Grasslands, wetlands, and agriculture: the fate of land expiring from the Conservation Reserve Program in the Midwestern United States

2016 Environ. Res. Lett. 11 094005

(http://iopscience.iop.org/1748-9326/11/9/094005)

Environmental Research Letters

LETTER

Grasslands, wetlands, and agriculture: the fate of land expiring from the Conservation Reserve Program in the Midwestern United States

Philip E Morefield[1], **Stephen D LeDuc**[1,3], **Christopher M Clark**[1] **and Richard Iovanna**[2]

[1] National Center for Environmental Assessment, US Environmental Protection Agency, 1200 Pennsylvania Ave. NW, ORD-NCEA-8623-P, Washington, DC 20460, USA
[2] US Department of Agriculture, Farm Service Agency, PO Box 2415, Washington, DC 20250, USA
[3] Author to whom any correspondence should be addressed.

E-mail: leduc.stephen@epa.gov

Keywords: Conservation Reserve Program, land use change, corn, soy, grasslands, wetlands, agriculture

Supplementary material for this article is available online

OPEN ACCESS

RECEIVED
18 March 2016

REVISED
2 June 2016

ACCEPTED FOR PUBLICATION
20 July 2016

PUBLISHED
31 August 2016

Abstract

The Conservation Reserve Program (CRP) is the largest agricultural land-retirement program in the United States, providing many environmental benefits, including wildlife habitat and improved air, water, and soil quality. Since 2007, however, CRP area has declined by over 25% nationally with much of this land returning to agriculture. Despite this trend, it is unclear what types of CRP land are being converted, to what crops, and where. All of these specific factors greatly affect environmental impacts. To answer these questions, we quantified shifts in expiring CRP parcels to five major crop-types (corn, soy, winter and spring wheat, and sorghum) in a 12-state, Midwestern region of the United States using a US Department of Agriculture (USDA), field-level CRP database and USDA's Cropland Data Layer. For the years 2010 through 2013, we estimate almost 30%, or more than 530 000 ha, of expiring CRP land returned to the production of these five crops in our study area, with soy and corn accounting for the vast majority of these shifts. Grasslands were the largest type of CRP land converted (360 000 ha), followed by specifically designated wildlife habitat (76 000 ha), and wetland areas (53 000 ha). These wetland areas were not just wetlands themselves, but also a mix of land covers enhancing or protecting wetland ecosystem services (e.g., wetland buffers). Areas in the Dakotas, Nebraska, and southern Iowa were hotspots of change, with the highest areas of CRP land moving back to agriculture. By contrast, we estimate only a small amount (~3%) of the expiring land shifted into similar, non-CRP land-retirement or easement programs. Reconciling needs for food, feed, fuel, and healthy ecosystems is an immense challenge for farmers, conservationists, and state and federal agencies. Reduced enrollment and the turnover of CRP land from conservation to agriculture raises questions about sustaining ecosystem services in this region.

Introduction

Established by the 1985 Farm Bill and administered by the US Farm Service Agency (FSA), the Conservation Reserve Program (CRP) is the largest agricultural land-retirement program in the US (Stubbs 2013). The program offers annual payments to landowners in exchange for the establishment of perennial cover (figure 1(a)), providing environmental benefits and ecosystem services. For example, CRP land prevented the loss of 205 million metric tons of sediment, and 283 and 56 million kg of nitrogen (N) and phosphorus (P), respectively, from agricultural fields nationwide in 2011 according to FSA estimates (USDA-FSA 2011). Since the program's inception, an extensive body of literature has documented other benefits of the CRP, including, but not limited to: habitat for invertebrates, mammals, waterfowl and non-game birds; improved soil quality; carbon (C) sequestration; and increased economic and recreational opportunities in rural areas (Allen and Vandever 2012).

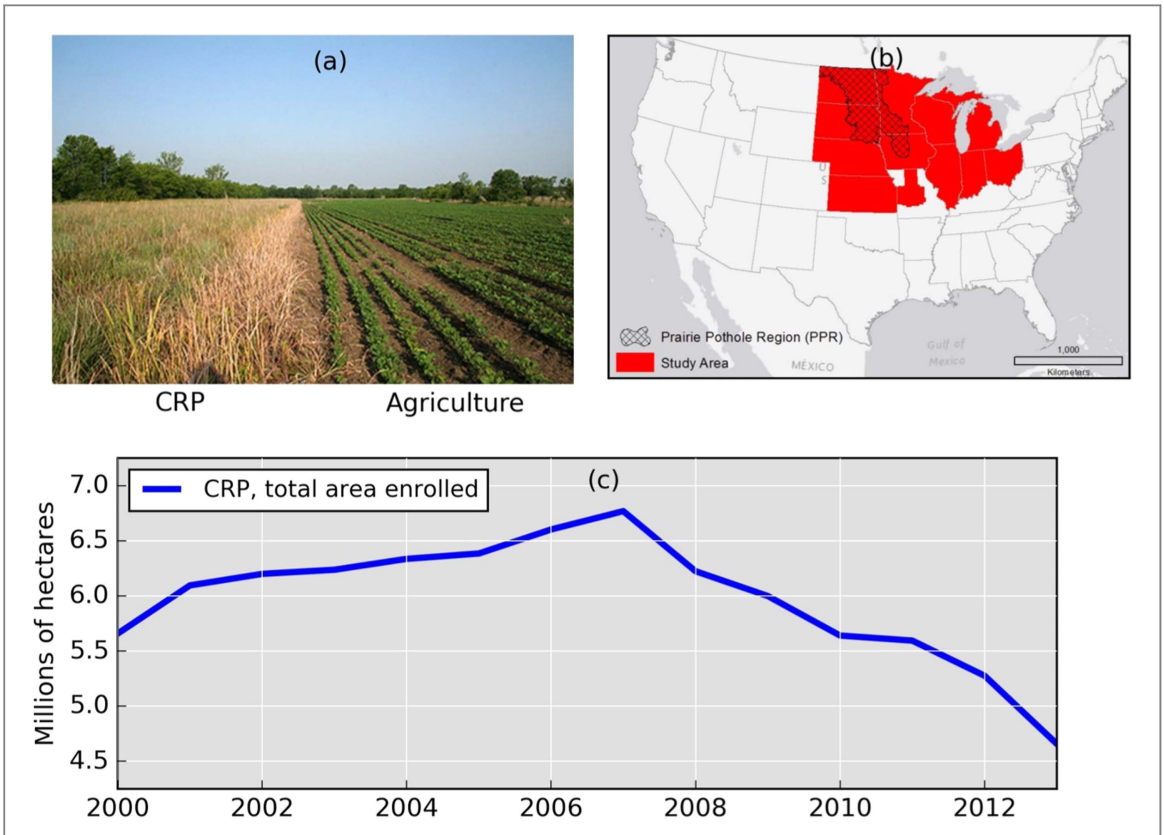

Figure 1. (a) CRP land planted with perennial grasses (left) abutting row crops (right) in Illinois; (b) the study area and the Prairie Pothole Region; and (c) area enrolled nationally in the CRP from 2000 to 2013 (USDA-FSA 2014).

Despite these benefits, the amount of CRP land has steadily declined in recent years since reaching a peak enrollment of 14.9 million ha in 2007. In the 2008 Farm Bill, the US Congress capped the program at 12.9 million ha (US Congress 2008) and again reduced the enrollment cap to 9.7 million ha in the 2014 Farm Bill (US Congress 2014). These declines in CRP land are occurring against a backdrop of agricultural expansion. After declining for decades, total cropland has increased (USDA-NRCS 2013, Lark *et al* 2015). Corn and soy production account for most of the new expansion, replacing other crops, such as wheat or barley (Johnston 2014), or uncultivated lands (Wright and Wimberly 2013, Johnston 2014, Lark *et al* 2015). Wright and Wimberly (2013) recently estimated that nearly 530 000 ha of uncultivated grassland converted to corn or soy production between 2006 and 2011 in a five-state region in the Western Corn Belt. Corn ethanol and soy biodiesel demand may be, in part, driving this extra production, and it has been suggested that increased corn production, in particular, may come at the expense of CRP land.

Recent data suggests large areas of CRP land are indeed converting back to agriculture, but the specific types of land being converted and crop-types being converted to remain unclear. The US Department of Agriculture (USDA) estimated that approximately 28% of all land in the CRP in 2007 (3.7 million ha) was converted to other land-uses by 2012, with 60% of that area (2.2 million ha) going to cropland and 34% (1.3 million ha) to pasture (USDA-NRCS 2015). In these estimates, however, the definition of cropland includes row crops, cultivated hayland, and non-cultivated, permanent hayland and horticultural cropland (USDA-NRCS 2015). The environmental effects of a shift of CRP land to hay is markedly different than a shift to corn, for example, and thus more specific information is needed on these land-use changes. To understand the environmental effects of any potential shift in CRP lands, it is necessary to know what types of CRP land have been converted back to agriculture and what crops have been re-introduced on that land.

To answer these questions, we quantified the amount and type of expiring CRP land recently converted to the production of five specific crop-types (corn, soy, winter and spring wheat, and sorghum) over a largely agricultural 12-state, Midwestern region, including a large portion of the ecologically important Prairie Pothole Region (PPR; figure 1(b)). Like the nation as a whole, this region has experienced similar declines in CRP enrollment (figure 1(c)). We used a USDA-FSA geospatial dataset to track field-level, land-use/land-cover changes for the years 2010 through 2013. Specifically, we sought to: (i) quantify specific CRP-to-crop conversions; and (ii) quantify the conversion of three distinct, CRP land-use/land-cover types: grasslands, wetlands, and wildlife habitat. We discuss the implications of our findings in the broader

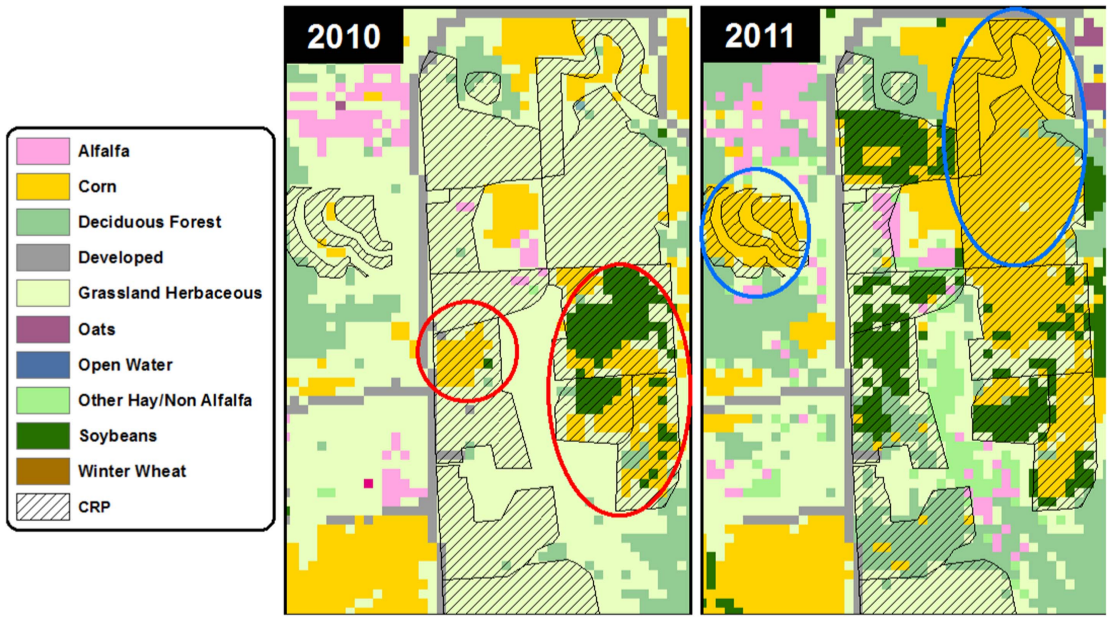

Figure 2. An illustration of the land-use changes measured in this study. Randomly selected CRP polygons are shown as hashed areas and were scheduled to expire in 2010. Large areas of newly planted corn (yellow) and soybean (dark green) are apparent the year following expiration, and are circled in blue. Corn and soybean areas within the red circles would be subtracted from our final estimates of land-use/land-cover change, since those pixels were classified as crops prior to the CRP expiration date (i.e., 30 September 2010). Areas circled in blue are counted as new production following the year of expiration, and so would be included in our final estimates of land-use/land-cover change. Pixels are 30 × 30 m.

context of land-use change and ecosystem services in this region.

Methods

Estimates of post-CRP land-use/land-cover changes

To quantify changes in expiring CRP land, we used a highly resolved geospatial dataset ('CRP polygons') collected by FSA that provides the precise location and management details of more than one million individual CRP parcels. Each parcel was hand-digitized by FSA using 1:7920 scale orthorectified photographs to within a three-meter tolerance. The database included the particular conservation practice (CP) category for each parcel as well as the scheduled date of expiration from the CRP. Because these data contain confidential business information, they are not available for unrestricted public dissemination, and all results were aggregated to the USDA Crop Reporting District (CRD) level (the CRDs in our study area averaged 1.85 million ha in size).

Using a standard geographic information system, we overlaid the expiring parcels onto USDA's Cropland Data Layer (CDL) (USDA-NASS 2007–2013) and tabulated the areal proportion of each CRP polygon in production of corn, soy, winter wheat, spring wheat, or sorghum (figure 2). We limited the analysis to these five crops since they are the dominant crops in our study area (making up almost 85% of cropland (USDA-NASS 2013)), and because of their high accuracy in the CDL. The stated user's accuracy for corn and soybean pixels was >95% over the entire study area for the years of our analysis, and accuracy for winter wheat was >85%. User's accuracy for spring wheat pixels in North Dakota, South Dakota and Minnesota was >90%, and user's accuracy for sorghum in Kansas was >85%. We found the accuracy for other crop/state combinations were either much lower (in some cases lower than 50%) or highly inconsistent, so we excluded those additional hectares of crop production from our analysis.

We also limited the analysis to CRP parcels expiring in 2009 through 2012. CRP contracts generally expire on 30th September of each year, and thus we observed land-use changes starting the subsequent calendar year. For example, if a CRP polygon expired in 2010 we expected to observe any potential shifts to agricultural production in 2011–2013. As a result, we estimated changes in land-use cover for a four year period that occurred in 2010 through 2013. We attributed all 'production' earlier than the expiration date to misclassification of CDL pixels, and subtracted that misclassified amount to generate our estimate of observed change (figure S1). We implemented this subtraction at the county level and then aggregated those values by CRD.

We found that the area of expired CRP polygons generally was lower than the amount recorded in the official county level tabulations (USDA-FSA 2013a). We assumed the digitized CRP polygons were an unbiased sample from the county of all CRP polygons and adjusted the county level areas using percentages (equation (1)):

$$\text{Expired CRP Land Converted} = \frac{\text{Area of CRP Polygons Cropped}}{\text{Area of CRP Polygons}} * \text{CRP}_E, \quad (1)$$

where: Area of CRP Polygons Cropped is our estimate of observed change described above, with misclassified CDL pixels subtracted; Area of CRP Polygons is the total area of CRP polygons; and CRP_E is the total amount of CRP land scheduled to expire per the official tabulations available online (USDA-FSA 2013a). For privacy concerns, adjustments were performed at the county level, but reported only by CRD. We also retained county level re-enrollment data from the official tabulations (USDA-FSA 2013a) which required no adjustment, and were simply summarized for the entire study area.

Land-use/land-cover definitions

To determine what types of CRP land were shifting to crops, we analyzed the data by designated CPs as noted in the USDA-FSA database, grouping them into three categories: grasslands, wetlands, and wildlife habitat. We combined establishments of native grasses (CP2) and introduced (CP1) grasses, as well as native and introduced grasslands established prior to CRP enrollment (CP10), into a general 'grassland' land cover category. Grasslands make up the vast majority of land in enrolled in the CRP and, on an areal basis, constituted approximately 75% of the polygon dataset used in this analysis. Likewise, we combined wetland-related CPs, specifically: newly constructed wetlands (CP39), wetland buffers (CP30), restored wetlands (CP23) and other farmable wetlands and wetlands buffers (CP27 and CP28). We refer to these CRP polygons collectively as 'wetlands', although it is important to note that not all areas included in this grouping are wetlands *per se*, but rather a mix of land uses and land covers that most directly serve to impart, enhance, or protect wetland ecosystem services. Our third CP grouping had the primary objective of establishing or maintaining wildlife habitat (CP4A-D), but also included: rare and declining habitats (CP25), shallow water areas for wildlife (CP9), duck nesting habitat (CP37), habitat for upland birds (CP33) and marginal pastureland wildlife habitat buffers (CP29). CRP polygons in this 'wildlife habitat' grouping consisted of aquatic ecosystems, as well as a variety of terrestrial land covers, including trees, shrubs and grasses. While benefits to soil or water quality may be realized under this set of CPs, the primary objectives are the establishment or improvement of wildlife habitat and habitat corridors.

Conservation-practice specific expiration and re-enrollment information in the official tabulations were not available, so these more specific estimates could not be adjusted using equation (1). Instead, we applied the net cumulative adjustment over the entire study area (an increase of approximately 16%) to each of the CP-specific tabulations.

Expiring CRP land moved to other conservation programs

To better understand the environmental effects of CRP reductions, we must also know how much CRP land moves into other conservation programs. To estimate the amount of expiring CRP lands subsequently enrolled into another comparable, set-aside conservation program, three publicly available geospatial databases were compared spatially to the CRP polygons. The Protected Areas Database of the United States (PAD-US; USGS 2012) and the National Conservation Easement Database (NCED; Foster 2013) each provide geographic boundaries and management information for federal, state, and county conservation lands nationally. PAD-US and the NCED also include voluntarily provided information on privately protected areas, and nearly all polygons in those databases include a USGS Gap Analysis Program (GAP) Status Code, a general indicator of the level of protection mandated for a given polygon. We retained only the polygons under GAP Status 1, 2, or 3, as these areas have permanent protection from conversion of natural land cover for the majority of the area, albeit with permissible extractive and recreational uses of varying intensities (USGS 2012). Some polygons were present in both the PAD-US and NCED datasets and the appropriate corrections were made to ensure that no double counting occurred.

We used a third spatial database, the Natural Resources Conservation Service (NRCS) Easement Areas dataset (USDA-NRCS 2014), to determine the location and boundaries of lands currently enrolled in one of four federal conservation programs: the Wetlands Reserve Program (WRP), the Grasslands Reserve Program (GRP), the Emergency Watershed Protection Program (EWPP), and the Healthy Forests Reserve Program (HFRP). Although the NRCS Easement Areas dataset not does not include GAP Status Codes, each of the polygons in this database is under either 30 year or permanent easement. The CRP polygons were spatially compared to polygons in the NRCS Easement Areas dataset, and we assumed that any overlap between the two indicated lands that expired from the CRP and were subsequently enrolled in one of these four federal programs.

To estimate the amount of expiring CRP lands subsequently enrolled into another comparable *non*-federal conservation program, we queried the PAD-US and NCED databases for conservation lands controlled by non-federal entities. As before, the same spatial comparison was used after accounting for polygons duplicated (i.e., overlapping) in both the PAD-US and NCED databases.

Results

Overall, we estimate that ca 30% (>530 000 ha) of expired CRP land was converted to the production of

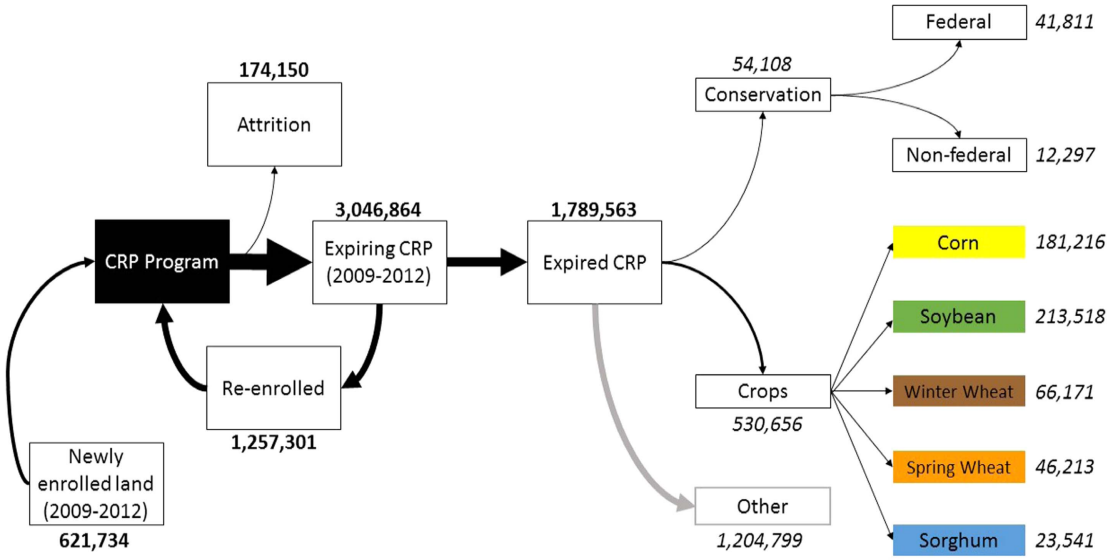

Figure 3. Land-use changes of expiring CRP areas (in hectares) between 2010 through 2013 for the 12-state, study region. Arrow thickness approximates relative amounts of land.

the five crops over the four-year study period (figure 3). A small proportion (ca 3%) remained under conservation protection. The remainder, and the majority of expiring CRP land (almost 70%), was characterized as 'other', meaning it either stayed in perennial cover, was converted to pasture or hay, or went to crops with low or highly inconsistent accuracy rates in the CDL and not included in our analysis.

Of the 530 000 ha that was converted, soy and corn cultivation accounted for over 70%, with approximately 213 000 ha (40%) going to soy and 181 000 ha (34%) to corn (figures 3 and 4(a)). Areas in the Dakotas, Nebraska, and Iowa had especially high conversion rates to these crops (figures 4(b), S2(a) and (b)). The other crops accounted for fewer hectares: approximately 66 000 ha (12%) went to winter wheat, 46 000 ha (9%) shifted to spring wheat in Minnesota and the Dakotas, and 23 000 ha (4%) were converted to sorghum production in Kansas. The majority of land converted was grasslands, nearly 390 000 ha, and almost two-thirds of that went to corn or soy (figure 4(c)). Another 76 000 and 53 000 ha of wildlife habitat and wetlands, respectively, were converted to agriculture—again, mostly to corn and soy.

We found no evidence that expired CRP lands shifted in large percentages into other set-aside conservation programs, either federal or non-federal; rather, as noted above, only 3% of expired CRP land, about 54 000 ha, remained under a comparable level of conservation protection (figure 3). About half of that total were lands absorbed into other public land bases, such wildlife management areas, and more than 13 000 ha moved to the WRP. Most of the remaining land appears to have moved into non-federal conservation programs. Only a miniscule amount, less than 40 ha, was estimated to have moved to the GRP. Overall, the amount of expired CRP land converted to crops was nearly ten times larger than the amount shifting to other set-aside conservation programs (figure 3).

Discussion

To make informed land-use management and policy decisions, it is necessary to understand the extent and type of land-use/land-cover changes occurring. Here, we estimate over 530 000 ha of expired CRP land converted to crop production over a four year period. This is nearly 30% of all land expired from the CRP in our study area. For comparison, this area converted is equal to approximately 12% of *all CRP enrollment* in the study area (4.4 million ha) (USDA-FSA 2013b). Our estimated rate is much lower than the rate estimated in USDA's Natural Resources Inventory (NRI) for 2007 to 2012. They estimate 60% of CRP land leaving the program went to cropland and 34% went to pasture (USDA-NRCS 2015). These high rates, however, can mask important distinctions: for instance, if a grass-covered CRP parcel came out of the program and went to hay production, it would be considered converted to cropland in the NRI, the same as if it were converted to corn; likewise, if it was covered in grass or shrubs and stayed in grass and shrubs after it came out, it would be classified as rangeland or pastureland regardless of whether it was grazed or not (Flanagan 2016). By contrast, our estimated rates illustrate a fundamental change from lightly managed, CRP land to intensively managed, high-input monocultures, predominantly to corn and soy, and secondarily to winter and spring wheat and sorghum.

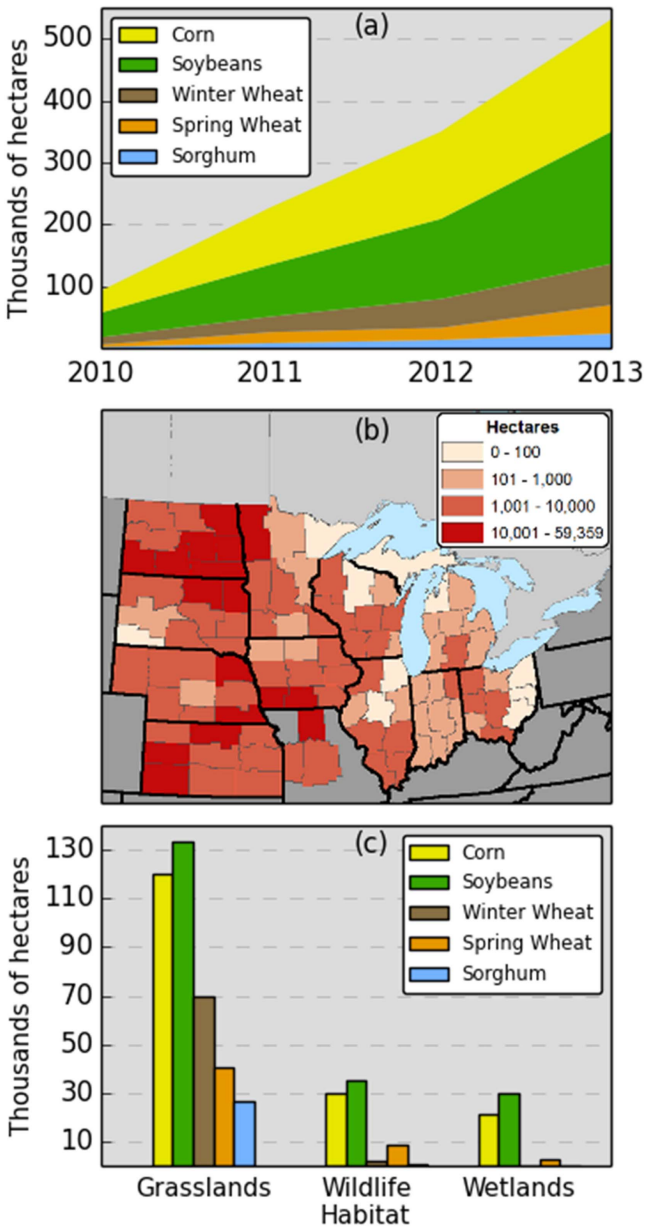

Figure 4. (a) Expiring CRP area converted to five crops (corn, soybean, spring wheat, winter wheat, and sorghum) cumulative for the entire 12-state region by year, 2010–2013 (b); the cumulative area of expiring CRP converted in the four-year period by Crop Reporting District (c); grasslands, wetlands and wildlife habitat expiring from the CRP and converted to the five crops for the four-year period.

Our findings of a shift in CRP grasslands to intensive agriculture is consistent with broader trends in land-use/land-cover change as shown in recent studies. Total cropland has increased nationally in recent years (2008–2012) according to Lark *et al* (2015). Almost 80% of new cropland came from converting grasslands, with 2.3 million ha converted nationally (Lark *et al* 2015). Corn, wheat (winter, spring and durum), and soy were the most common crops planted on this newly converted land (Lark *et al* 2015). All of these findings are consistent with and are strengthened by our study. We also found similar support for Lark *et al*'s (2015) finding of hotspots of change in areas of the Dakotas and southern Iowa. Similarly, Johnston (2014) reported an almost 30% increase in corn and soy plantings in the Dakota PPR from 2006 through 2012, mostly at the expense of other crops and grasslands. As noted previously, Wright and Wimberly (2013) estimated that nearly 530 000 ha of grasslands were converted to corn or soy in the Western Corn Belt. Their study was met with some criticism, largely due to an inability to distinguish between intact grassland ecosystems and agricultural 'grasslands' frequently managed in rotation with cropland (e.g., fallow land, pasture, or cultivated hay) (Kline *et al* 2013). Our estimates support the general finding of Wright and Wimberly (2013) that grassland conversions to corn and soy are indeed occurring. Concomitantly, however, our estimates on the area converted may be more accurate, since we avoid the

confounding factor of including fallow land, pasture, or cultivated hay in our conversion estimates.

Like grasslands, we show that large areas of CRP wetlands have been converted back to agriculture. Putting these results in context, total wetland area has declined in our study region: the National Land Cover Database shows a net areal decline in wetlands in our study region between 2001 and 2011, a finding consistent with national trends (Dahl 2014). Even though wetland area overall has declined, net wetland area on agricultural land increased nationally between 2004 and 2009 (Dahl 2011). Likewise, net enrollment of CRP wetland area increased slightly (from 833 to 898 thousand ha) between 2007 and 2011 in the Mississippi River Basin, an area encompassing most of our study region (USDA-FSA 2011). The FSA has prioritized enrollment of restored or constructed wetlands and stream buffers to maintain CRP water quality benefits. Our results suggest this practice will need to continue in order to help compensate for the movement of wetland areas to agriculture after they leave the CRP.

CRP-to-agriculture conversions are likely to negatively affect multiple ecosystem services. The ability of CRP land to sequester greenhouse gas emissions declined nationally by ca 15% between 2007 and 2011 (USDA-FSA 2011). Moreover, this does not include soil C loss from conversion of CRP land back to intensive agriculture, particularly if conventional tillage is used (Gelfand *et al* 2011). Aquatic ecosystems are also almost certainly impacted by post-CRP land-use change. The conversion of CRP to agriculture decreases the amount of nutrients and chemicals intercepted before reaching water bodies, while concomitantly increasing the use of chemicals on converted land. One recent study, for example, found that in Iowa subbasins where CRP lands were converted to cropland, nitrate concentrations in runoff increased by 1200% (Osmond *et al* 2012). Additionally, the FSA estimates a decline in the ability of the CRP to prevent N, P, and sediment loss in the Mississippi River Basin since 2007 despite modest areal *increases* in stream buffers and wetlands (USDA-FSA 2011). This trend suggests that the strategic prioritization of CPs does not entirely compensate for large losses in enrolled areas. Given that, the changes observed here may greatly hamper the realization of long-term water quality goals, including federal and state efforts aimed at reducing the hypoxic zone in the Gulf of Mexico (Alexander *et al* 2008, Gulf Coast Ecosystem Restoration Task Force 2011).

A few caveats should be considered when assessing the findings of this study. First, our conversion estimate is likely conservative because we did not include conversion to other crops, alfalfa or hay, or pasture in our estimates. We categorized almost 70% of the land as 'other', which has several possible fates: (1) conversion to a crop not included in this analysis; (2) conversion to alfalfa or other hay; (3) conversion to pasture; or (4) remaining in perennial cover without grazing or haying. We excluded other crops in this study because of their generally low or highly inconsistent accuracy rates in the CDL, and the five crops we did include (corn, soy, winter and spring wheat, and sorghum) make up almost 85% of cropland in our study area (USDA-NASS 2013). We also excluded conversions to alfalfa, other hay, or pasture because we wanted to estimate a conversion rate representing a true shift to intensive agriculture, and the accuracy of these grassland-type covers in the CDL can also be highly variable and quite low (Kline *et al* 2013). To provide greater insight into the possible fates of this 70% of CRP land, however, we did characterize these pixels to the extent possible using the CDL. Overall, about 7.5% of the area went to other crops (e.g., barley, oats, and rye); approximately 45% went into alfalfa, non-alfalfa hay, or mixed categories that include pasture and/or hay; a small percentage, 0.03%, went into development (e.g., roads, buildings); while the remainder fell into other, non-anthropogenic categories (e.g., grasslands, forestlands). The user's accuracy for the other crops was highly variable depending upon the specific crop-state combination (from 4% for oats in Missouri to 98% for canola in Kansas). If we had added these other crops, our overall conversion estimate would have increased marginally from 30% to approximately 35%. Adding alfalfa, non-alfalfa hay, and the mixed category including pasture and hay would have approximately doubled our conversion rate. However, since such a shift would not reflect a fundamental conversion from CRP land to intensively managed crops and the user's accuracy rate for these grassland-related covers, such as hay or alfalfa, can also be quite low (e.g., 6% for pasture/hay in Kansas), we conclude that this exclusion is appropriate.

Secondly, we also could not account for the specific management practices implemented on the converted cropland. The environmental impacts of post-CRP land-use change depends in part on the management practices implemented on the converted land. The implementation of no-till practices, for example, could reduce soil C loss from the conversion of CRP land (Gelfand *et al* 2011). A recent USDA survey found widespread employment of farmland practices to reduce erosion (e.g., reduced tillage) in the Mississippi River Basin; yet also found that farmers generally fail to use appropriate nutrient management strategies (USDA-NRCS 2012). As a result, sediment and C loss from CRP conversion may be less problematic than nutrient loss. We did not attempt to quantify environmental effects here, but practices on the converted lands would have to be considered if such an attempt were made.

Third, and finally, enrollment in working land programs, such as the Environmental Quality Incentive Program and the Conservation Stewardship Program has been increasing considerably in recent years (Osteen *et al* 2012). These programs offer payments to

land owners for the implementation of certain CPs (e.g., a nutrient management plan) without removing the land from agricultural production. These programs could both influence the practices employed on converted CRP land, and also practices on other agricultural land. It is unclear, however, if this shift in conservation strategies can entirely make up for the loss of CRP land. The wildlife habitat benefits of CRP land may be difficult to replace on a working farm, for example. For water quality, conversion of CRP land to agriculture has been shown to sharply increase nitrate concentrations (Schilling and Spooner 2006, Osmond *et al* 2012), and our results show areas of concentrated CRP-to-agriculture conversion, particularly in the western half of our study area (figure S2). Thus, it remains to be seen if increases in environmental benefits from working land programs can equal out reductions in CRP benefits.

Conclusions

Overall, we estimate expiring CRP land reverted back to intensive agriculture at a 30% rate across our study area from 2010 through 2013, predominantly to corn and soy production. Areas in the Dakotas, Nebraska, and southern Iowa were hotspots of change. Our estimate is likely conservative, yet more reflective of a true change from perennial cover to intensive agriculture than other studies in this area. The changes described here are likely to continue in the near term. The CRP enrollment cap was reduced through 2018, and recent trends in enrollment suggest that landowner interest in the CRP as currently implemented may be declining (Osteen *et al* 2012). The combination of commodity prices, reduced land retirement options, and diminishing interest in land retirement programs may continue driving extensification of agriculture at the expense of grasslands, wetlands, and ecosystem services. Reconciling needs for food, feed, fuel, and healthy ecosystems is an immense challenge for farmers, conservationists, and state and federal agencies. This study helps inform that challenge by examining post-CRP land-use changes occurring in the context of current agricultural and environmental policies and trends.

Acknowledgments

We thank M Mehaffey and R Bruins for facilitating access to data; A Barbarika for providing advice and expertise; and C Ridley and R Bruins for their comments on the manuscript. We also gratefully acknowledge two anonymous reviewers whose comments improved the quality of this manuscript. The views expressed here are those of the authors and do not necessarily represent the views or policies of the US Environmental Protection Agency or the US Department of Agriculture.

References

Alexander R B, Smith R A, Schwarz G E, Boyer E W, Nolan J V and Brakebill J W 2008 Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin *Environ. Sci. Technol.* **42** 822–30

Allen A W and Vandever M W 2012 Conservation Reserve Program (CRP) contributions to wildlife habitat, management issues, challenges and policy choices—an annotated bibliography *US Geological Survey Scientific Investigations Report* 2012–5066 (Reston, VA: US Geological Survey)

Dahl T E 2011 *Status and Trends of Wetlands in the Conterminous United States 2004 to 2009* (Washington, DC: US Department of the Interior, Fish and Wildlife Service)

Dahl T E 2014 *Status and Trends of Prairie Wetlands in the United States 1997 to 2009* (Washington, DC: US Department of the Interior, Fish and Wildlife Service, Ecological Services)

Flanagan P 2016 personal communication

Foster K 2013 *National Conservation Easement Database (NCED), Phase III* released July 2013 (www.conservationeasement.us)

Gelfand I, Zenone T, Jasrotia P, Chen J Q, Hamilton S K and Robertson G P 2011 Carbon debt of Conservation Reserve Program (CRP) grasslands converted to bioenergy production *Proc. Natl Acad. Sci. USA* **108** 13864–9

Gulf Coast Ecosystem Restoration Task Force 2011 *Gulf of Mexico Regional Ecosystem Restoration Strategy* (http://archive.epa.gov/gulfcoasttaskforce/web/pdf/gulfcoastreport_full_12-04_508-1.pdf)

Johnston C 2014 Agricultural expansion: land use shell game in the US Northern Plains *Landscape Ecol.* **29** 81–95

Kline K L, Singh N and Dale V H 2013 Cultivated hay and fallow/idle cropland confound analysis of grassland conversion in the Western Corn Belt *Proc. Natl Acad. Sci. USA* **110** E2863

Lark T J, Salmon J M and Gibbs H K 2015 Cropland expansion outpaces agricultural and biofuel policies in the United States *Environ. Res. Lett.* **10** 044003

Osmond D, Meals D, Hoag D, Arabi M, Luloff A, Jennings G, McFarland M, Spooner J, Sharpley A and Line D 2012 Improving conservation practices programming to protect water quality in agricultural watersheds: lessons learned from the National Institute of Food and Agriculture-Conservation Effects Assessment Program *J Soil Water Conserv.* **67** 122A–7A

Osteen C, Gottlieb J and Vasavada U 2012 *Agricultural Resources and Environmental Indicators* EIB-98 (Washington, DC: US Department of Agriculture, Economics Research Service)

Schilling K E and Spooner J 2006 Effects of watershed-scale land use change on stream nitrate concentrations *J. Environ. Qual.* **35** 2132–45

Stubbs M 2013 Agricultural conservation: a guide to programs *Congressional Research Service Report for Congress* R40763

US Congress 2008 *Food, Conservation, and Energy Act of 2008* Pub L. 110–234 (Washington, DC: US Government Printing Office) (http://gpo.gov/fdsys/pkg/PLAW-110publ234/pdf/PLAW-110publ234.pdf)

US Congress 2014 *Agricultural Act of 2014* Pub. L. 113–79 (Washington, DC: US Government Printing Office) (http://gpo.gov/fdsys/pkg/PLAW-113publ79/html/PLAW-113publ79.htm)

USDA-FSA (US Department of Agriculture, Farm Service Agency) 2011 *Conservation Reserve Program Annual Summary and Enrollment Statistics, FY 2011* (www.fsa.usda.gov/Internet/FSA_File/annualsummary2011.pdf)

USDA-FSA (US Department of Agriculture, Farm Service Agency) 2013a *Changes in CRP Acreage from 2007 to October 2013 by County* (www.fsa.usda.gov/Internet/FSA_File/acrescounty012213.xls)

USDA-FSA (US Department of Agriculture, Farm Service Agency) 2013b *Summary of Active and Expiring CRP Cropland Acres by State, January 2013* (https://fsa.usda.gov/Internet/FSA_File/jancrpstat2013.pdf)

USDA-FSA (US Department of Agriculture-Farm Services Agency) 2014 *CRP Enrollment and Rental Payments by State,*

1986–2014 (https://fsa.usda.gov/programs-and-services/conservation-programs/reports-and-statistics/conservation-reserve-program-statistics/index)

USDA-NASS (US Department of Agriculture National Agricultural Statistics Service) 2007–2013 *Cropland Data Layer* (http://nassgeodata.gmu.edu/CropScape)

USDA-NASS (US Department of Agriculture National AgriculturalStatistics Service) 2013 *Acreage Report* (http://usda.mannlib. cornell.edu/usda/nass/Acre//2010 s/2013/Acre-06-28- 2013.pdf)

USDA-NRCS (US Department of Agriculture-Natural Resources Conservation Service) 2012 *Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin* (http://nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042093.pdf)

USDA-NRCS (US Department of Agriculture-Natural Resources Conservation Service) 2013 *Summary Report: 2010 National Resources Inventory* (Washington, DC and Ames, IA: Natural Resource Conservation Service, and Center for Survey Statistics and Methodology, Iowa State University) (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167354.pdf)

USDA-NRCS (US Department of Agriculture, Natural Resources Conservation Service) 2014 *Easement Areas* (https://gdg.sc.egov.usda.gov/)

USDA-NRCS (US Department of Agriculture-Natural Resources Conservation Service) 2015 *Summary Report: 2012 National Resources Inventory* (Washington, DC and Ames, IA: Natural Resources Conservation Service, and Center for Survey Statistics and Methodology, Iowa State University) (http://nrcs.usda.gov/technical/nri/12summary)

USGS (US Geological Survey) 2012 *Gap Analysis Program Protected Areas Database of the United States (PADUS), version 1.3* (http://gapanalysis.usgs.gov/padus/)

Wright K and Wimberly C 2013 Recent land use change in the Western Corn Belt threatens grasslands and wetlands *Proc. Natl Acad. Sci. USA* **110** 4134–9