, conservation practices were grouped and analyzed by agricultural land use: pasture and row crop. Additionally, poultry-based conservation practices were identified by local experts and were either related to nutrient management or air quality; they are included in the results for reporting but not discussed because ACPF is not intended for assessing conservation practices associated with poultry production (e.g., litter poultry sheds, housing, etc.). Additionally, many conservation concerns identified by the local experts were related to nutrient management and soil health. Those concerns are excluded in the direct comparison because soil health is the foundation to watershed conservation in the "ACPF conservation pyramid" (Tomer et al. 2013). The concerns related to soil health identified by the local experts include conservation tillage, nutrient and/or manure management, animal management, and diversification and intensity of the crop rotation.

The discussion thus includes a comparison between the "structural" practices intended to control the flow of water, as well as trap and treat nutrients in fields, at field edges, and in riparian zones. The structural practices identified by the local experts were matched to the corresponding ACPF output and compared by location and watershed. It should be noted that WASCOBs were not identified by the local experts because they are not used in these watersheds; there have been no recorded WASCOB contracts in North Carolina from 2005 to 2019 (USDA 2021). However, there are a large number of farm ponds used as an alternative water source for cattle and/or to irrigate tobacco (*Nicotiana tabacum* L.) that previously was grown in both watersheds.

Results and Discussion

Southern Piedmont Landscape and Conservation Concerns. Originally hardwood forest, settlers cleared the Southern Piedmont to produce corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and tobacco, which led to topsoil (13 to 25 cm) being eroded (Schomberg et al. 2020). Conservation starting in the 1930s led to land use changes so that the current landscapes consist of forest and pastures. Pasture is the dominant agricultural land use in both watersheds, comprising over 85% of the agricultural land area (table 1), which reflects the Southern Piedmont NRCS Major Land Resource Area (166,251 km^2 of which forest is 57%, cropland 2%, and pasture/hay is 15%). Conservation tillage of crop lands began in the Southern Piedmont in the 1970s and is the predominant tillage (O'Connell and Osmond 2018; Schomberg et al. 2020). The Southern Piedmont area is distinctly different from the land resource area where ACPF was developed, intended, and tested—the Central Feed Grains Region (Iowa, Illinois, Wisconsin, Indiana, Minnesota, Kansas, Nebraska, Missouri, and Ohio) that includes a total of 737,656 km^2 of land of which 57% is cropland, 14% pasture/hay, and 13% forest (figure 2; USGS 2019). The substantial differences in land use between these regions supports the objective of this work as there are significant differences in land uses, topography, climate, and nutrient loss pathways.

Land uses in Terrell's and Dry Creeks have changed over time from cropland, primarily tobacco, to mostly pasture due to the tobacco buy-out program (Schomberg et al.

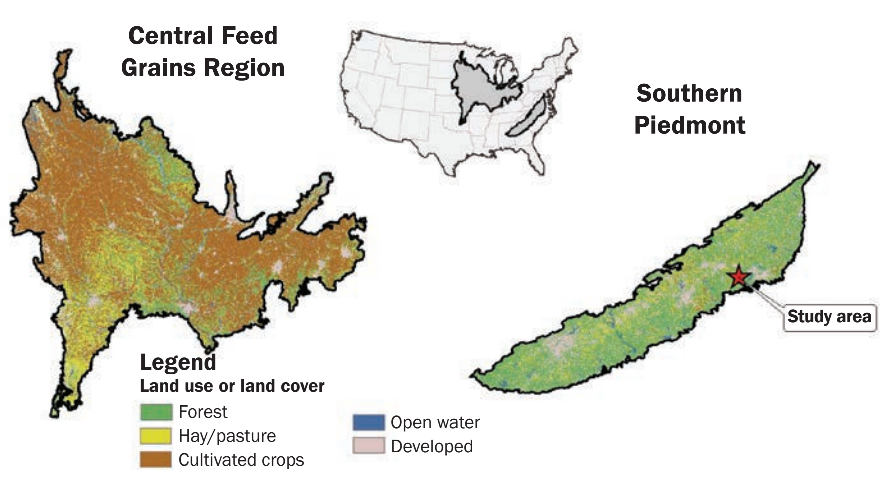
Table 1

Summary of landscape, hydrologic, and agriculture characteristics in the two study watersheds.

Characteristic	Terrell's Creek	Dry Creek
Area (km^2)	75.5	90.5
Row crop agriculture (ha)	297	62
Total fields/average field size (ha)	49/6	12/5
Pasture (ha)	1,440	763
Total fields/average field size (ha)	282/5	135/6
Hydrologic characteristics		
Total stream length (km)	86	168
Drainage density (km km^{-2})	1.14	1.86
Number of impoundments	176	157

Figure 2

Primary land use in the Southern Piedmont land resource region compared to the Central Feed Grains and Livestock Region. Agricultural land use in the two study watersheds is representative of the Southern Piedmont.



2020; USDA FSA 2021), with current conservation focused on pasture management, including exclusion fencing (ponds and streams), as well as stream crossings and filter strips. Exclusion fencing is the most currently accepted structural practice; research has shown nitrogen (N), phosphorus (P), and sediment reductions 20%, 47%, and 60%, respectively, when implemented in these watersheds (Line et al. 2016, 2019).

ACPF Predicted Conservation Practices. The number of conservation practices sited by ACPF was similar between the two watersheds when scaled against the relative difference in agricultural land area. The frequency that ACPF sited grassed waterways and contour buffer strips was also reflective of the amount of row crop agriculture in each watershed (table 2). Opportunities to site grassed waterways are limited to agricultural fields in row crop production (table 2) and thus exclude pasture, which covers 86% of agricultural land in both watersheds. Of the grassed waterways sited, all were located in convergent areas in fields (i.e., concave areas where overland flow concentrates and erosion potential is high). Visual confirmation demonstrated good spatial agreement between existing grassed waterways and those placed by the ACPF (figure S1). Similar to grassed waterways, contour buffer strips are only predicted in fields under row crop production. Although there were no instances of existing contour buffer strips in the watershed, ACPF identified a majority of the row crop fields as suitable for contour buffers. In Terrell's Creek, seven sites identified for contour buffer strips also had mean field slopes greater than 10%, indicating that these areas are also suitable for terraces based on NRCS conservation standards and ACPF documentation (Porter et al. 2018).

Unlike contour buffer strips and grassed waterways, WASCOBs were identified by ACPF for both crop and pasture and with a wide range in the number and placement based on the user-specified bank height. Bank heights between 1.0 to 1.5 m sited the greatest number of WASCOBs with varied placement, while a bank height around 4.5 m was identified as a maximum upper limit for siting WASCOBs in this area. The placement of WASCOBs generally followed the landscape incision within a field. Specifying a 1.0 m bank height would generate WASCOBs at locations within a field with the lowest amount of incision, while specifying 4.5 m bank height identified high incision areas where grade stabilization (NRCS Code 410) is likely suitable. In some scenarios, multiple WASCOBs were identified in the same field. The difference in the number and placement of WASCOBs as determined by a single user-specified bank height illustrates the importance of parameter selection and local knowledge, but also suggests the need for evaluating multiple model runs within a range of values to assess the appropriateness of results and sensitivity of outputs.

There were 84 ponds generated by the farm ponds tool, but a majority (71) did not drain agricultural land. For the 13 ACPF pond opportunities that drained agricultural land, most were in close proximity to an existing pond or impoundments. We interpret this to mean two things. First, in this case ponds are likely of low priority due to the high level of implementation that already exists in this area. Existing impoundments in both watersheds are positioned in the midlands draining to nearly all low-order stream reaches. Second, the identification of ponds by ACPF in similar landscape positions to those that currently exist suggests that ACPF is capable of identifying relevant and meaningful locations for farm ponds draining agricultural lands. However, ACPF does not detect the presence or absence of existing structural practices and thus requires visual confirmation or prior knowledge to assess their need. No NRWs were sited due to the constraints discussed previously.

Comparison of ACPF with Expert Knowledge. Results from the double-blind discussion illustrate important differences between conservation concerns and practices identified by the local experts compared to the outputs generated by ACPF. Local experts listed conservation concerns in a

Table 2
Number of Agricultural Conservation Planning Framework (ACPF) conservation practices sited by watershed.

	Terrell's Creek		Dry Creek	
Conservation practice	Total number	Number draining row crops	Total number	Number draining row crops
Grassed waterways	85	85	15	15
Contour buffer strips	69	69	16	16
1.0 m bank height WASCOBs	40	6	20	0
1.5 m bank height WASCOBs	53	11	19	1
4.5 m bank height WASCOBs	0	0	3	0
Ponds	11	2	73	11
Nutrient removal wetlands	0	0	0	0

Note: WASCOBs = water and sediment control basins.

Table 3
Summary of conservation practices by agricultural type identified by the Agricultural Conservation Planning Framework (ACPF) compared to those identified by expert conservation planners.

	Terrell's Creek		Dry Creek Haw River	
Conservation practices	ACPF	Expert	ACPF	Expert
Pasture related	44	40	28	24
WASCOB	27	—	17	—
Exclusion fencing*	—	26	—	14
Stream crossings	—	1	—	2
Poultry related	NA	12	NA	5
Crop related	39	12	9	3
WASCOB	5	—	0	—
Grass waterway	10	—	5	—
Contour buffer strip (in-field practice)	36	—	10	—
Filter strips	—	1	—	0
Crop specific soil health	NA	9	NA	3
Cover crop	—	9	—	3
No conservation practices needed	248	60	110	27
Crop/pasture	10/238	3/57	3/107	0/27
Total fields/sites†‡	49 row crop 282 pasture	12 row crop 86 pasture	12 row crop 135 pasture	5 row crop 39 pasture

* Includes fencing around streams and ponds.

† ACPF identified conservation practices summarized by field. Conservation practices identified by local experts are summarized by "site." Sites reflect a single farm operation or a set of adjacent fields.

‡ Hay and pasture combine into pasture for comparison.

broad context spanning the range of land uses across the watershed, but also provided conservation practices by field or fields (table 3). As designed, ACPF identified conservation practices and their placement in the landscape primarily in row crop agriculture. To compare ACPF results with tallies from the expert discussion, instances where multiple ACPF practices of the same type were located in the same field were counted once (e.g., a field with three grassed waterways). Over 80% (81/96) of the conservation practices identified by the experts were outside the ACPF control and trap practices, as they were primarily nutrient management or soil health practices. In fields under row crop agriculture, ACPF identified three times the number of conservation practices as those identified by local experts (48 versus 15). In most instances the crop-related practices suggested by ACPF would result in a significant loss of field acreage. As such, these practices would have little landowner support and very limited adoption. In general, the experts identified conservation practices proportional to the area of farmland identified as either pasture, crop, or poultry related. As such, and with over 85% of the fields identified as pasture in these two representative Southern Piedmont watersheds, the importance of using ACPF as a conservation planning tool in areas with limited row crop agriculture is underscored and highlighted by this comparison.

The main conservation practice identified by the local experts within row crop agriculture was over the use of cover crops. Of the 17 sites discussed, 12 included a recommendation for cover crops; a filter strip and riparian buffer were also recommended for one field. The cover crop recommendations were based on known production practices, familiarity of management within those fields, and the use of practices that avoid sediment and nutrient losses when possible. This is consistent with "avoid practices," such as cover crops, being usually recommended as a baseline before structural practices are identified in ACPF.

The need for filter strips and riparian buffers was identified by local expects based on visual inspection of imagery within Google Maps combined with personal knowledge about conservation practices at that site. In comparison, ACPF placed approximately three times the number of conservation practices than that of the local experts in each watershed respectively. The use of contour buffer strips as an in-field practice was the most identified conservation practice by ACPF and placed in 75% of cropped fields; this is not a common practice in North Carolina partially because conservation tillage has been widely and successfully adopted with concomitant low sediment and nutrient loading (Line et al. 2016, 2019; Schomberg et al. 2020), but also because of the small field size (<5 ha). Between 2005 and 2019, only two contour buffer strips were installed in North Carolina (USDA 2021). Considering practices similar to contour buffer strips during this time period, there were 179 contracts for terraces (NRCS Code 600), 4,212 contracts for contour farming (NRCS Code 330), and 137 contracts for strip cropping

(NRCS Code 585) statewide. Knowing these three practices are used more frequently in the state and take less land area out of production, there may be an opportunity to assess the suitability for these three practices where contour buffer strips were produced by ACPF.

Within each watershed, pasture land had the largest number of conservation practices identified by the local experts. Almost exclusively, exclusion fencing around streams and ponds was the conservation practice most discussed. On a few occasions, however, a stream crossing was recommended. The judgment about conservation practices at a site was primarily based on personal knowledge about the landowner and history of conservation at that location. In comparison, the practices identified by ACPF were similar in number but different in practice than those identified by the local experts. ACPF identified locations of concentrated flow and depressions in the underlying digital elevation model (DEM) outputs that may be useful in locating areas for exclusion fencing, and could possibly improve the effectiveness of the fencing investment; however, because ACPF is not intended for pasture, it does not include exclusion fencing as a conservation practice (Porter et al. 2018).

The ACPF was able to site impoundments, rate runoff risk, and determine buffer needs on pasture land using the same toolbox operations designed for crop land. These outputs were pertinent directly or as a proxy to help prioritize and identify the need for riparian buffers and filter strips in and surrounding pastures. By extension, any identified riparian buffer or filter strip in a pasture will, by necessity, need exclusion fencing.

Overall, the local experts relied heavily on knowledge acquired over 20 years working in, and living next to, these watersheds. Information and understanding gained from working directly with landowners and state conservation programs helped inform their approach to resource conservation planning and to the specific practices identified within this discussion. Their knowledge about the transition from tobacco to pasture in this landscape and changes of priorities and conservation practices over time made their recommendations adapted to local needs and applicability. Although not explicitly mentioned, knowledge about state conservation programs and local incentives influenced the conservation practices identified by the experts. For instance, local working groups, such as the Jordan Lake Watershed Oversight Committee in North Carolina, have identified conservation practices of higher importance to be prioritized in the area (e.g., exclusion fencing). There was no mention about the use of WASCOBs in these watersheds by the local experts, highlighting the importance of understanding local priorities and history of conservation in a watershed.

Utilizing ACPF in the Southern Piedmont. Implementing ACPF in the Southern Piedmont requires some efforts that are different than, and extended beyond that typically required in a Midwest landscape. In particular, the development of field boundaries and the hydro-enforcement of the elevation models required region-specific attention. In the Southern Piedmont, agricultural fields are comparatively smaller, irregularly shaped, and more sparsely distributed. As a result, additional time is required when using larger map scales to locate field boundaries precisely and accurately. Additional steps were also required to correct erroneous agricultural land cover classifications (row crop, pasture, or other) resulting from the "update edited field boundaries" utility script in ACPF. This script uses the USDA Crop Land data layer to assign a land use class. Because of the data's relatively coarse raster resolution (30 m), this tool is increasingly prone to error when fields are smaller and highly irregular in shape. In these watersheds, a current higher resolution (<1 m) orthorectified aerial image was required to visually identify the location of field boundaries and to verify or correct the corresponding land use. However, in areas without current basemap imagery, the ability to resolve and identify existing landscape characteristics may be limited.

A comparatively different workflow was also required to produce a hydrologically representative DEM. Stream paths in the Southern Piedmont are highly dissected by man-made structures such as culverts, storm drains, and small ponds. Due to the relatively large amount of forested land in the region, visually locating these structures in aerial imagery is difficult and can require in-person, on-ground verification. Additionally, ponds were distributed across the study area at a density of nearly 2 km^{-2}, each requiring manual enforcement. Given their small size, ponds did not interrupt flow paths as severely as road crossings. In total, the modifications required for small ponds outnumbered the corrections made for culverts at road crossings. Consequently, the time required to properly classify land use, digitize agricultural fields, and hydro-enforce stream networks in the study landscape can be higher than in the Midwest where the Daily Erosion Project has aided in the development of these datasets. Overall, the effort required to preprocess data and set up ACPF for use in the study watersheds was approximately two to three times the number of person-hours required in other landscapes with larger fields, fewer impoundments, and sparser road networks.

Further, it is also important to consider the sources and magnitude of nutrient losses in the Southern Piedmont compared to the Midwest where ACPF was developed as soils, cropping system, climate, and many other factors affect runoff, leaching, and erosion, and the appropriate conservation practices. Total N losses in the North Carolina watersheds near to the HUC-12 watersheds used in this study were approximately three times lower (8 kg ha^{-1} y^{-1}) than Midwestern watersheds (Cedar River in Iowa-Minnesota or Lake Erie watershed in Ohio), which lost approximately 25 kg ha^{-1} y^{-1} (Hanrahan et al. 2021; Kalkhoff 2018). Compared to the Iowa and Ohio watersheds, annual P losses in the nearby North Carolina watersheds were three times greater in the pasture watershed (3.3 versus ~1 kg ha^{-1}) but three times lower in the crop fields (0.32 versus ~1 kg ha^{-1}). To maximize the utility of ACPF in the Southern Piedmont, the conservation practice(s) selected for output should account for the water quality benefits, appropriateness, and intended use of that practice. Particular to the Southern Piedmont, it is likely users of ACPF will benefit more from the riparian characterization aspects of the ACPF toolbox than from the tools intended for Midwestern row crop agriculture.

Although not intended for use in a pasture-dominant landscape, ACPF was able to provide data outputs, analysis, and map-based information relevant to watershed planners in the Southern Piedmont. A strong understanding of ACPF data and functionality is required to produce value for planners focused on conservation in forage production and grazing operations. In the case of the Southern Piedmont, where these operations are common, novel adaptations to the way ACPF is used may be beneficial, for example, using outputs from ACPF to identify and predict closely related conservation practices (e.g., proxies). Proxies may be used to predict and/or site conservation practices outside of the intended scope of ACPF. Specific to this study, ACPF proxies were identified and matched to practices identified by the local experts and with known value and use in local conservation efforts. The conservation practices identified by the local experts that map to ACPF proxies are illustrated in table 4.

The feasibility of using ACPF conservation proxies in the Southern Piedmont will vary based on local conservation priorities and the ability of the ACPF analyst to identify and create such proxies. This is done by either identifying local conservation practices with similar function or by extracting and interpreting ACPF outputs for a use that is different than intended. An example in this study is using ACPF outputs to locate areas in need of exclusion fencing. ACPF does not directly site exclusion fencing; however exclusion fencing is expected where streams intersect fields classified as pasture. When used in this manner, ACPF lends itself as a scouting tool, helping guide local experts to locations with likely conservation concerns. Additionally, the use of ACPF proxies may bring focus to overlooked areas where a more locally accepted practice may be considered. When paired with on-site visits and an understanding of the appropriateness of the conservation proxy to the actual conservation practice, a proxy may offer planners additional value outside its intended scope. Although a greater understanding of ACPF is required to identify and use conservation proxies in watershed planning, their value should be considered against the additional time, effort, and knowledge required to generate and assess these outputs.

Proxy conservation practices can also be considered by local watershed planners when ACPF sites practices that are not regionally recommended or without local preference, but there is need at that location for a practice with similar function. Examples include grassed waterways and contour buffer strips. ACPF predicts the use of contour buffer strips at locations in need for reduced runoff; however local practices with similar function, including strip cropping, diversions, or contour farming, may be viable alternatives. This approach broadens the applicability of ACPF and provides flexibility to help meet the needs and resources available in a watershed or region. A conservation planner could exercise their best judgment while leveraging the spatially precise identification of conservation concerns from ACPF.

The data developed for ACPF and the landscape characterization contain rich spatial and attribute data that could be of interest to planners in the Southern Piedmont. Datasets developed include hydrologically corrected elevation, high resolution streams networks, field boundaries, and a by-field crop history. Attribute information that accompanies these datasets may add value to traditional conservation planning by facilitating watershed-scale spatial analysis, queries, and visualizations. At minimum, access to these datasets in a GIS environment grants planners more capabilities than visually inspecting aerial imagery alone. Additionally, stream and field boundary datasets offer improvements on most nationally available streamline and land use data. For instance, streamlines identified by ACPF can provide a more accurate depiction of jurisdictional streams as well as pertinent descriptors about the stream and the surrounding environment. In addition to being topographically enforced, the ACPF stream layer provided attributes for stream drop, upslope drainage area, bank height, and height of low-lying land. Both improved spatial precision and the ability to compare across a common set of attributes may help extend the use of streams and land use datasets produced by ACPF in planning scenarios in the Southern Piedmont.

As previously mentioned, utilizing this tool is an intensive process even though technical support is available in the form of data development tools, training resources, and quality control guidelines. Conservation practice identification by ACPF overlapped in some instances with feedback from discussion respondents, but there are many capabilities of the tool that were not appropriate for this landscape, such as the entire suite of tools that identify opportunities for tile drainage treatment. Although buffer design recommendations were produced as well, the streams in our study watersheds were forested on both banks in most locations (Osmond and Neas 2007). Notably, the tool does not recognize existing buffers, and thus, the results of riparian analysis do not account for the existing buffer coverage in the watershed. Such limitations are more significant in the Southern Piedmont where most stream reaches consist of forested riparian buffers.

Summary and Conclusions

This work provides a comparison between expertly identified conservation oppor-

Table 4

List of conservation practices identified by local experts compared to Agricultural Conservation Planning Framework (ACPF) outputs. (The ACPF conservation pyramid [Tomer et al. 2013] assumes practices are already in place to build soil health and not included in the table.)

Local expert	ACPF output	ACPF proxy
Exclusion fencing (pond)*	No ACPF equivalent	Pond is in close proximity to pastured fields. Polygons for ponds can be added to the ACPF water bodies dataset after being extracted from US Geological Survey hydrography datasets and/or identified during DEM fill analysis and referencing imagery.
Exclusion fencing (stream)*	No ACPF equivalent	Individual stream reaches visually assessed for fencing along flow routes using aerial imagery or riparian buffer toolkit used to estimate a setback.
Stream crossings*	No ACPF equivalent	Intersection between ACPF's perennial stream layer and field boundaries.
Filter strips	No ACPF equivalent	Riparian area: apply setback for fields draining to adjacent stream. Filter strips: extract a fixed distance (e.g., 3 m horizontal distance) from downslope edge of fields in the top 20% of slope and stream proximity.

* Pasture-related best management practice. No direct ACPF equivalent and outside scope of intended model use.

tunities and those produced by a recently developed planning tool, the ACPF toolbox. Although ACPF has been run in the Southern Coastal Plain, to our knowledge, this is the first time the ACPF has been used in the Southern Piedmont. Despite only 15% agricultural land cover, the effort required to digitize field boundaries for use in ACPF remains substantial due to a small average field size (5 ha) and irregularly shaped fields (Osmond and Neas 2007) in the region. When combined with the hydro-enforcement of DEMs and the training, skillsets, and time required to run ACPF, local conservation planners should consider the potential for better, more impactful conservation planning before adoption.

Direct comparison of ACPF-identified conservation practices to those of local experts re-emphasized the importance of including both regional and local knowledge in watershed planning with ACPF (Ranjan et al. 2019). The use of ACPF in pasture-dominated landscapes without significant modification poses risks related to the prioritization of resources and misintended use of its output. Locally, knowledge about the historic use, support, and acceptance for specific conservation practices should be utilized when reviewing ACPF-derived conservation practice planning output.

Compared to the Midwest where ACPF has been used extensively in row crop agriculture, there is a largely different need for application in the Southern Piedmont. Currently, and without modification or additional processing, many of the conservation practices are misaligned with this landscape, and thus the benefits are restricted to a subset of practices used in the Southern Piedmont. However, when interpreting ACPF outputs as performing a general conservation function, and matching that need to locally recognized and supported conservation practices, the tool provides options in regions and landscapes outside its intended scope through proxy practices. These "proxy" measures can leverage existing spatial data and output from ACPF, while allowing planners to consider additional or regionally preferred and appropriate conservation practices. Future work should include recommendations for additional conservation practices and proxies not included in ACPF. As the ACPF software continues to develop and evolve, analyses from the Southern Piedmont can provide information and insight on regionally implemented conservation practices and potential methods for characterizing and extending its functionality as it is used and adapted to new regions throughout the United States.

Supplemental Material

The supplementary material for this article is available in the online journal at https://doi.org/10.2489/jswc.2022.00138.

Acknowledgements

The authors are very grateful to USDA Natural Resources Conservation Service (NRC20IRA0010309) for project funding and collaboration from Lisa Duriancik (USDA NRCS).

References

ESRI (Environmental Systems Research Institute). 2019. ArcGIS Desktop: Release 10.7. Redlands, CA: Environmental Systems Research Institute.

Gale, J.A., D.E. Line, D.L. Osmond, S.W. Coffey, J. Spooner, J.A. Arnold, T.J. Hoban, and R.C. Wimberley. 1993. Evaluation of the Experimental Rural Clean Water Program: Abbreviated Version. Raleigh, NC: National Water Quality Evaluation Project, North Carolina State University Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University.

Hanrahan, B.R., K.W. King, E.W. Duncan, and V.S. Shedekar. 2021. Cover crops differentially influenced nitrogen and phosphorus loss in tile drainage and surface runoff from agricultural fields in Ohio, USA. Journal of Environmental Management 293:112910.

Kalkhoff, S.J. 2018. Transport of Nitrogen and Phosphorus in the Cedar River Basin, Iowa and Minnesota, 2000–15. Scientific Investigations Report 2018-5090, Prepared in cooperation with the City of Cedar Rapids, Iowa. Reston, VA: US Geological Survey. https://doi.org/10.3133/sir20185090.

Lewandowski, A.M., M.D. Tomer, J.I. Buchanan, A. Kiel, L. Olson, R.L. Power, and J.J. Sloan. 2020. Agricultural Conservation Planning Framework: Watershed applications, research, opportunities, and training resources. Journal of Soil and Water Conservation 75(4):427-433. https://doi.org/10.2489/jswc.2020.00073.

Line, D.E., D.L. Osmond, and W. Childres. 2016. Effectiveness of livestock exclusion in a pasture of central North Carolina. Journal of Environmental Quality 45:1926-1932. https://doi.org/10.2134/jeq2016.03.0089.

Line, D.E., D.L. Osmond, and W. Childres. 2019. Nutrient export from agricultural watersheds in the Piedmont and Coastal Plain. Transactions of the ASABE 62(5):1135-1145. doi.org/10.13031/trans.13052.

NC DEQ (North Carolina Department of Environmental Quality). 2021. Jordan Lake Nutrient Strategy. Raleigh, NC: NC DEQ. https://deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/jordan-lake-nutrient-strategy.

O'Connell, C., and D.L. Osmond. 2018. Carolina Dreamin': A case for understanding farmers' decision-making and hybrid agri-environmental governance initiatives in agricultural communities as complex assemblages. *In* Agri-environmental Governance as an Assemblage: Multiplicity, Power, and Transformation, eds. J. Forney, H. Campbell, and C. Rosin. London: Rutledge Press.

Osmond, D., D. Meals, D. Hoag, and M. Arabi. 2012a. How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture–Conservation Effects Assessment Project Experience. Ankeny, IA: Soil and Water Conservation Society.

Osmond, D., D. Meals, D. Hoag, M. Arabi, A. Luloff, M. McFarland, G. Jennings, A. Sharpley, J. Spooner, and D. Line. 2012b. Improving conservation practices programming to protect water quality in agricultural watersheds: Lessons learned from the National Institute of Food and Agriculture Conservation Effects Assessment Project. Journal of Soil and Water Conservation 67(5):122A-127A. https://doi.org/10.2489/jswc.67.5.122A.

Osmond, D.L., and K. Neas. 2007. Delineating Agriculture in the Jordan Lake Watershed. Final Report for the Sampling Analysis: Delineating Agriculture in the Jordan Lake Watershed. Raleigh, NC: North Carolina State University. https://content.ces.ncsu.edu/delineating-agriculture-in-the-lake-jordan-river-basin.

Porter, S.A., M.D. Tomer, D.E. James, J.D. Van Horn, and K.M.B. Boomer. 2018. Agricultural Conservation Planning Framework: ArcGIS®Toolbox User's Manual, Ver. 3. Ames, IA: USDA Agricultural Research Service, National Laboratory for Agriculture and the Environment. http://northcentralwater.org/acpf/.

Ranjan, P., A.S. Singh, M.D. Tomer, A.M. Lewandowski, and L.S. Prokopy. 2019. Lessons learned from using a decision-support tool for precision placement of conservation practices in six agricultural watersheds in the US midwest. Journal of Environmental Management 239:57-65. https://doi.org/10.1016/j.jenvman.2019.03.031.

Ranjan, P., A.S. Singh, M.D. Tomer, A.M. Lewandowski, and L.S. Prokopy. 2020. Farmer engagement using a precision approach to watershed-scale conservation planning: What do we know? Journal of Soil and Water Conservation 75(4):444-452. https://doi.org/10.2489/jswc.2020.00072.

Schomberg, H., G. Hoyt, B. Brock, G. Naderman, and A. Meijer. 2020. Chapter 20: Southern Piedmont case study. *In* Conservation Tillage Systems in the Southeast: Production, Profitability, and Stewardship, eds. J. Bergtold and M. Sailus. SARE Handbook, series 15. Washington, DC: USDA Sustainable Agriculture Research and Education. https://www.sare.org/wp-content/uploads/

Conservation-Tillage-Systems-in-the-Southeast_compressed.pdf.

Tomer, M., and M. Locke. 2011. The challenge of documenting water quality benefits of conservation practices: A review of USDA-ARS's Conservation Effects Assessment Project Watershed Studies. Water Science and Technology 64:300-310. https://doi.org/10.2166/wst.2011.555.

Tomer, M.D., S.A. Porter, K.M.B. Boomer, D.E. James, J.A. Kostel, M.J. Helmers, T.M. Ishehart, and E. McLellan. 2015. Agricultural Conservation Planning Framework: 1. Developing multipractice watershed planning scenarios and assessing nutrient reduction potential. Journal of Environmental Quality 44:754-767. https://doi.org/10.2134/jeq2014.09.0386.

Tomer, M.D., S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. Journal of Soil and Water Conservation 68(5):113A-120A. https://doi.org/10.2489/jswc.68.5.113A.

USDA. 2021. Soil and Water Resources Conservation Act (RCA) Data Viewer for North Carolina from 2005-2019. Washington, DC: USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/Internet/NRCS_RCA/reports/cp_nc.html.

USDA FSA (Farm Service Agency). 2021. Tobacco Transition Payment Program. Washington, DC: USDA Farm Service Agency. https://www.fsa.usda.gov/FSA/webapp?area=home&subject=toba&topic=landing.

USDA NRCS (Natural Resources Conservation Service). 2021. Using the ACT Conservation System on Farmland –Avoid, Controlling Trapping. Washington, DC: USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1470384&ext=pdf.

USGS (US Geological Survey). 2019. National Land Cover Database (NLCD) 2016 Products (ver. 2.0, July 2020). US Geological Survey data release. Reston, VA: US Geological Survey. https://doi.org/10.5066/P96HHBIE.