Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands

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Loss of biodiversity and degradation of ecosystem services from agricultural lands remain important challenges in the United States despite decades of spending on natural resource management. To date, conservation investment has emphasized engineering practices or vegetative strategies centered on monocultural plantings of nonnative plants, largely excluding native species from cropland. In a catchment-scale experiment, we quantified the multiple effects of integrating strips of native prairie species amid corn and soybean crops, with prairie strips arranged to arrest run-off on slopes. Replacing 10% of cropland with prairie strips increased biodiversity and ecosystem services with minimal impacts on crop production. Compared with catchments containing only crops, integrating prairie strips into cropland led to greater catchment-level insect taxa richness (2.6-fold), pollinator abundance (3.5-fold), native bird species richness (2.1-fold), and abundance of bird species of greatest conservation need (2.1-fold). Use of prairie strips also reduced total water runoff from catchments by 37%, resulting in retention of 20 times more soil and 4.3 times more phosphorus. Corn and soybean yields for catchments with prairie strips decreased only by the amount of the area taken out of crop production. Social survey results indicated demand among both farming and nonfarming populations for the environmental outcomes produced by prairie strips. If federal and state policies were aligned to promote prairie strips, the practice would be applicable to 3.9 million ha of cropland in Iowa alone.

agriculture | agroecosystem services | perennials | US Corn Belt | sustainability

The global footprint of agriculture is expected to grow in coming decades with a rising human population and changing diets (1). Given linked, negative impacts of agriculture on other Earth processes, strategies for balancing agricultural production with conservation of biodiversity and protection of environmental quality are sorely needed (2). The US Midwest is one region where there is a salient need to balance production, conservation, and environmental-quality goals. Agroecosystems dominate the region (3) and are primarily composed of corn and soybean croplands, which cover 43% of the Midwestern Corn Belt and 69% of Iowa (4). While producing one-quarter of global corn and soybean supplies (5), these agroecosystems are also associated with loss of native habitat and contingent biodiversity (3, 6, 7), degradation of air, water, and soil quality (8–10), and declines in rural communities (11). Impacts are not restricted to the region: Loss of nutrients from corn and soybean agroecosystems in the Midwest is linked with persistent environmental and economic problems of national and global concern, including hypoxia in the Gulf of Mexico (12) and greenhouse-gas emissions (13, 14). National declines in biodiversity, as observed with declining populations of pollinators (15) and monarch butterfly (*Danaus plexippus*), prompted a Presidential Memorandum and a national strategy centered on the Midwest to reverse losses and restore their populations (16).

Strategically integrating perennial vegetation into land used for annual crop production is one strategy that could help balance agricultural production, conservation, and environmental-quality goals (17). Compared with their annual row-crop counterparts, perennial communities enhance hydrologic regulation, improve soil and water quality, foster carbon sequestration and storage, support populations of beneficial organisms for pest control and pollination, and generally foster biological functioning (17–19). Perennial species can also moderate the impacts of climate change, which pose a major threat to sustaining high crop yields into the future (20). Perennial species typically established within a cropland context in the Midwestern United States, e.g., on field borders, terraces, and grass waterways, are monocultures of nonnative grasses, e.g., *Bromus* spp. and *Festuca* spp. Native

Significance

Prairie strips are a new conservation technology designed to alleviate biodiversity loss and environmental damage associated with row-crop agriculture. Results from a multiyear, catchment-scale experiment comparing corn and soybean fields with and without prairie vegetation indicated prairie strips raised pollinator and bird abundance, decreased water runoff, and increased soil and nutrient retention. These benefits accrued at levels disproportionately greater than the land area occupied by prairie strips. Social surveys revealed demand among both farm and nonfarm populations for the outcomes prairie strips produced. We estimated prairie strips could be used to improve biodiversity and ecosystem services across 3.9 million ha of cropland in Iowa and a large portion of the 69 million ha under similar management in the United States.

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Data deposition: The data reported in this paper have been deposited in the ISU-STRIPS repository, https://github.com/ISU-STRIPS/STRIPS/releases/tag/v0.2.

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perennial plants are not commonly used, but such communities have the potential to offer even greater function, resilience, and stability because of ecological traits that are well adapted to regional climate and soil conditions (21). They also provide habitat for a broad suite of native taxa.

To quantify the effects of integrating strips of native perennial vegetation on the biodiversity and ecosystem services within row-crop agricultural fields, in 2007 we established a catchment-scale experiment in central Iowa termed "STRIPS" (Science-based Trials of Row-crops Integrated with Prairie Strips). We chose to reconstruct and evaluate prairie vegetation because it was the historically dominant plant community in the Midwestern United States before Euro-American settlement in the mid-1800s. We sowed prairie plant species in strips along hillside contours and in footslope areas within nine agricultural catchments while using three catchments solely for crop production. Catchments were 0.47–3.19 ha in size (Fig. 1 and Fig. S1). Cropped areas were planted in soybean (*Glycine max*) and corn (*Zea mays*) in alternate years using continuous no-till management and conventional agrichemicals. Treatments were selected to test whether prairie strips could deliver increases in benefits at levels disproportionately greater than the area of the catchments they occupied, compared with a 100% row crop control (17); e.g., we expected prairie strips comprising 10% of an agricultural catchment would result in greater than 10% increases in biodiversity and ecosystem services.

In previous disciplinary papers we established that prairie strips in row cropland provided habitat for native biodiversity (22–24), improved soil quality (25), fostered desirable patterns of biogeochemical functioning and hydrological regulation (26–29), and offered a low-cost agricultural conservation option for farmers and farmland owners relative to alternative best-management practices (30). Here, we sought to use a holistic, integrative approach to assess the effects of prairie strips relative to the proportion of the catchments they occupied. We used a consistent, comprehensive statistical treatment of multidimensional data derived from the STRIPS experiment that included agronomic, biological, and hydrological measures within the same analysis and allowed an explicit consideration of tradeoffs among various performance indicators. Next, we evaluated the attitudes of Iowa farm and nonfarm residents with regard to environmental, socioeconomic, and agronomic conditions that could be affected by integrating prairie strips into cropland. Finally, we used spatial data and models to determine the extent to which prairie strips might be used more broadly in Iowa to address conservation and environmental-quality concerns.

Results

STRIPS Experiment. Tradeoffs among agronomic and financial factors with environmental measures were prominent for the 100% cropland treatment, which formed the baseline for the experiment. Mean annual corn grain yield was 8.9 Mg/ha, ranging between 7.3 Mg/ha in 2014 and 11.0 Mg/ha in 2008; soybean yield averaged 3.6 Mg/ha, ranging between 2.1 Mg/ha in 2013 and 4.3 Mg/ha in 2009. These yields were similar to averages within Iowa (Table S1) and were associated with average net revenues (returns to land and labor resources) of \$482/ha for corn and \$603/ha for soybean in 2016 US dollars (2016 USD). Yields were achieved with concomitant average annual losses of 13 Mg/ha of soil, 41 kg/ha of nitrogen, and 11 kg/ha of phosphorus with 170 mm of water runoff.

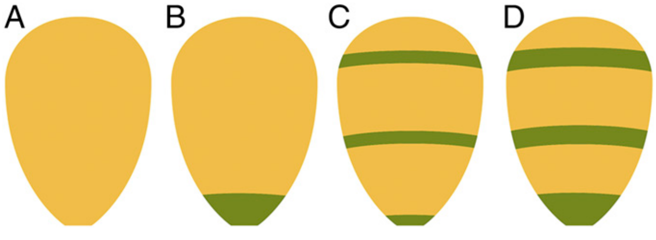

Fig. 1. Schematic representation of the STRIPS experiment. Treatments from left to right are 100% row crop control (*A*), 90% row crop and 10% footslope prairie strip (*B*), 90% row crop and 10% contour prairie strips (*C*), and 80% row crop and 20% contour prairie strips (*D*).

We found many significant differences between prairie and fully cropped control treatments among investigated response variables, with prairie treatments conferring benefits at levels greater than expected based on the spatial extent of prairie vegetation (Fig. 2). As a result of our manipulation, native perennial plant cover and species richness were significantly higher in catchments with prairie strips, with respective increases that were 13 times (95% CI: 5.1, 34) and 7.8 times (95% CI: 3.8, 16) higher than the fully cropped control treatment. Among responses not directly manipulated, sediment transport through water runoff exhibited the greatest magnitude of difference: Sediment loss was reduced 20-fold (95% CI: 5.6, 50) in catchments with prairie strips compared with fully cropped catchments (Fig. 2). Several other measures associated with water quality were also improved with prairie strips: Total phosphorus lost in surface runoff was 4.3 times (95% CI: 1.4, 14) lower, while total nitrogen in surface water and nitrate-nitrogen concentrations in groundwater were 3.3 times (95% CI: 0.9, 12) and 3.6 times (95% CI: 1.0, 13) lower, respectively (Fig. S2 and Table S2). These reductions in sediment transport and nutrient loss were coincident with 1.6 times (95% CI: 1.1, 2.3) less water runoff leaving catchments with prairie strips relative to all-crop catchments. However, while prairie strips reduced water runoff, the impact was not disproportionate to the area removed from annual row crops (Fig. 2).

The establishment of native plants also resulted in significant increases in associated insect and bird biodiversity (Fig. 2). The number of insect taxa recorded was 2.6 times (95% CI: 1.5, 4.6) greater with prairie strips, including 2.2 (95% CI: 1.4, 3.5) and 2.4 (95% CI: 1.6, 3.8) multiplicative increases in natural enemy and pollinator taxa, respectively; insect pollinator abundance was also 3.5 times (95% CI: 1.4, 9.0) greater (Table S2). Bird species richness increased by a factor of 2.1 (95% CI: 1.8, 2.5), abundance increased by a factor of 2.6 (95% CI: 1.9, 3.7), and diversity increased 1.9-fold (95% CI: 1.7, 2.3) with prairie strips; increases in all birds were paralleled by increases in several species of greatest conservation need (SGCN) but not by increases in bird species dependent on expansive grassland ecosystems (Table S2).

Agronomic yields and weed cover did not vary on cropped portions of catchments with or without prairie strips (Fig. 2). Yields were lower when considering whole catchments (both cropped and prairie areas) (Fig. 2), resulting in trends toward lower catchment-scale net revenues (Table S3). Although associated loss in net revenues—accounting for property taxes, crop production costs, prairie strip establishment costs, maintenance costs, and crop revenues—did not differ significantly among treatments, average net revenue was –\$124/ha lower (95% CI: –\$422, \$175) during corn years and –\$88/ha lower (95% CI: –\$277, \$102) during soybean years for catchments with prairie strips.

We found few significant differences among the three treatments containing prairie (Fig. S2 and Table S2), although most measures associated with the cover and richness of native perennial plants trended toward higher values within the 20% prairie treatment. The 20% prairie treatment had small but significantly higher grassland bird abundance, species richness, and diversity and lower dissolved organic carbon (DOC) concentrations in surface runoff compared with the 10% prairie treatments, but differences in total DOC loads were not detected. Concentrations of dissolved phosphorus in groundwater were 4.0 times (95% CI 1.9, 8.3) higher in the 10% footslope prairie treatment compared with multiple prairie strips (Table S2). Pollinators trended toward higher abundance with multiple prairie strips (Fig. 2). The 20% treatment had slightly but significantly greater corn yield on the cropland (Table S2) but not when the area in prairie was also factored in. The higher yield did not translate into higher net revenues, which did not differ among prairie treatments (Table S3).

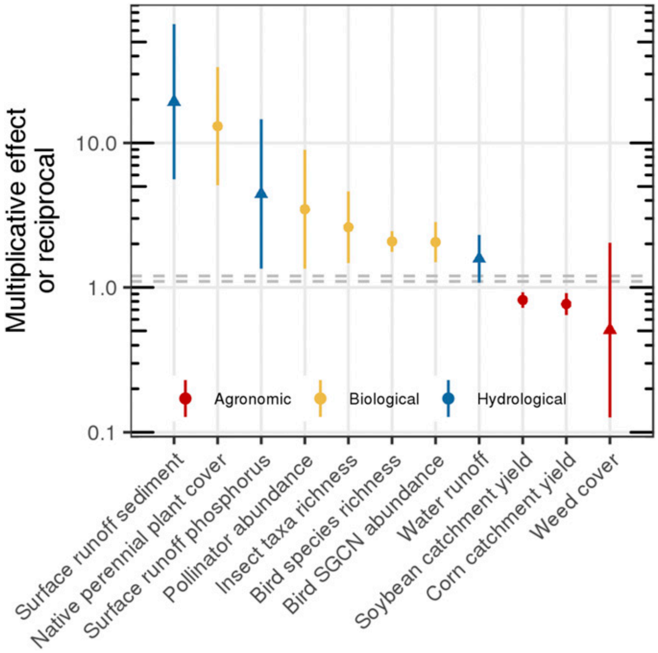

Fig. 2. Multiplicative effects (circles) or their reciprocals (triangles) comparing prairie and no-prairie treatments in the STRIPS experiment. Bars represent 95% CIs. Dashed lines at 1.1 and 1.2 respectively represent the expected response levels for 10% and 20% conversions of annual row cropland to prairie if effects were area proportional.

Social. Results from our 2011–2012 statewide random survey indicated that benefits provided by prairie strips—including improvements in water quality measures, reduced runoff, and improved wildlife habitat—are priorities for both farm and nonfarm populations in Iowa. Among 15 potential policy and programmatic priorities provided in the survey, Iowans ranked protection of drinking water quality as the highest priority overall followed by protection of water quality for aquatic life, increasing rural job opportunities, improving flood control, protecting water quality for recreation, and improving game wildlife habitat (Fig. 3). Farm and nonfarm residents both ranked protection of drinking water as the top priority and shared the next three priority rankings, although in slightly different order. Respondents who lived on a farm placed comparatively lower priority on protecting water quality for aquatic life and swimming, reducing greenhouse-gas emissions, and increasing tourism opportunities (Table S4). Farm and nonfarm residents did not differ significantly in their support for increased crop and livestock production, although these priorities ranked higher for farm than nonfarm populations (Fig. 3 and Table S4).

Estimation of Applicable Extent. We identified all cropped fields in Iowa with slopes ranging from 4 to 10%, similar to our experimental catchments, using the Agricultural Conservation Planning Framework (ACPF) toolbox and database (31, 32). Results indicated prairie strips are applicable to 40% of row croplands and to 27% of Iowa as a whole (Tables S5 and S6). Based solely on erosion potential, we predicted that 3.9 million ha of the 9.8 million ha of annual row croplands in Iowa would benefit from prairie strips or similar conservation practices that slow and impede the flow of water (Table S6). Currently, 97.8% of these croplands are managed for production of continuous corn or corn in rotation with soybean. The croplands vulnerable to erosion are distributed over 92,605 fields that are spatially concentrated in, but not restricted to, areas with steeper and more dissected topography in the northeastern, southern, and western parts of the state (Fig. 4 and Table S7). The need for erosion-control practices is less extensive, although not absent, in northcentral Iowa, where the topography is less dissected (Fig. 4 and Table S7).

Discussion

Data from the STRIPS experiment support the hypothesis that, in landscapes dominated by annual crops, small amounts of strategically integrated native prairie vegetation can provide multiple environmental benefits at levels disproportionately greater than the area diverted from annual crop production. The responses depicted in Fig. 2 indicate that prairie strips provided biological and hydrological benefits, including reduction in the transport of sediment and nutrients by water, far in excess of reduced agronomic production. Results presented here are consistent with our previously published articles in terms of the direction and magnitude of responses (22–24, 26–28, 33). Several responses reported here differed slightly in terms of numeric outcome because here we included more complete datasets where available and used a consistent analytical framework across measures, incorporating a unique multidimensional summary achieved by calculating a scalar for each response. Companion studies have additionally established that prairie strips have the potential to improve soil quality (25), reduce nitrous oxide emissions losses from croplands through denitrification (29), and reduce exposure of beneficial insects to neonicotinoid insecticides (34). Collectively, our data indicate that, relative to other conservation options available to farmers and farmland owners, prairie strips may be a low-cost way (30) to address many major environmental problems associated with agriculture in the US Corn Belt, including soil erosion, emissions of nutrients and concomitant declines in water quality, and loss and degradation of habitat for native biota. We found few differences among treatments that included prairie, suggesting a robust functional response at the catchment scale to the amount and configuration of prairie vegetation.

The differences we recorded between agricultural catchments with and without prairie strips were expected, based on previously observed biodiversity–ecosystem function relationships (17, 19, 21). Our catchment-scale results are directionally congruent with the field-level findings of Werling et al. (18) in terms of reduced provisioning ecosystem services with perennials compared with annual crops but improvements in all other ecosystem service categories. However, the magnitude of the responses we observed was much larger than we expected based on the small proportions of the catchments diverted from crop production, especially for sediment- and nutrient-retention measures.

Several characteristics of the reconstructed prairie vegetation used in the experiment are particularly noteworthy in comparison

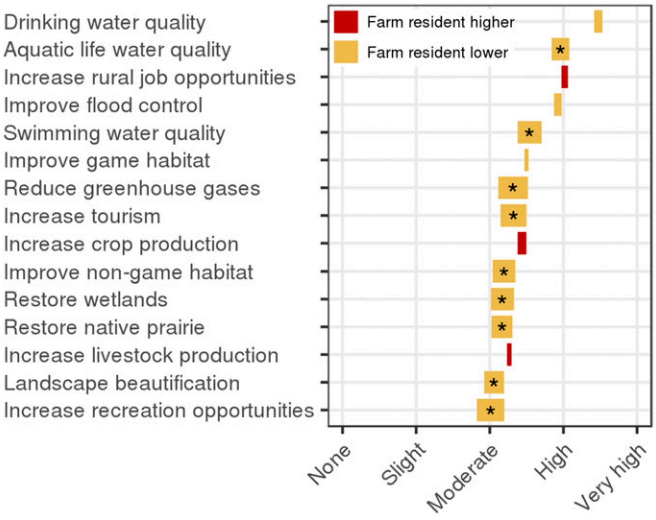

Fig. 3. Iowans' ranked priorities for agricultural programs and policies. Bar length indicates differences in mean responses between populations who live on a farm ($n = 130$) and do not live on a farm ($n = 1,033$). Differences significant at the $P < 0.05$ level are indicated by asterisks.

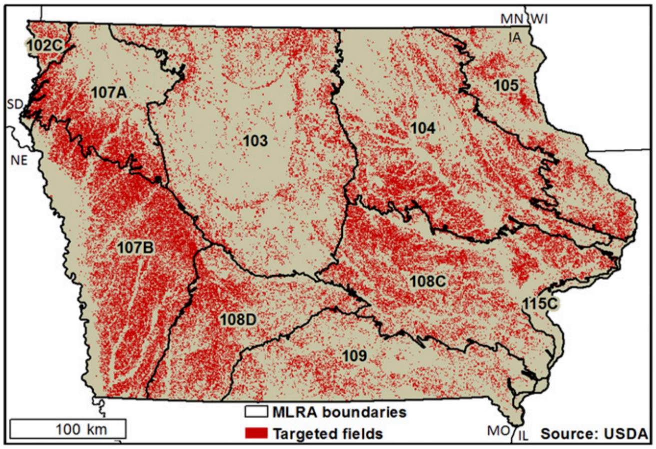

Fig. 4. Distribution of row-crop fields in Iowa with an area ≥10 ha and with a 4–10% slope; boundaries of USDA Natural Resource Conservation Service Major Land Resource Areas (MLRA) (Table S7) are also shown.

with the baseline treatment of 100% annual crops: dominance by plants with perennial life histories that are actively growing for a greater portion of the year, the production of long-lived, deep and/or dense root systems (35), and the availability of floral resources throughout the growing season (36). The first two characteristics are associated with more consistent evapotranspiration rates (37), improved soil quality (38) and nutrient retention (25), increased water-holding capacity (39), and reduced runoff during heavy rainfall events (27). In addition to well-developed root systems, many prairie plant species have stiff stems that stand up in heavy rains and impede the flow of runoff. By incorporating several highly attractive forb species in the community, prairie strips provide greater benefit than plantings of grasses or a single plant species for the many arthropod species that require floral resources throughout the growing season (18, 36). While not directly assessed within our experiment, previous research on biodiversity–ecosystem function relationships support the role of plant diversity—at levels commonly established through prairie reconstruction in the Midwest—in conferring ecosystem stability and ecosystem services (18, 21, 40, 41). Studies also indicate that native prairie is unlikely to be highly attractive to crop pests (42), but associated species can provide benefits through pest suppression (18).

Beyond our biophysical and financial findings, social survey data suggest both farm and nonfarm residents believed agricultural policies and programs should prioritize several ecosystem services that prairie strips provide. Prairie strips have the potential to generate multiple benefits from the same action, an outcome that practice-based conservation policy has long promoted (43). By comparison, terraces and sediment-control basins have traditionally been used to reduce soil erosion and retain phosphorus but are likely to have less impact on groundwater quality than prairie strips (44) and, as infrastructural practices, pose higher costs and challenges to the efficient movement of farming equipment (30). Bioreactors and saturated buffers treat nitrate-nitrogen in subsurface water (45, 46) but do not address other environmental goals. Cover crops provide a number of benefits similar to those generated by prairie strips, including improvements in water infiltration, soil organic matter content, and nutrient retention (47, 48), but can pose management challenges that result in cash crop yield reductions (49) and are comparatively more expensive than prairie strips (50). Longer crop rotations provide benefits similar to cover crops and may confer reduced levels of crop diseases and neutral financial impacts where there are markets for additional crops such as small grains and forages but require additional labor, equipment, and management skills (51). While prairie strips could be used with cover crops and/or longer rotations to potentially provide even greater levels of ecosystem services, the additional management complexity associated with adopting multiple practices may dampen farmers' enthusiasm for combined approaches (52). Perennial species used as dedicated energy crops offer a substantial opportunity for diversification to help meet both economic and environmental goals for the Midwest (18, 53, 54), but the levels of benefits realized are likely to be dependent on placement, crop species, management, and market factors (18, 54–56).

In sum, compared with other agricultural conservation practices available to farmers and farmland owners, prairie strips are a low-cost approach for garnering multiple benefits with one management action while also requiring few changes to existing farming operations. As such, prairie strips strongly complement the eligibility ranking goals of the US Department of Agriculture (USDA) Conservation Reserve Program as promoted via the Environmental Benefits Index (57). This is key to a management practice being promoted by the USDA Natural Resources Conservation Service and in turn gaining broad access to USDA Farm Service Agency cost-share and land-rent funding (58).

We estimate prairie strips could offer substantial improvements across a suite of metrics to the long-term sustainability of 3.9 million ha, 40% of Iowa cropland, based on the extent of crop fields with slope criteria similar to our experiment (4–10% slopes) and to a large portion of the 69 million ha of corn and soybean grown in the United States (4). Croplands with more gently sloping terrain are likely to provide similar levels of slope-independent ecosystem services, e.g., biodiversity measures, and lower levels of slope-dependent measures, e.g., soil and water process measures. We found few differences among our prairie strip treatments, suggesting options for farmers in terms of placement of prairie strips on their farms to accrue associated benefits. We recognize, however, that field-level responses may not always match those recorded in our experiment.

We have initiated new research to address the extent to which the agronomic, biological, and hydrological results reported here are more broadly applicable. Specifically, we seek to determine consistency in the joint production of benefits on different soil types and in different landscapes. The effect of prairie plant species and functional diversity is also not well understood, especially regarding the potential to optimize for specific goals, e.g., reduced soil erosion on highly dissected and steep fields, nitrogen uptake on undulating fields with saturated soils, or biomass production for bioenergy feedstocks. The choices made in perennial species selection and management could be altered toward a number of goals depending on local or regional contexts, needs, and opportunities.

Despite the many potential benefits of diverse, perennial cover, the extent of such vegetation is presently limited in the agricultural Midwest due to the absence of strong market, cultural, and policy supports (56). Like other practices that do not contribute to short-term farm revenue, strategies for encouraging broader adoption include mandates or premiums for farmers from food processers and retailers, enhanced learning and decision-making by farmers through education and outreach programs, and government policies that create incentives and/or penalties (59). Our experience working with Midwestern farmers suggests all three will need to be pursued simultaneously for prairie strips to be widely adopted (60–62). Only then do we expect societal goals for natural resource management such as those posed by the 2008 Gulf Hypoxia Action Plan (12) and the 2014 Presidential Memorandum on pollinator conservation (16) can be met.

Methods

Experimental Design. Field data were collected from a well-established, catchment-scale experiment at Neal Smith National Wildlife Refuge, Iowa (33). The experiment, which was initiated in 2007, comprises 12 catchments (0.5–3.2 ha) arranged in a randomized, balanced, incomplete block design (three replicates of four treatments across four blocks). Treatments consist of varying proportions of reconstructed prairie vegetation (0, 10, and 20%) within row crops (100, 90, and 80%) (Fig. S1). The 100% row crop control treatment represents the agricultural norm. Prairie treatments were selected based on previous research and model simulations (57, 63–65). Cropland in the experiment is in a corn–soybean rotation using standard no-till soil and weed-management techniques. Crop seeds were treated with neonicotinoid insecticides until banned by the US Fish and Wildlife Service in 2013. Corn hybrids and soybean varieties were glyphosate resistant; glyphosate was applied at planting and near the middle of June of each year for weed control. Fertilizers were applied to crops based on soil test levels. Nitrogen was applied as anhydrous ammonia (NH_3) in the spring before corn planting and was injected with standard equipment. Prairie strips were sown on 6 July 2007 with a mixture of 32 native grass and forb species; an additional forb species was sown in spring 2008 (22). Prairie strips had a minimum width of 4 m; the minimum distance between strips was 36 m, which accommodated agricultural operations using standard farming equipment. We collected data on agronomic, biological, hydrological, and financial responses for each catchment.

Agronomic Data. Corn (2008, 2010, 2012, 2014) and soybean (2009, 2011, 2013, 2015) yields were measured by a Case IH AFS Pro-600 combine-mounted yield monitor every 3 s or ∼2.2 m during crop harvest, resulting in a fine-scale spatially referenced dataset of crop yields across the study area. Estimates of wet and dry yields were reported by mass and volume along with sample time, geographic coordinates, estimated moisture content, and flow rate. Data were clipped to experimental catchment boundaries, determined to submeter accuracy using real-time kinematics (RTK) GPS technology using ArcGIS (66). We calculated average crop yield for each catchment based on data points lying within catchment boundaries. Yield data were expressed in units of megagrams per hectare at standard agronomic moisture concentrations for corn and soybean grain. For catchments with prairie, we multiplied the cropland mean yield by cropland proportion to obtain a mean yield for the catchment. Weed cover in cropped portions of all 12 catchments was surveyed annually during 2009–2011 (22).

Biological Data. The percent plant cover by species was collected annually in 2008–2011 in each of the nine catchments containing prairie strips; surveys were conducted in July–August to capture peak flowering period (22). Insects were collected using monthly sweep net samples during May–September in 2009 in both soybean and prairie habitat, during May–September in 2010 in prairie habitat, and during June–September in 2011 in both soybean and prairie habitat (23, 67). During 2010, insect samples were collected monthly during June–August by suctioning from corn foliage using a modified leaf blower (36, 67). All insect samples were stored at −20 °C until identification to at least family and, when possible, to species. Plant and insect data were transformed to represent catchment responses by weighting according to the land cover proportion associated with the treatment; e.g., for a 10% prairie treatment, counts recorded in the cropped and prairie areas were respectively multiplied by 0.9 and 0.1. Native bird surveys were conducted annually in 2008–2012 (24); approval was obtained through Iowa State University (ISU) Institutional Animal Care and Use Committee (IACUC log no. 4-10-6935-Q). Bird species were grouped for analysis by grassland habitat requirements (68) and SGCN (69).

Hydrological Data. Each experimental catchment had a distinct surface flow outlet point where an H-flume was installed in 2005 to monitor surface water runoff volume and chemistry. Each of these locations was sampled with an automated water sampler to obtain flow measurements and discrete water samples based on flow intervals (28). Water samples were collected during the 2008–2013 growing seasons to determine nitrate-nitrogen (NO_3-N), total nitrogen, and total phosphorus loads. Groundwater samples were extracted monthly during the growing season from shallow wells installed at upslope and footslope positions. Samples were analyzed for NO_3-N (33) and orthophosphate (PO_4-P) (70) through 2014.

Financial Data. We used a farm-level financial model to assess annual establishment, management, and opportunity costs associated with crop production and prairie strips for 2008–2015. Data used to compute catchment revenue (2016 USD/ha) included crop-yield data from the experiment, estimated crop management rates and operational costs for owned land including property taxes using ISU's AgDecisionMaker (Table S1) (71), and the cost of seeding and managing prairie strips (30). All costs were monetized over a 15-y horizon, an analytical time frame that corresponds to a maximum, one-time USDA Conservation Reserve Program contract length (72).

Social Data. We conducted a statewide random sample survey of 2,400 Iowa residents in 2011–2012 to assess public concerns about environmental quality and expectations for the state's agricultural sector. As the project was categorized as exempt from full Institutional Review Board review (ISU IRB ID no. 11-244), signed informed consent was not necessary, but formal informed consent language (e.g., voluntary nature, confidentiality) was required and included in the survey. The survey garnered a 47% response rate, and data did not show evidence of nonresponse bias (73). We analyzed survey responses regarding Iowans' ranked priorities for agricultural programs and policies comparing the 13% of the sample who lived on a farm at the time of the survey, since adoption of prairie strips depends on farmer and landowner willingness to implement them, with the rest of the sample. Responses were recorded on a five-point integer scale corresponding to the following categories: 1, no priority; 2, slight priority; 3, moderate priority; 4, high priority; and 5, very high priority.

Data Analysis. We modeled the yearly average of the logarithm of agronomic, biological, and hydrological responses collected from 2008 onward for data that lent themselves to the statistical framework. For responses with zeros, we added the smallest nonzero value for that set of responses to avoid taking the logarithm of zero. We used a mixed-effect, weighted linear regression model in which block, treatment, and the logarithm of catchment size were treated as fixed effects, and catchment and year were treated as random effects. Including blocks provided treatment comparisons adjusted for landscape and block-wide spillover between plots. Catchment financial returns were analyzed in the same manner except that data were not log transformed due to some negative net returns. Separate analyses were performed for corn and soybean for yield and economic return data. We estimated contrasts to assess the treatment effects according to Table S8. We report results as 95% CIs for the exponentiated contrasts; thus, the result can be interpreted as the multiplicative effect unless otherwise noted. Analysis was performed using the statistical software R (74) and the R packages lme4 and lsmeans (75). Social data were analyzed using a *t* test to compare the responses of those who lived on a farm with those who did not. All data used in these analyses are publicly available at https://github.com/ISU-STRIPS/STRIPS/releases/tag/v0.2 along with explanatory metadata.

Geographic Modeling. We used the ACPF toolbox (31, 32) to determine the extent to which prairie strips may be applicable as a conservation practice in Iowa. Selection criteria included fields in row-crop production in 2014 with slope angles of 4–10% comprising at least a 10-ha area within the field boundary. The 4–10% slope criteria matched the range of slopes within our experimental catchments; slopes of >10% frequently have terraces installed through USDA programs. Slope calculations were made by field using a slope raster derived from a 2-m–resolution digital elevation model. The slope calculation was estimated in percent slope using ArcGIS (66). The slope raster was reclassified into three classes: 0–4%, 4–10%, and >10% slope. Area totals for each class were compared with the overall field area to estimate the percent of the field in each slope class. These totals were summed for all fields by land-use class. The 10-ha criterion was conservatively considered the minimum operable unit given typical equipment sizes used in farming operations in Iowa; a sensitivity analysis on this factor is presented in Table S9.

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