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Temporal trends in amount and placement of conservation practices in the South Fork of the Iowa River watershed

T.B. Moorman, D.E. James, J. Van Horn, S.A. Porter, and M.D. Tomer

Abstract: Conservation practices (CP) for erosion prevention include contour buffers, terraces, grassed waterways, water and sediment control basins, and ponds. Quantifying the amount and placement of CP in watersheds is one step in assessment of their potential effectiveness at the watershed scale. We used geographic information system (GIS) mapping techniques and aerial photography to document installation and removal of these CP from the 1930s to 2016. The study was performed in the South Fork of the Iowa River in central Iowa as part of the Conservation Effects Assessment Program (CEAP). Installation of CP increased in each decade from the 1930s to 2002 and then increased only slightly from 2,169 CP in 2002 to 2,282 in 2016. Grassed waterways were the most numerous and treated the largest area within the watershed. In the 1980s through 2010, some grassed waterways were removed as water and sediment control basins (WASCOBs) were installed. The mean duration of 1,696 grassed waterways installed before 2007 was 31.6 ± 18.6 years, and the duration of WASCOBs averaged 24 years, suggesting that farmers are making long-term commitments to these CP. Land areas treated with CP tended to be greater in the HUC12 subwatersheds where estimated erosion was greater. Land areas treated by existing grassed waterways (21,609 ha) tended to match areas identified for that CP by the Agricultural Conservation Planning Framework (ACPF) tool: 20,866 ha of existing grassed waterways overlapped with the area predicted by the ACPF. However, the ACPF identified an additional 20,866 ha where grassed waterways could be installed, primarily in the western part of the watershed. Mapping of CP and the land areas treated illustrates some of the potential utility of these techniques at the watershed scale. The application of these techniques, which integrate CP amounts and placement in relation to potential placement of CP, provide a different perspective on conservation planning that may interest soil conservationists.

Key words: conservation planning—erosion—grassed waterways—watersheds—terraces

Conservation practices (CP) for agricultural lands were developed to prevent erosion and the concomitant loss of crop production on eroded lands (Pimentel et al. 1995). Initial efforts on soil conservation began in the 1930s and 1940s (Bennett 1939). Although reduction of soil loss was the initial objective of conservation programs, additional CP have been developed to reduce losses of pesticides and nutrients. Conservation programs have been promoted by both state and federal governments through several programs that offer technical assistance and financial support. The history of conservation programs and their economic costs have been evaluated previously in a number of ways (Cain and Lovejoy 2004; McGranahan et al. 2015; Reimer 2015).

Conservation practices developed for use on farm fields for erosion control include no-till and other conservation tillage methods, terraces, water and sediment control structures (WASCOB), grassed waterways, contour farming, and cover crops (USDA NRCS 2012). Conservation practices delivered through USDA Natural Resources Conservation Service (NRCS) programs are designed and implemented at the field scale. Despite the application of CP at the field scale, there has long been interest on the effect of CP on water quality in agricultural watersheds, where agricultural amendments (i.e., manure, fertilizers, and chemicals applied to control weeds, insects, and disease) and eroded sediments can have adverse impacts on water quality. The Conservation Effects Assessment Program (CEAP) used various methods to assess the relationship of CP use on water quality including monitoring of selected watersheds for water quality changes (Duriancik et al. 2008).

Changes in CP have been reported previously, but these changes in CP coincide with other changes in rural landscapes. Brown and Schulte (2011) analyzed aerial photographs starting in the late 1930s through 2002 to show that the corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.) crop rotation increased in three Iowa townships while hay, small grains, and grass cover decreased. Simultaneously, average field size increased, and the number of farmstead buildings declined. In a later study using the same townships, the proportion of land with CP showed only a small increase in CP over the 1940 to 2000 period (McGranahan et al. 2015), but the degree of CP implementation was greater in the two townships with land more prone to erosion. Similarly, but in a larger context of Iowa's Raccoon River basin, which provides drinking water for the capital city of Des Moines, the effects of seasonal precipitation on increasing nitrate (NO_3^-) concentrations in the river were exacerbated by decreased diversity in crop rotations, as small grains and forage crops were displaced by corn and soybean rotations (Hatfield et al. 2009).

Watersheds provide the opportunity for the integrated evaluation of water quality for areas that contain multiple farming operations. At the regional scale, the CEAP project used the Natural Resource Inventory and simulation modeling to assess CP effects in the Upper Mississippi River Basin. They concluded that edge-of-field losses of sediment were reduced by existing CP by 61% compared to simulations of sediment loss without CP (USDA NRCS 2012). Jones and Schilling (2011) show declining sediment concentrations in the Raccoon River above

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Des Moines, Iowa, that occurred after 1985 when US Farm Bill Conservation Title provisions requiring CP for highly erodible land took effect. Later, for the same watershed, Villarini et al. (2016) related the variability in Raccoon River sediment concentration to USDA expenditures on technical and financial assistance for CP. Gassman et al. (2010) examined changes in stream water quality using a paired watershed approach, where the watershed receiving more CP showed declines in sediment transport (1991 to 2001), but increased NO_3^- concentrations. A similar paired watershed approach was employed in the upper, tile-drained part of the Mackinaw River in central Illinois. After seven years of installation of CP (primarily strip-tillage, grassed waterways, and stream buffers) in one watershed and water quality monitoring, no improvement in NO_3^- or stream sediment transport was observed (Lemke et al. 2011). However, the contribution of stream bank and bed sediment to stream sediment load in addition to sediment leaving fields in overland runoff complicates assessment of CP (Tomer and Locke 2011).

Knowing that CP implementation leads to varying watershed responses in terms of erosion control and sediment reductions in watersheds, we examined the historical pattern of CP presence in a CEAP experimental watershed, the South Fork of the Iowa River. Our objectives were to establish a historical record of erosion control CP in this watershed and to compare the location of these practices to locations where potential CP placement could be implemented as determined by the Agricultural Conservation Planning Framework (ACPF) developed by Tomer et al. (2015). The effectiveness of CP have mostly been evaluated in terms of the fraction of contaminant removal for each CP, regardless of the number in the watershed or their placement. Here we examine effectiveness at the watershed scale in terms of the amount and placement of CP in relation to potential erosion and potential placement of CP estimated by the ACPF. The approach used is explorative and aimed to develop a method for documenting the history of conservation in a watershed, which could provide an important context for development and evaluation of modern watershed improvement plans.

Materials and Methods

The South Fork of the Iowa River (SFIR) was chosen for this analysis. This watershed covers about 79,700 ha in Hamilton and Hardin counties. The land use is primarily agriculture (85%), mostly corn and soybeans (figure 1). Previous studies have characterized the water quality and CP (Tomer et al. 2008a,

Figure 1

The South Fork of the Iowa River and the HUC12 subwatershed boundaries and land use. Identification codes for the subwatersheds are the last three digits of the full HUC12 code: all these codes would be preceded by 070802070 to obtain the full code.

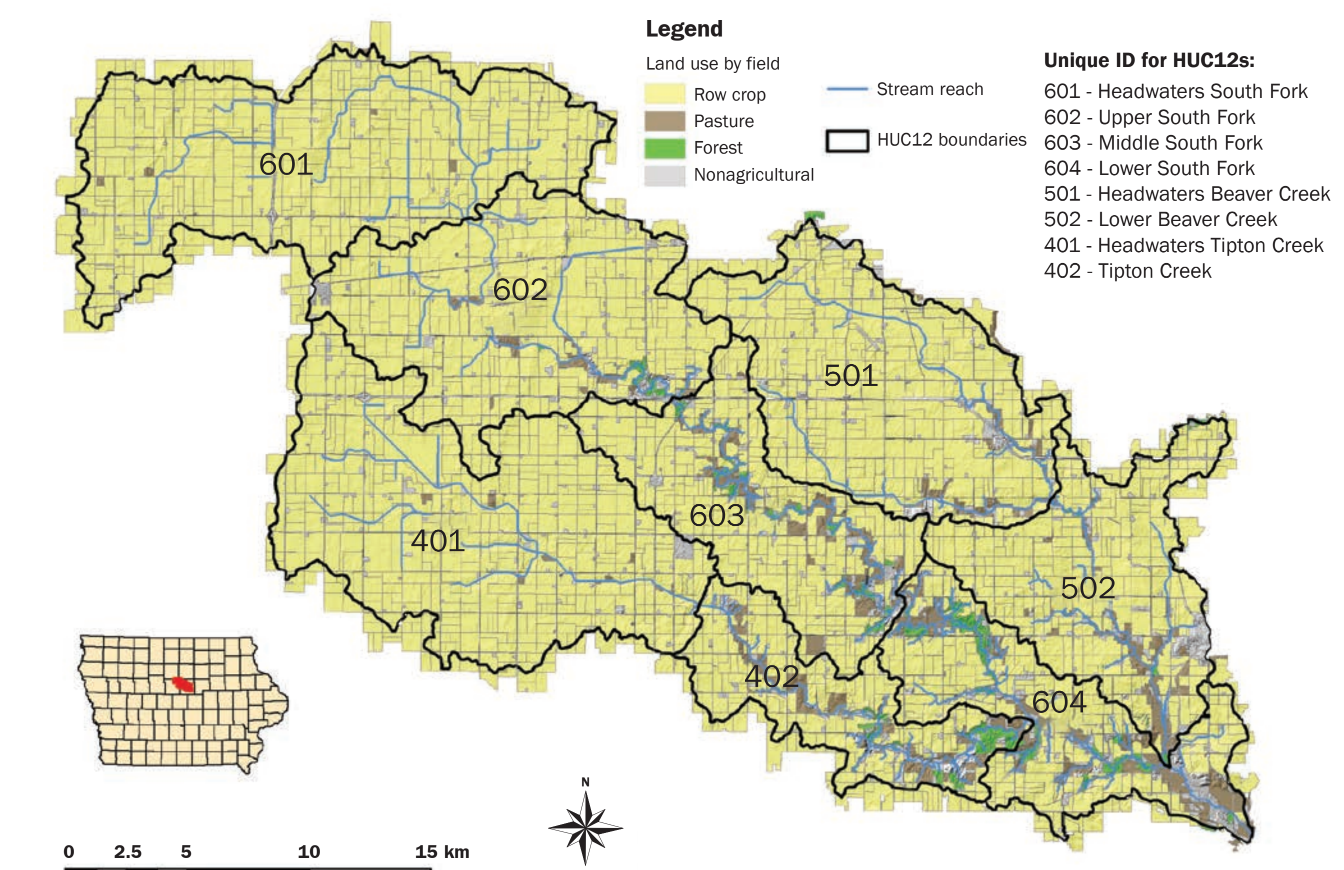
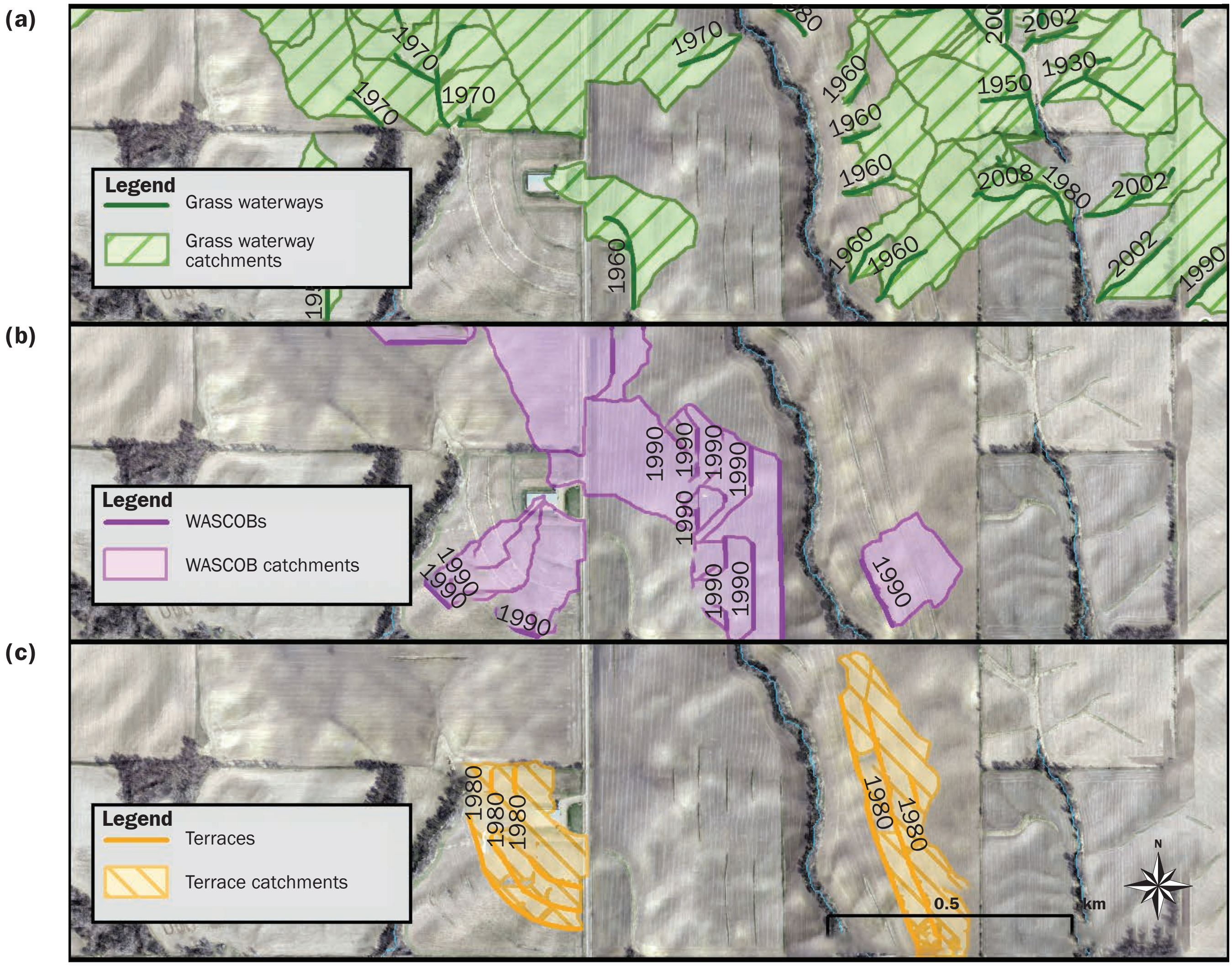


Figure 2

Selected fields showing mapped water and sediment control basins (WASCOBs), grassed waterways, and terraces. These conservation practices (CP) are shown as colored lines, and the area that they treat (catchment/watershed) are the shaded areas. Note the presence of CP can be seen in each of the panels: for instance, (a and c) unmapped WASCOBS compared to (b) mapped WASCOBs.



2008b). The western and central portions of the watershed are nearly flat, and subsurface drainage (tile drains) is the predominant flow path. The eastern portion of the watershed has more sloping lands adjacent to the SFIR and its principal tributaries, Beaver Creek and Tipton Creek. To further quantify the variability in soil erosion in the SFIR, we used estimates of hillslope erosion provided by the Daily Erosion Project (DEP) (Gelder et al. 2018). The DEP uses radar-derived precipitation, Light Detection and Ranging (LIDAR)-derived topography, soil properties and land management information derived from USDA databases, or remote sensing as inputs to drive Water Erosion Prediction Project model (WEPP; Flanagan et al. 2007) simulations of rill and interrill erosion on a daily basis. Between 75 and 100 hillslope simulations are performed within each hydrologic unit code 12 (HUC12) catchment. The procedures for selecting hillslopes for WEPP simulation that reflect the soils, crops, and management conditions within the HUC12 are described by Gelder et al. (2018) and at https://dailyerosion.org/docs/.

Methods for Mapping Conservation Practices. Past CP were mapped at the Iowa State University's (ISU) Geographic Information System (GIS) Support and Research Facility using aerial imagery and LIDAR-derived elevation products such as hillshade and slope. Hillshade and slope images were derived from the Iowa Department of Natural Resources 1 m LIDAR-derived digital elevation models (DEM). LIDAR flights were made between 2007 and 2010. Only CP that were visually observed in the imagery were mapped: WASCOBs, grassed waterways, and contour buffer strips. In this landscape, few farm ponds were present, and this practice was omitted from our analysis. The CP visually mapped from photographs and also intercepted hydrologic flow paths were judged to be correctly mapped. Conservation practices identified by the ISU GIS Facility were further reviewed at The National Laboratory for Agriculture and the Environment (NLAE). Figure 2 shows the delineation of CP from the GIS analysis of historical photos at the field scale. By design, the placement of WASCOBs and grassed waterways occurs on hillslopes, either perpendicular to the flow path (WASCOBs) to intercept water and sediment or along the flow path (grassed waterways) to protect the soil from concentrated flow and gully erosion. Differences in spatial configuration of the CP mapped resulted in a different digitization method for each; contour buffer strips were identified using a by-field presence/absence, grassed waterways were digitized as a polygon for the main channel and separate polygons for each of the branches, and terraces and WASCOBSs were digitized as a single line along the ridge of each respective practice (McNeely et al. 2017). These digitized features resulted in counts of CP within the watershed or its HUC12 subwatersheds. Figure 2 also shows the delineation of the land area contributing water flow into the CP, which we term as the area treated by an individual CP. These treated areas were also summed for individual CP in the HUC12 subwatersheds.

Conservation practices were originally mapped as part of the Iowa Water Quality Initiative (IWQI) project using historic imagery from the USDA (1930s, 1950s, 1960s, and 1970s), National High Altitude Photography (NHAP) (1980s), US Geological Survey (USGS) (1990s), and National Agricultural Imagery Program (NAIP) aerial photography from 2000 to 2010 (McNeely et al. 2017). The mapping of these CP from photographs was further assessed using additional aerial imagery from 2002 through 2016, but are reported in decadal increments, except for the 2010 to 2016 period.

Mapping Potential Sites for Conservation Practices. We used the ACPF to assess where potential CP could be placed in the watershed for comparison against the actual CP placement. The ACPF utilizes the same DEM and hydrologic flow path routing described previously in combination with previously described algorithms to indicate where CP could be placed on the watershed (Tomer et al. 2015; Porter et al. 2018). Briefly, the ACPF sites grassed waterways using a stream power index (SPI) threshold, with SPI being the log of the upgradient contributing area times slope. The (default) minimum threshold used is based on the watershed distribution of SPI values. Contour buffers and terraces are sited along topographic contours that have at least 100 m length with average slopes exceeding 4% for contour buffer strips and 10% for terraces. WASCOBs are tested as 100 m length, 1 m high impoundments placed perpendicular to flow paths receiving runoff from 0.8 to 20 ha of agricultural land. The test applied is to ensure adequate plan curvature such that the ends of the embankment are above, yet within 1 m below, the surface elevation at the embankment end points. Spacing between adjacent contour buffers, terraces, and WASCOBs are linked to NRCS practice standards, as described by Porter et al. (2018). For our purposes, the areas potentially treated, as indicated by the ACPF results, represent a maximum potential placement of CP and are compared to the actual adoption of CP. To evaluate spatial variation within the SFIR these comparisons are reported separately for the eight HUC12 subwatersheds. Clearly, different types of CP may overlap in terms of viable placement options and alternatives to resource improvement (in this case, erosion control), and therefore, results can be used to interpret shifts in CP preferences among producers in the watershed.

Comparison of Current versus Potential Conservation Practice Placement and Conservation Practice Duration. The impacts of CP placement within SFIR were further investigated by counting individual CP and by using GIS and the DEM to estimate the area treated by individual CP (figure 2). Individual existing CP were represented by line features, and each of these features carried attributes detailing the year the practice was first observed and if it was removed and/or reinstalled. Using these attributes, the duration of each practice was calculated, and for each available year of data, total counts were summed for each CP. In the period from 1930 to 2000 the year of removal cannot be exactly known because the images were not obtained each year, but removals during this period are fairly rare. Individual catchments or the contributing areas above existing practices and CP sited by the ACPF were delineated using the watershed tool within ArcGIS (ESRI 2017). By practice (e.g., grass waterway, WASCOB, contour buffer strips, and terraces), the existing CP and ACPF CP catchments were overlaid on each other. The overlaid catchments defined the following three types of treated areas: (1) those treated by CP currently in place, (2) those where conservation is suggested by the ACPF but not present, and (3) those where conservation is suggested and is currently in place.

It should be noted, if a CP is present in the DEM (i.e., WASCOBs), the terrain derivatives, such as flow accumulation, used to site CP by the ACPF will reflect their presence. This may cause the ACPF to not site CP in that location if criteria are not met; however, this does not imply that the area is not suitable for the type of CP.

Results and Discussion

Conservation practices were mapped in SFIR, and we quantified those CP in two ways: counts of CP, and the land area treated by those CP. We aggregate counted or area-treated data into sums at the HUC12 or the whole watershed scales. The presence of CP for erosion prevention in the SFIR initiates with installation of grassed waterways in the 1930s and 1940s (figures 3 and 4). Counts of these CP increase until the early 2000s when numbers of CP become more or less stable, increasing slightly from 2,169 CP in 2002 to 2,282 in 2016 (figure 3). Grassed waterways are the most predominant erosion prevention CP in SFIR, accounting for 58.9% of the total CP count and 87.3% of the total area treated by all CP. WASCOBs adoption began in 1970 and increased to account for 32.6% of the watershed CP practice counts in 2016. Terraces and contour buffers account for only 8.5% of the CP count in the watershed, but this likely reflects the difference in criteria for use of these CP and farmer preferences. The increase in the number of WASCOBs resulted in some grassed waterways being removed in the period from 1980 to 1990 (figure 4). Since 2004 only 20 new WASCOBs were installed compared to the total of 729 WASCOBs present in 2016. In this same time period, installation of new grassed waterways barely exceeds removal of grassed waterways. The mean (± standard deviation) duration of 1,696 grassed waterways installed before 2007 was 31.6 ± 18.6 years. Including grassed waterways installed after 2006 results in a downward bias of mean duration time as these waterways can only have a duration of 10 years or less. Alternatively, using only grassed waterways that have a removal date before 2016 results in 21.5 years mean duration. The mean duration of WASCOBs was 24 years. Of the 747 WASCOBs installed in SFIR, only 18 have been removed.

The comparison of mapped CP to CP sited by the ACPF provides another view of the potential effectiveness (placement and amount) of the CP on the landscape. For this comparison we used the area treated by the CP, as shown in figure 2. The analysis divides the landscape into four categories: (1) land without ACPF-sited CP or existing CP; (2) land without ACPF-sited CP, but with existing CP; (3) land with ACPF-sited CP, but without existing CP; and (4) land with ACPF-sited CP overlapping with existing CP. At the watershed scale these are represented in figure 5. For contour buffer strips and terraces, there is divergence in the placement of these existing CP (1,049 ha) compared to placement predicted by the ACPF; only 126 ha are treated by these CP in locations predicted by the ACPF. In contrast to the terraces and contour buffer strips, placement of existing grassed waterways more closely matches the ACPF-sited placements. Only 723 ha treated by grassed waterways were not sited by the ACPF while 20,867 ha are treated by existing grassed waterways that agree with the ACPF siting. The use of land area treated by CP offers a different metric to that obtained by counts of CP. For instance, in figure 3 the count of WASCOBs is approximately 30% of the CP in SFIR while the total land area treated by WASCOBs is only 1.9% (figure 5).

The distribution of grassed waterways and the other CP in figure 5 show that the distribution of CP is not uniform within SFIR. Grassed waterways and other CP are widely distributed in the eastern part of the watershed compared to the western part of the watershed. The purpose of the ACPF and other schemes for targeted placement of conservation programs is to match practices to the lands most vulnerable to erosion, nutrient losses, or other risks for soil degradation. The CP that we examine in this report are all intended to prevent soil erosion or sediment transport. To examine the differential risk for soil erosion within SFIR we used the DEP estimates of soil erosion that are provided at the HUC12 level (table 1). Their procedures take into account the effect of structural CP and CP such as reduced tillage. These estimates show that the eastern part of the watershed are more vulnerable to soil erosion than the western part of the SFIR. This would also suggest that the general allocation of existing CP to this part of the watershed reflects the NRCS-farmer assessment of erosion risk.

To further examine the past and current distribution of CP in SFIR we examined the area treated by existing practices within the HUC12 and compared them to areas that

Figure 3
Increase in the presence of grassed waterways, water and sediment control basins (WASCOBs), contour buffer strips (CBS), and terraces in South Fork of the Iowa River for the decades beginning in the years shown. Only one image for each decade (*x*-axis) was processed to obtain the number of conservation practices (CP) within the watershed. For the decades beginning in 2000 and 2010, images were available annually, and those data are accumulated for the 2000 to 2009 and 2010 to 2016 periods.

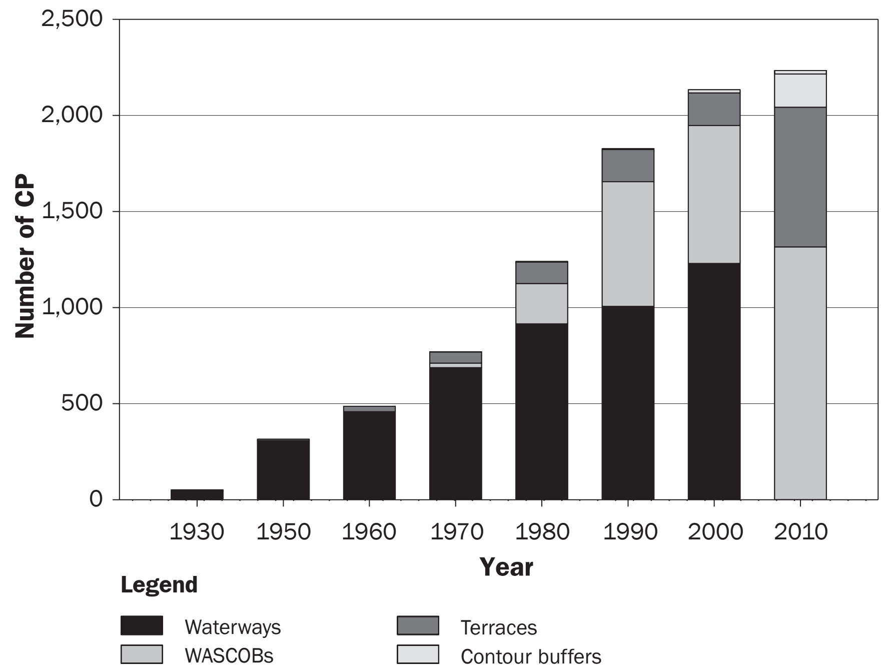


Figure 4
Number of installed and removed grassed waterways (GWW) and water and sediment control basins (WASCOBs) in South Fork of the Iowa River for the decade beginning in the year shown. Installations and removals are evaluated by comparison with previous decade's imagery for 1930 to 1990. For the decades beginning in 2000 and 2010, images were available annually, and those data are accumulated for the 2000 to 2009 and 2010 to 2016 periods.

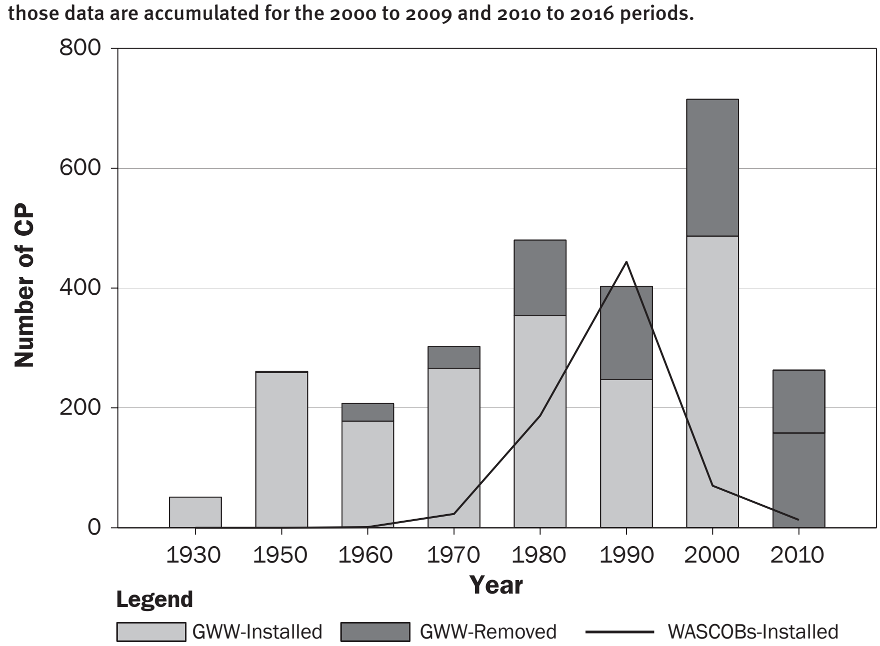
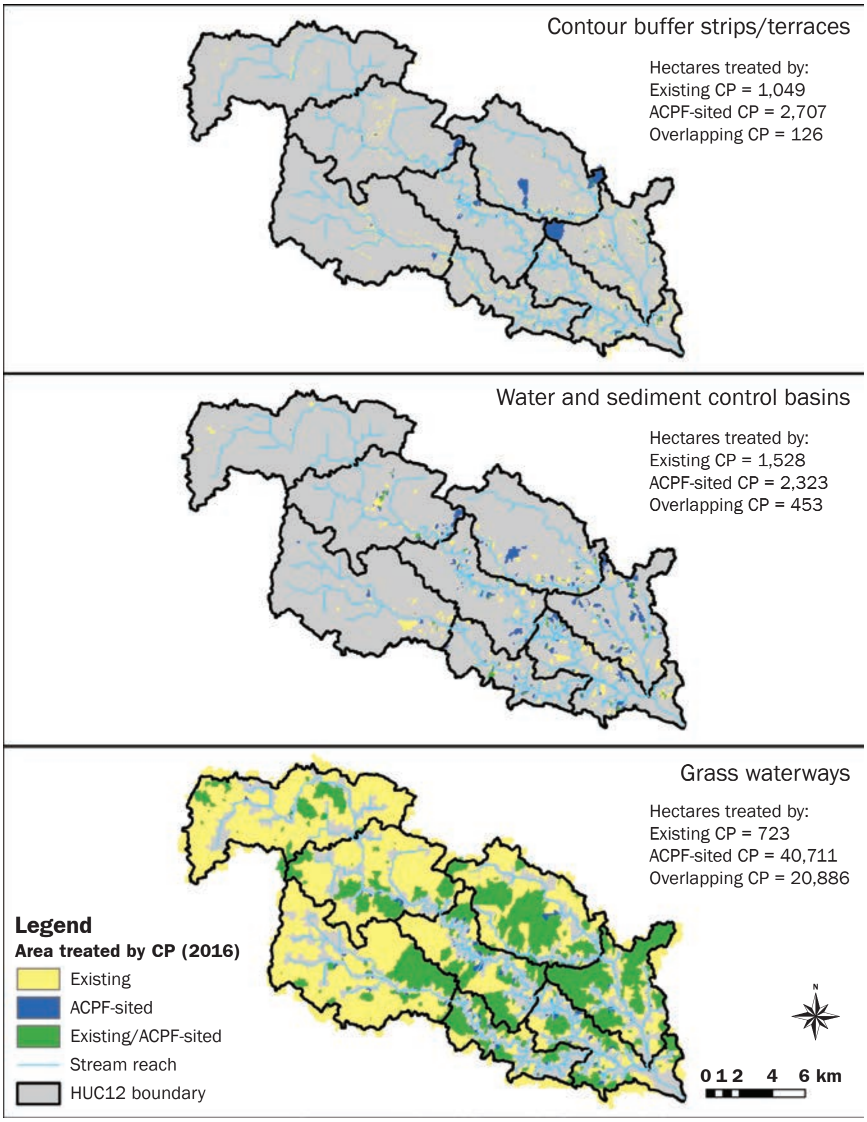


Figure 5

Map of areas treated by conservation practices (CP) coded by presence/absence of existing practices. The total area treated for each CP is the sum of existing CP (no overlap with Agricultural Conservation Planning Framework [ACPF], blue) and the overlapping CP (existing CP area overlapping with placement predicted by the ACPF, green). The ACPF identified land areas without existing CP where CP could be installed (yellow).



could be treated from the ACPF (figure 6). The temporal trend in adoption of grassed waterways shows an increase from 1960 to 1990 and then little further adoption from 1990 to 2016, and this trend is present in all of the HUC12 subwatersheds. The existing practices (green bars in figure 6) are greatest in the 501 and 502 HUC12 (Headwaters and Lower Beaver Creek) and least in 601 (Headwaters South Fork). Grassed waterways treat 38.5% and 55.6% of the land in 501 and 502, respectively, in 2016, but only 10.2% of land in 601 (table 2). Estimated soil erosion is also greater in 501 and 502 compared to 601 (table 1).

Similar to grassed waterways, the land areas treated by the existing WASCOBs and terraces/contoured buffer strips is greatest in HUC12 subwatersheds 501, 502, and 604, ranging from 3.0% to 7.4% of the subwatershed area and least 0% to 0.4% in subwatersheds 601 and 401 (table 2, figure 5). These CP account for a much smaller fraction of land treated than the grassed waterways.

Summary and Conclusions

The CP in the watershed are quantified in two ways: watershed-scale counts of CP or as land area treated by these CP. This latter method of quantifying CP is a departure from previous methods. While it is straightforward in interpretation for practices that intercept water flow to prevent sheet and rill erosion (WASCOBs, terraces, and contour buffer strips), it is more complex with grassed waterways. Grassed waterways prevent the erosion leading to gullies due to the accumulation of water from catchments upstream from the grassed waterway.

From 1930 to 2016 the implementation of CP in the SFIR increases steadily until 2002, and then increases very slowly thereafter. This pattern of adoption is similar to that described by Brown and Schulte (2011) for three townships in Iowa, although those data only continue through 2002. Presently (2016), grassed waterways are the predominate erosion control practice compared to WASCOBs and terraces/contour buffer strips, either as counts of practices or by the area treated. This result is in agreement with a previous assessment of CP in SFIR based on ground-based observations (Tomer et al. 2008b). In that study, cropped fields with grassed waterways accounted for 14.1% of the total fields in the watershed compared to 6.2% for terraces. Tomer et al. (2008b) also reported that no-tillage accounted for only 7.2% of the watershed area, conventional tillage accounted for 28.9%, and the mulch tillage CP for 58.1%. The predominance of grassed waterways is also seen in previous years in SFIR (figures 3 and 6). This is also consistent with only 8.8% of SFIR fields having more than 34% highly erodible land (Tomer et al. 2008b).

The present level of grassed waterways represents the net result of implementation (new grassed waterways) and removal of grassed waterways. Since 2002, the installation and removal of grassed waterways is only a small fraction of the total waterways present in the watershed. The 21.5-year mean duration of grassed waterways and the 24-year mean duration of WASCOBs suggest that farmers are making long-term commitments to these CP that exceed the period of USDA NRCS or Farm Service Agency (FSA) financial support (Reimer et al. 2015). There appears to be similar long-term support for WASCOBs and terraces/contour buffers. The duration of these CP exceeds their stated design lifes-

Table 1
Annual average estimates of annual precipitation, runoff, and soil loss for the South Fork of the Iowa River HUC12 watersheds obtained from the Daily Erosion Project for 2010 through 2015.

Subwatershed				
Partial HUC12 code*	ID	Precipitation (cm)	Runoff (cm)	Sediment loss (Mg ha^{-1})
601	Headwaters South Fork	86.5	10.9	1.87
401	Headwaters Tipton Creek	86.8	11.0	2.50
602	Upper South Fork	86.1	10.7	2.85
501	Headwaters Beaver Creek	87.9	11.1	3.10
603	Middle South Fork	87.3	11.9	3.19
502	Lower Beaver Creek	90.9	13.3	4.18
604	Lower South Fork	89.5	13.4	6.03
402	Tipton Creek	89.0	13.4	6.35

*Identification codes for the subwatersheds are the last three digits of the full HUC12 identification code: all these codes would be preceded by 070802070 to obtain the full code.

Table 2
Land area treated by existing conservation practices (CP) for erosion control in the South Fork of the Iowa River HUC12 watersheds in 2016.

		HUC12 area treated by CP (%)		
HUC12 subwatershed*	Area (ha)	Grassed waterways	WASCOBs†	Terraces and contoured buffers
601	14,044	10.2	0.0	0.0
401	14,566	16.6	0.4	0.2
602	11,549	19.3	2.1	1.0
501	10,977	38.5	3.0	3.7
603	8,013	33.2	2.6	1.3
502	8,180	55.6	7.4	4.6
604	7,176	27.3	5.4	1.6
402	5,237	36.0	2.5	0.2

*Identification codes for the subwatersheds are the last three digits of the full HUC12 identification code: all these codes would be preceded by 070802070 to obtain the full code.
†Water and sediment control basins.

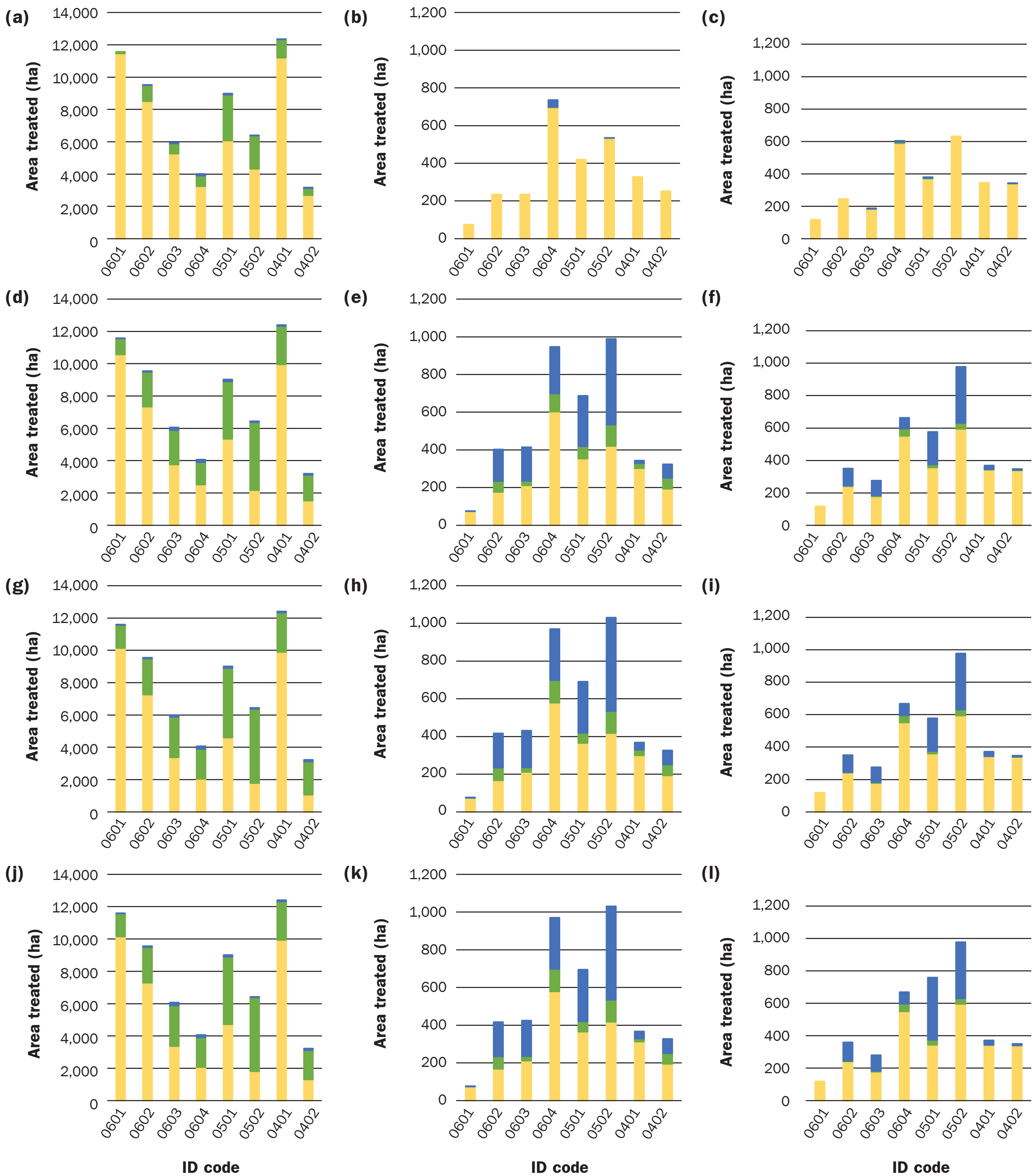
pan of 10 years for grassed waterways and 20 years for terraces and WASCOBs.

The quantity of CP hectares across the watershed is not uniform, but in general, the CP are distributed in areas where greater erosion is expected. Erosion was estimated at the HUC12 scale by using a six-year average of soil loss modeled by the DEP (table 1). The DEP uses the WEPP model and field-scale DEM to estimate rill and inter-rill (sheet) erosion within fields (Gelder et al. 2018) that would be treated by WASCOBs and terraces/contour buffers, but not gully erosion that would be treated by grassed waterways and WASCOBs (USDA NRCS 2012). Nevertheless, factors such as hill slope and length drive both rill and inter-rill erosion, and eventually produce concentrated flow that grassed waterways are designed to mitigate. Given these considerations the DEP predicts greater erosion in the eastern end of the SFIR (table 1). Current and past CP installations (table 2, figure 6) are targeted against these erosion risks when assessed at the HUC12 subwatershed scale (table 1, figure 5). The HUC12 502 (Lower Beaver Creek), 501 (Headwaters of Beaver Creek), 604 (Lower South Fork), and 402 (Tipton Creek) have the greatest erosion predicted by DEP and the greatest percentage of land area treated by CP in 2016 (table 2). The magnitude of these erosion-control CP used in SFIR is similar to that for the Upper Mississippi River Basin (USDA NRCS 2012). In addition to these CP, land farmed in no-till and mulch till is also greater in the eastern part of the watershed compared to the western part (Tomer et al. 2008b).

The placement of past and present CP within SFIR HUC12 subwatersheds was further examined by comparing placement of CP to areas predicted for CP placement across the HUC12 subwatersheds. Figures 5 and 6 indicate general agreement between the ACPF and existing CP both in the past and currently for grassed waterways. Among subwatersheds 604, 501, and 502 there are WASCOBs and terrace/contour buffer present in places not predicted by the ACPF. This may reflect different siting criteria used by NRCS at the time that these CP were installed. The comparison of existing CP against the ACPF predictions indicate that further installation of CP, particularly grassed waterways in the eastern end of the watershed (HUC12 601 and 401), should be considered. Finally, the decisions to install CP are varied and complex and include farm and market economics, demands on time, technical implementation, sources of information, and the perceived need for conservation (Luloff et al. 2012). In addition costs of CP installation, cost-sharing, and other program requirements affect CP adoption (Reimer 2015). These factors likely affect both the

Figure 6

Temporal change in areas of land within South Fork of the Iowa River HUC12 subwatersheds that are treated by existing conservation practice (CP) (blue), treated by existing CP in locations that CP are also predicted for treatment by the Agricultural Conservation Planning Framework (ACPF; green), and areas that the ACPF indicates could be treated by these CP, but are not presently treated (gold). The total area treated for each CP is the sum of existing CP (no overlap with ACPF) and the overlapping CP (existing CP area overlapping with placement predicted by the ACPF). Identification codes for the subwatersheds are the last four digits of the full HUC12 code: all these codes would be preceded by 07080207 to obtain the full code. CPs include (a, d, g, j) grass waterways, (b, e, h, k) WASCOBs, and (c, f, i, l) terraces/contour buffer strips for (a through c) 1960, (d through f) 1990, (g through i) 2010, and (j through l) 2016.



temporal and spatial patterns of CP adoption observed here.

The mapping of these CP and the quantification of their potential land areas treated illustrates some of the potential utility of these techniques at the watershed scale. We did not consider riparian buffers and edge-of-field filter strips in this study, but those practices may also be amenable to the approaches reported here. Other practices such as nutrient management plans or saturated buffers that cannot be detected with aerial imaging may require different techniques.

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