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POTENTIAL OF RESTORED PRAIRIE WETLANDS IN THE GLACIATED NORTH AMERICAN PRAIRIE TO SEQUESTER ATMOSPHERIC CARBON

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EXECUTIVE SUMMARY

The Prairie Pothole Region (PPR) covers about 900,000 km^2 (347,500 mi^2), which is approximately a fourth of the area in the Plains CO_2 Reduction (PCOR) Partnership region. Specifically, the PPR covers portions of Iowa, Minnesota, Montana, North Dakota, and South Dakota in the United States and Alberta, Saskatchewan, and Manitoba in Canada. Formed largely by glacial events, this region historically was dominated by grasslands interspersed with shallow palustrine wetlands.

Prior to European settlement, this region may have supported more than 20 million ha (49 million acres) of wetlands, making it the largest wetland complex in North America. However, fertile soils in this region resulted in extensive loss of native wetlands as cultivated agriculture became the dominant land use. With cultivation through agricultural practices resulting in oxidation of organic matter, the soil organic carbon (SOC) in wetlands was depleted.

Recent work by the U.S. Geological Survey (USGS) and Ducks Unlimited Canada scientists for the PCOR Partnership demonstrated that restoration of previously farmed wetlands results in the rapid replenishment of SOC lost to cultivation at an average rate of 3 Mg ha^{-1} yr^{-1} (1.34 tons acre^{-1} yr^{-1}).

The findings that restored prairie wetlands are important carbon sinks provide a unique and previously overlooked opportunity to store atmospheric carbon (CO_2-C) in the PCOR Partnership region. The overall goal of this study was to develop a database to estimate the regional potential to store atmospheric carbon by restoring previously farmed wetlands. Additional topics discussed in this report include other forms of potential carbon storage processes and greenhouse gas (GHG) offsets derived from restored wetlands.

To develop the regional database, scientists used SOC data collected from 231 wetlands in the PPR. This sample included wetlands with no known history of cultivation and wetlands with a history

of cultivation. The average difference in SOC stocks between native and previously farmed wetlands was then multiplied to corresponding area (ha) estimates of palustrine wetlands in cultivated croplands (i.e., potentially restorable wetlands). The differences between native and previously farmed wetland carbon estimates (i.e., SOC sequestration potential) were then aggregated by county for the United States and by rural municipality districts for Canada.

We estimate that up to 4,944,000 ha (12.2 million acres) of potentially restorable wetlands exist in the PPR. If restored, these wetlands have the potential to sequester 111,216,000 Mg (122.6 million tons) of SOC over a 10-year period. Additionally, we estimate that the vegetative standing crop in restored wetlands represents an additional carbon storage benefit of approximately 24,720,000 Mg (27.2 million tons). To put this into perspective, the prairie pothole wetlands have the potential to sequester up to 25% of the transportation-related CO_2 emissions for the entire PCOR Partnership region annually (Jensen et al., 2005).

Limited data suggest that restoration of wetlands may reduce emissions of other GHGs such as nitrous oxide (N_2O) and, possibly, methane (CH_4), providing additional potential GHG reduction benefits. Preliminary studies have been initiated in the United States and Canada by PCOR Partnership partners to evaluate the potential of restored wetlands to reduce emissions of CH_4 and N_2O.

We anticipate that the spatial database developed as our contribution to the PCOR Partnership will be used as a decision support tool for development of action plans to sequester atmospheric carbon within the region. As new data become available from PCOR Partnership partners, the database will be updated to better refine estimates and reduce uncertainty of GHG reduction benefits derived from restored wetlands.

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We thank Brian Tangen and Murray Laubhan for their help developing a database for this report and for reviewing earlier drafts of this report. We also thank Brian Kazmerik and Bill Tedford for providing spatial datasets for Canada and for their advice on data-processing procedures. Lastly, we thank U.S. Fish and Wildlife Service Habitat and Evaluation Teams, from Regions 3 and 6, for providing National Wetlands Inventory data. We also thank Daniel Daly, Melanie Jensen, Lynette de Silva, Steven Smith, and Wesley Peck, from the Energy & Environmental Research Center (EERC), for reviewing this report.

The PCOR Partnership is a collaborative effort of public and private sector stakeholders working toward a better understanding of the technical and economic feasibility of capturing and storing (sequestering) anthropogenic CO_2 emissions from stationary sources in the central interior of North America. It is one of seven regional partnerships funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnership (RCSP) Program. The EERC would like to thank the following partners who provided funding, data, guidance, and/or experience to support the PCOR Partnership:

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- Minnesota Power
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- Montana–Dakota Utilities Co.
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- North Dakota Natural Resources Trust
- North Dakota Petroleum Council
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BACKGROUND/INTRODUCTION

As one of seven Regional Carbon Sequestration Partnerships, the Plains CO_2 Reduction (PCOR) Partnership is working to identify cost-effective carbon dioxide (CO_2) sequestration systems for the 3.5-million-km^2 (1.4-million-mi^2) area of the Great Plains of North America PCOR Partnership region and, in future efforts, to facilitate and manage demonstration and deployment of these technologies. In this phase of the project, the PCOR Partnership is characterizing the technical issues, enhancing the public's understanding of CO_2 sequestration, identifying the most promising opportunities for sequestration in the region, and detailing an action plan for the demonstration of regional CO_2 sequestration opportunities. This report focuses on the potential of prairie wetland restorations, as an important terrestrial sink, to sequester atmospheric CO_2 (Euliss et al., in press).

Concentrations of CO_2, the dominant greenhouse gas (GHG), and other important GHGs such as nitrous oxide (N_2O) and methane (CH_4) have increased steadily in the atmosphere since the 1800s (Edmonds, 1999). Consequently, there have been increasing concerns regarding climate change, and governments worldwide have been developing strategies to reduce GHG emissions. One such strategy in terrestrial ecosystems is to implement land-use activities that enhance the capture and storage of atmospheric carbon (CO_2-C) in the soils of agricultural lands (Lal et al., 1998). Of particular interest in the PCOR Partnership region is the potential to sequester atmospheric carbon in the soils of restored prairie wetlands.

Wetlands are emerging as a very significant sink for atmospheric CO_2 for two reasons. First, wetlands represent approximately 4% of the Earth's land area, yet store almost 33% of all organic matter (Eswaran et al., 1993). Second, because the habitat has been greatly decreased over the past 200 years, restoring wetlands could be a simple, near-term way to greatly increase carbon storage capacity. The PCOR Partnership region includes the Prairie Pothole Region (PPR), a major biogeographical region that encompasses approximately 900,000 km^2 (347,500 mi^2) and includes portions of Iowa, Minnesota, Montana, North Dakota, and South Dakota in the United States and Alberta, Saskatchewan, and Manitoba in Canada (Figure 1).

With a surface topography formed largely by glacial events, this region historically was dominated by grasslands interspersed with shallow palustrine wetlands that formed as ice from receding glaciers melted. Prior to European settlement, the region may have supported more than 20 million ha (49 million acres) of shallow wetlands (Millar, 1989; Tiner, 1984), making it the largest wetland complex in North America. However, rich soils in this region resulted in the extensive conversion of this native grassland–wetland system to agriculture (Figure 2). Previous estimates indicate more than 50% of PPR wetlands in the United States (Tiner, 1984) and 71% of PPR wetlands in Canada (Environment Canada, 1986) have been drained or otherwise altered for agricultural production.

An increasing number of previously farmed wetlands have been restored in the PPR largely through funding provided by federal, provincial, state, and private conservation programs. For example, approximately 669,000 ha (1.65 million acres) of wetlands have been restored in the PPR in the United States on private lands enrolled in the U.S. Department of Agriculture's (USDA's) Conservation Reserve Program (CRP) (U.S. Department of Agriculture, 2005) (Figure 3). Wetland restoration generally consists of plugging drains and establishing permanent grasses

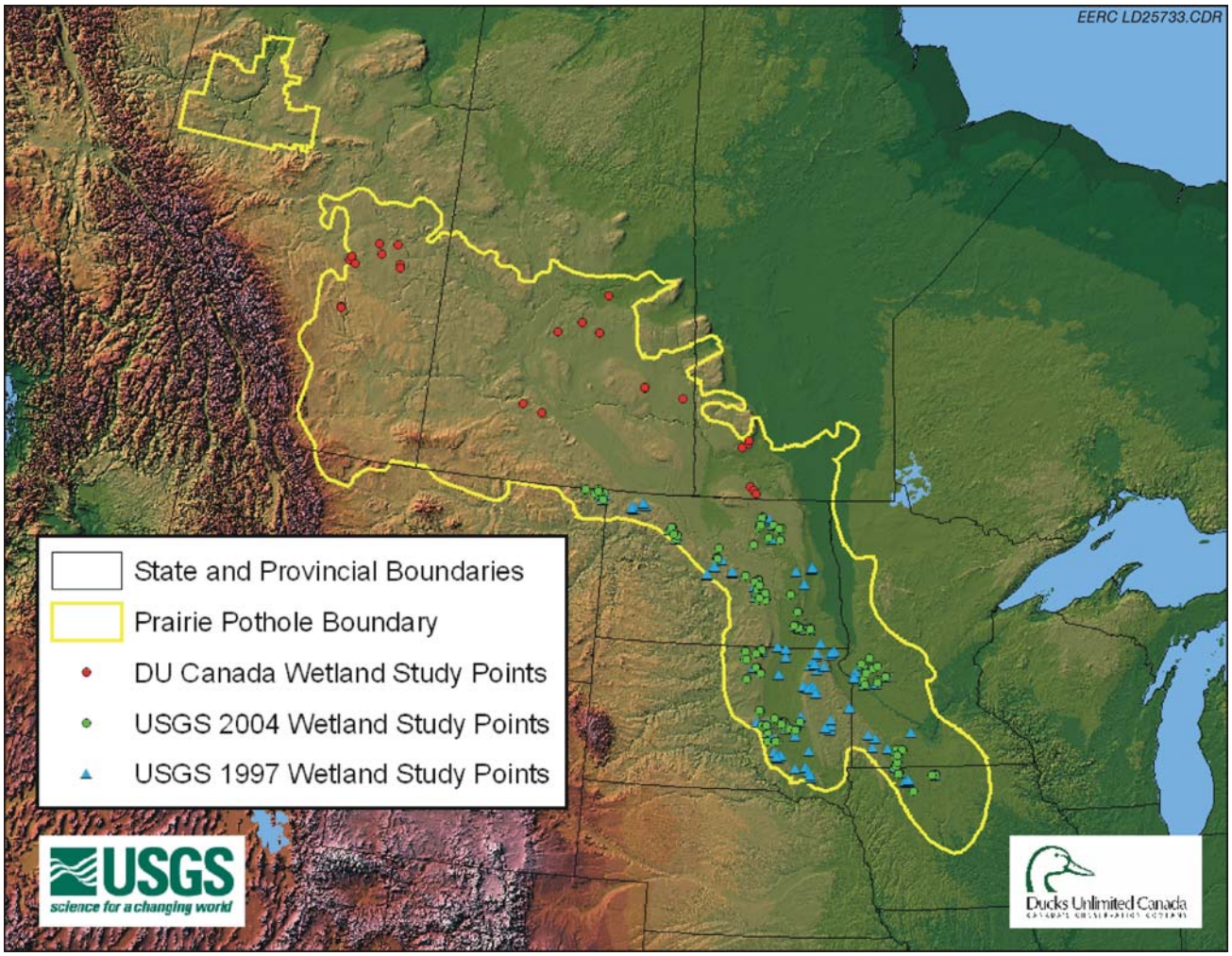

Figure 1. Extent of the PPR in Canada and the United States showing location of study sites.

in the surrounding catchments. Environmental benefits derived from wetland restorations in perennial grassland include a broad suite of ecosystem services, such as reduction in soil erosion, improved water quality, floodwater storage, and wildlife habitat (Knutsen and Euliss, 2001). However, recent research by scientists in the United States and Canada demonstrated that wetlands in the PPR were sinks of atmospheric carbon, but conversion of native wetlands to cultivated agriculture has shifted their function from net sinks to net sources of atmospheric carbon (Euliss et al., in press). It has been estimated that conversion of wetlands to agricultural cropland has resulted in an average soil organic carbon (SOC) loss of 10 $Mgha^{-1}$ (4.46 tons $acre^{-1}$) (Euliss et al., in press). Work by Euliss et al. (in press) also suggests that SOC stocks are rapidly replenished when wetlands are restored, averaging a rate of 3 Mg SOC ha^{-1} yr^{-1} (1.34 tons SOC $acre^{-1}$ yr^{-1}). Based on this work, a recent inventory of GHG emissions and sinks for the United States (U.S. Environmental Protection Agency, 2003) identified prairie wetlands restored on USDA CRP and Wetland Reserve Program

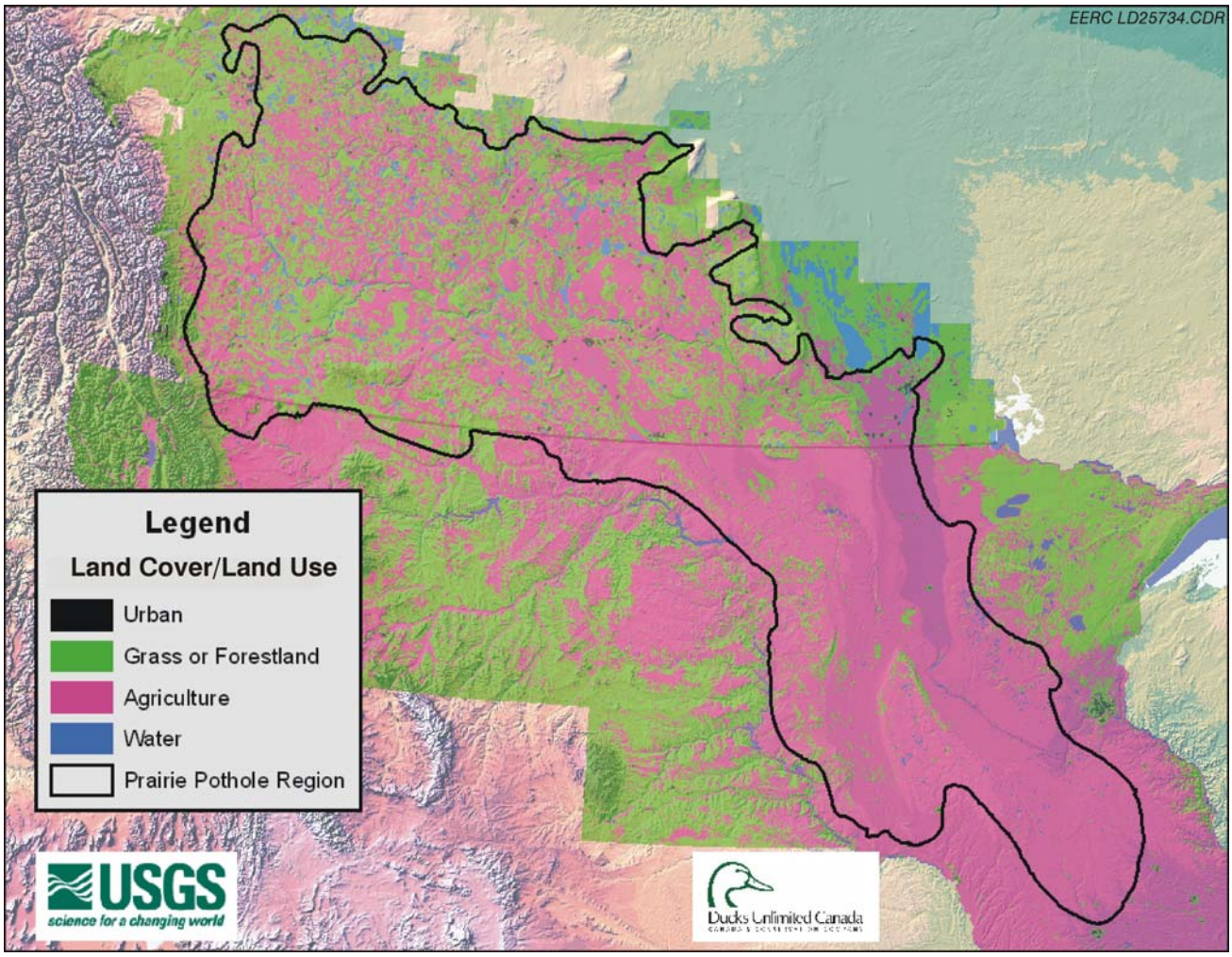

Figure 2. Extent of cropland and grassland in the PPR of the United States and Canada.

lands as carbon sinks. In addition, recent research suggests that restored wetlands may lower emission of the GHGs N_2O and CH_4 because of reduced enrichment from agricultural fertilizers (Merbach et al., 2002).

Study Goals

The finding that restored prairie wetlands are important carbon sinks that also may reduce other GHGs offers a promising opportunity to expand our knowledge of the role of wetlands in climate change mitigation in the PCOR Partnership region. The goal of this study was to develop a database to provide broad regional estimates of the potential of restoring previously farmed wetlands as a means to sequester atmospheric carbon in soil.

Additional topics discussed in this report include other forms of potential carbon storage processes and GHG reduction benefits from restored wetlands.

Methodology

To develop the regional database, we used SOC data collected from 174 wetlands during 1997 in the PPR of the United States (Euliss et al., in press) and

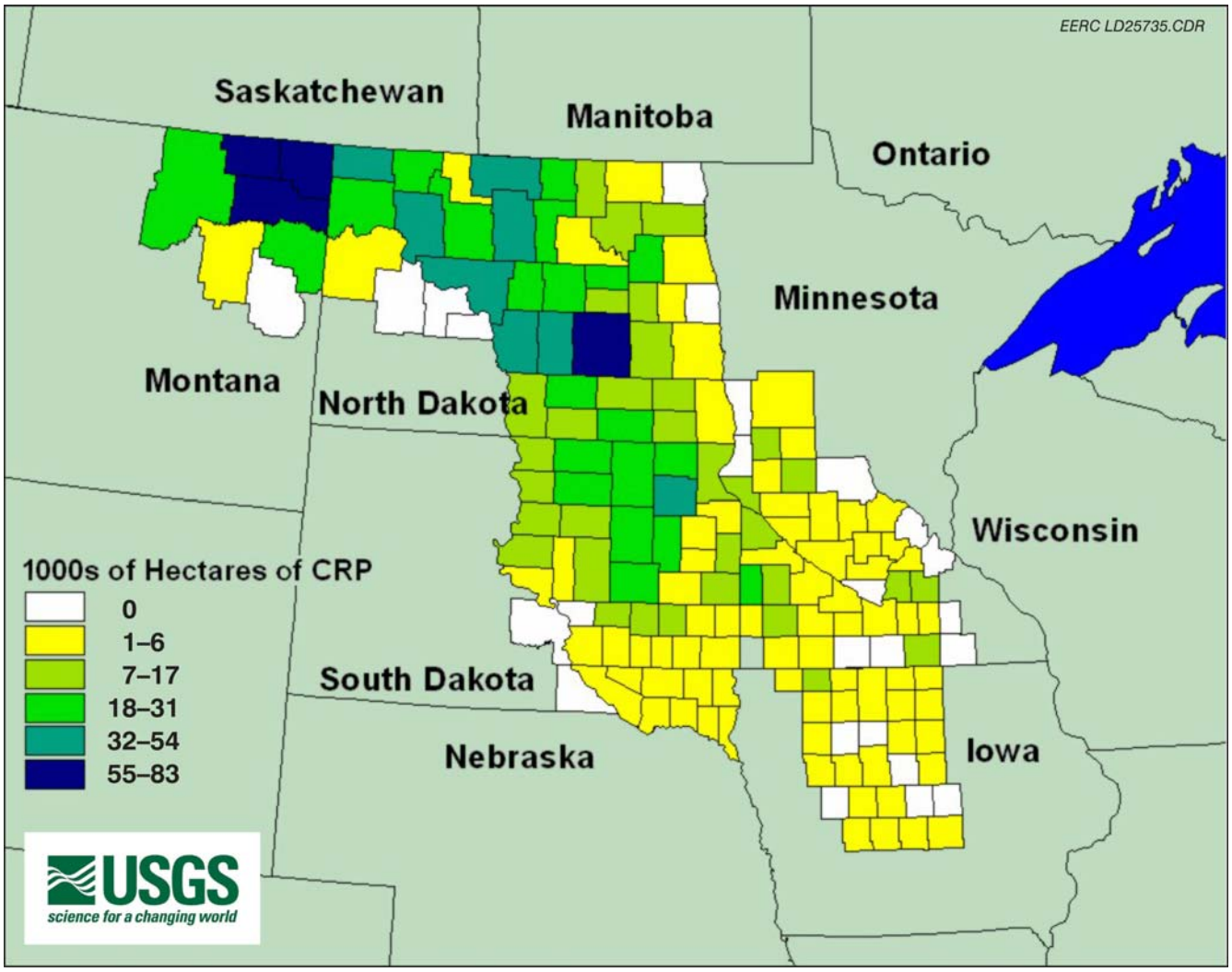

Figure 3. Hectares of land enrolled in CRP in 1997 by county in the United States PPR.

57 wetlands in Canada (McDougal et al., 2002) (Figure 1). Both the Canada and U.S. wetland carbon datasets include estimates of SOC for native prairie wetlands with no known history of cultivation and previously farmed wetlands that had been restored. These data were used to estimate the average SOC content for the 0–15-cm (0–6-in.) soil depth of native and previously farmed wetlands sampled within each major land resource area (MLRA) (U.S. Department of Agriculture, 1981) in the United States and for wetlands sampled within each province in Canada (Figure 4). We only used SOC estimates for the 0–15-cm (0–6-in.) depth because prior wetland work by Euliss et al. (in press) found that carbon content only differed in the surface 15 cm (6 in.), with greater carbon in native wetlands than in previously farmed wetlands. The differences in SOC stocks among native and previously farmed wetlands ranged from 1 to 25 Mg ha^{-1} (0.5 to 11.2 tons $acre^{-1}$), depending on MLRA (Euliss et al.,

in press), and from 8 to 67 Mg ha^{-1} (3.6 to 30 tons $acre^{-1}$), depending on province (McDougal, 2001).

Average SOC estimates for native and previously farmed wetlands were then multiplied to corresponding area estimates of palustrine wetlands (Cowardin et al., 1979) in cultivated cropland within each MLRA or province. The differences between native and previously farmed wetland carbon estimates were then aggregated by county (United States) and rural municipality district (Canada). The difference in SOC stocks between native and previously farmed wetlands represents the amount of carbon that has been depleted from cultivation and, hence, the amount of carbon that potentially could be replenished through restoration (i.e., carbon sequestration potential). Standard errors associated with estimates of carbon sequestration potential were estimated following Neter et al. (1982) and Stuart and Ord (1987) for products of constants with random variables and for products of independent random variables. Also aggregated for each county and rural municipality district in the database is the total area of palustrine wetlands in cultivated cropland (i.e., potentially restorable wetlands).

For the United States, the database includes two area estimates of palustrine wetlands in cultivated cropland. One estimate was generated by selecting palustrine wetlands in the National Wetland Inventory (NWI) (www.nwi.fws.gov) with cropland as the dominant land cover within a 20-meter (65-ft) buffer surrounding each wetland. Land cover was based on the 1992 National Land Cover Dataset (NLCD) (www.landcover.usgs.gov/natlandcover.asp) reclassified to four categories: crop, natural, water, and urban. A limitation of the NWI is that only existing and partially drained wetlands were mapped. Hence, well-drained wetlands are not well accounted for in the NWI. To account for other potentially restorable wetlands not mapped by the NWI, a second estimate was generated using the 1997 National Resources Inventory (NRI) (U.S. Department of Agriculture, 2000). Using the NRI, wetland areas with a broad cover category of "cultivated cropland" and a Food Security Act wetland (FSAWET) designation of "prior converted," "converted wetland," "farmed wetland," or "wetland" were aggregated to estimate area of wetlands in cultivated cropland by county.

In general, the four FSAWET designations included in this estimate account for existing wetlands (e.g., those typically mapped by the NWI) and wetlands that have been drained, dredged, filled, leveled, or otherwise manipulated to make production of an agricultural commodity possible (wetlands not typically included in the NWI). A limitation of the NRI database is that it does not provide estimates of wetland resources on federal lands. Additionally, the NRI comes from a statistically based sample survey and differs from the spatially explicit NWI database. For example, the NRI is limited to providing a statistical estimate of wetlands by county but cannot be used to explicitly identify the precise location of wetland areas.

To estimate wetland areas in Canada, the Ducks Unlimited Canada Wetland Inventory (Ducks Unlimited Canada, 1986) was overlain with the Prairie Farm Rehabilitation Administration (1995) generalized land cover. The wetland inventory included total wetland area for each quarter section overlain with land cover data. The percent of cropland in each quarter section was then multiplied by the corresponding total wetland area to estimate area of cropland wetlands. Similar to the NWI, the wetland inventory in Canada does not contain accurate estimates for drained or altered wetlands;

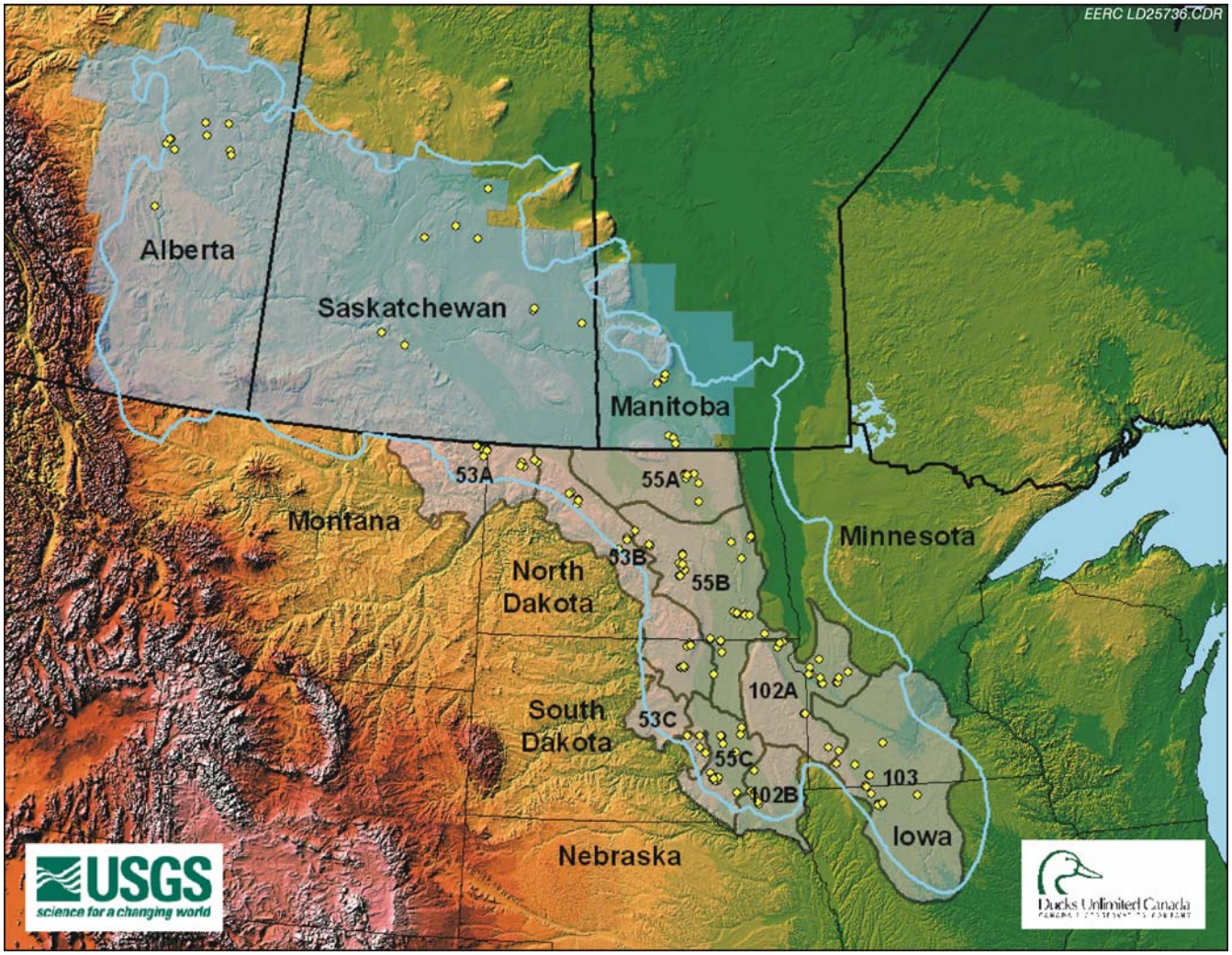

Figure 4. Wetland study sites within MLRAs in the United States and within provinces in Canada.

hence, wetland area estimates in the database are conservative.

RESULTS AND DISCUSSION

Database Summary of Wetland Carbon Sequestration Potential

We estimated that the Canadian PPR had 1.1 million ha (2.7 million acres) of potentially restorable wetlands (i.e., cropland wetlands), and in the United States, NWI- and NRI-derived estimates of restorable wetlands ranged from 1,364,000 to 3,844,000 ha (3.4 million to 9.5 million acres), respectively (Table 1). When combined, the area of potentially restorable wetlands in the PPR ranges from 2,464,000 to 4,944,000 ha (6.1 million to 12.2 million acres) (Table 1). Based on this range, restoration of cropland wetlands in the PPR has the potential to sequester 54,852,000 to 111,216,000 Mg (60.4 million to 122.6 million tons) of SOC (Table 1, Figure 5) or, in terms of CO_2 equivalents, 200,758,000 to 407,053,000 Mg (221.3 million to 448.7 million tons).

As expected, the NRI database accounted for more drained wetlands than the NWI. Consequently, spatial distribution of potential carbon storage (Figure 6) estimated using the NWI and the NRI differed the most in areas of Minnesota and Iowa that have been extensively drained (Tiner, 1984). However, for some counties in North and South Dakota, carbon storage potentials were greater based on NWI area estimates (Figure 7). This may suggest that the spatially explicit NWI more accurately quantifies wetland acreage where higher densities of wetlands remain than the statistically based NRI.

Our estimates of potential carbon storage are likely conservative because the estimates are based on previously farmed wetlands that had been restored previously and had accumulated carbon relative to their farmed condition. Hence, the difference in SOC content between actively farmed wetlands and native wetlands is likely greater than we estimated. Future refinements to the database will include estimates of carbon sequestration potentials based on the difference in SOC stocks between actively farmed and native wetlands. During 2004, an additional 270 wetlands in the U.S. PPR were sampled for SOC by scientists with the U.S. Geological Survey (Euliss et al., 2004) (Figure 1). This sample of wetlands included actively farmed wetlands in addition to restored and native prairie wetlands. Data from this later study are being analyzed and will be used to update our database during 2006. Work by Euliss et al. (in press) indicated that the replenishment of SOC stocks in restored wetlands previously depleted by cultivation increased at an average rate of 3 Mg ha^{-1} yr^{-1} (1.34 tons $acre^{-1}$ yr^{-1}). Based on this sequestration rate, most restored wetlands would replenish carbon stocks depleted by cultivation within 10 years (Euliss et al., in press).

Potential Carbon Stores in Standing Crops of Vegetation in Restored Wetlands

In addition to replenishment of SOC stocks, the vegetative community that rapidly develops in restored wetlands represents an additional pool of sequestered carbon (Euliss et al., in press). Prairie wetlands are highly productive, and the standing biomass of emergent plants in prairie wetlands can be >12 Mg ha^{-1} (5.5 tons $acre^{-1}$), depending on the species (van der Valk and Davis, 1978). If 45% of a 12 Mg ha^{-1} (5.5 tons $acre^{-1}$) standing crop is carbon by dry weight (Boyd, 1978), the

Table 1. Estimate of Potential Carbon Storage in Wetlands in the PPR of North America

	Area of Potentially Restorable Wetlands, mi^2	Potential Soil Organic Carbon Storage (SE),[a] million short tons	Potential Atmospheric Carbon (SE),[a] CO_2-C storage, million short tons
United States	5260[b] to 14,800[c]	17.3 (3.2) to 79.4 (15.4)	63.1 (11.7) to 290.5 (56.5)
Canada	4250[d]	43.2 (10.6)	158.2 (38.8)
Total	9500 to 19,100	60.4 (11.1) to 122.6 (18.7)	221.3 (40.5) to 448.7 (68.6)

[a] Standard error of the mean.
[b] Area of potentially restorable wetlands (i.e., wetland in cropland) estimated using the NWI database.
[c] Area of potentially restorable wetlands estimated using the NRI database (U.S. Department of Agriculture, 2000).
[d] Area of potentially restorable wetlands estimated using Ducks Unlimited Canada Wetland Inventory (Ducks Unlimited Canada, 1986).

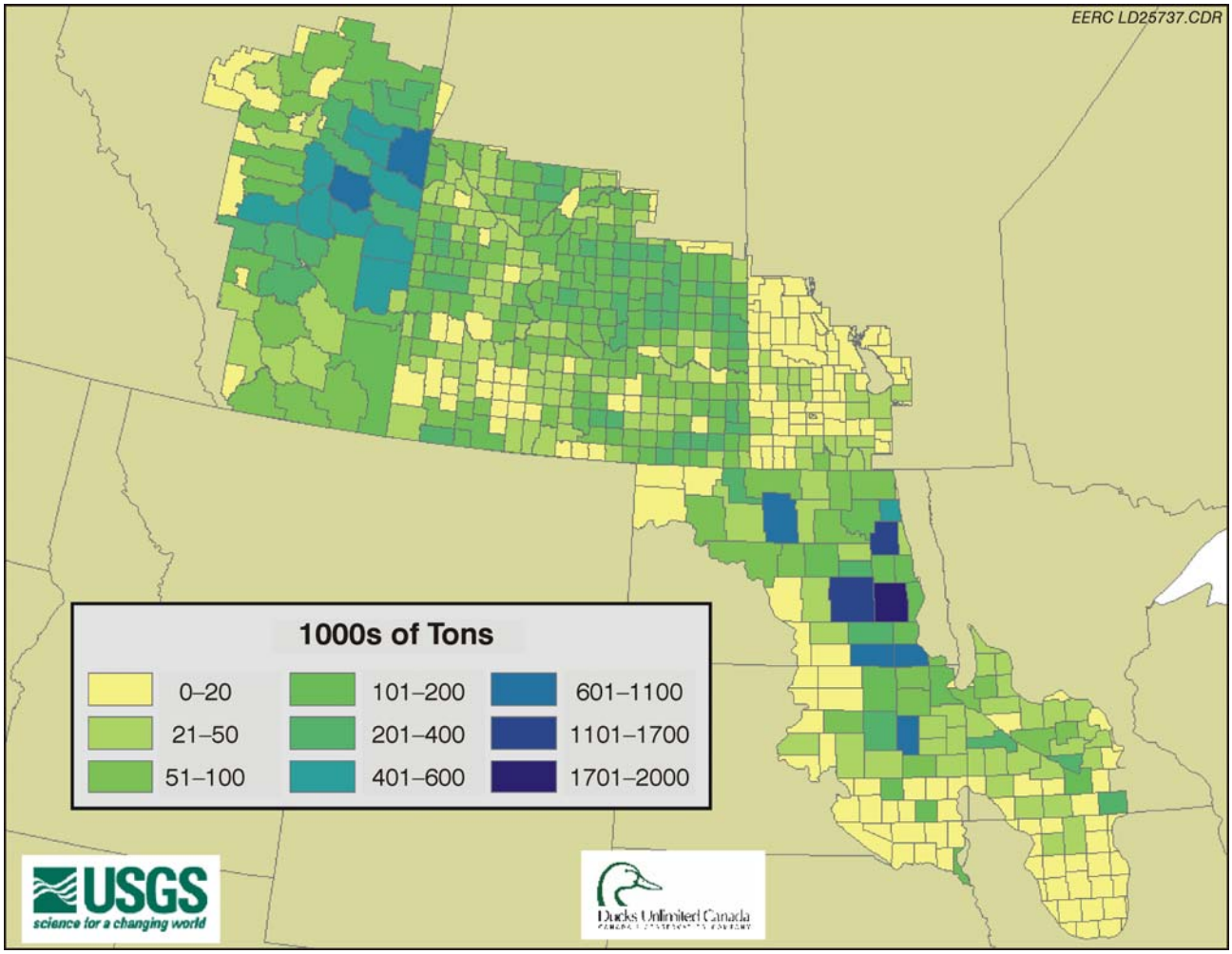

Figure 5. Carbon sequestration potential for counties and rural municipalities in the PPR based on wetland restoration. Areas of potentially restorable wetlands in the PPR of the United States were estimated using the NWI.

emergent vegetation would contain 5 Mg of carbon ha^{-1} (2.25 tons C $acre^{-1}$). Based on work by McDougal (2001) and Wetzel (2001), Euliss et al. (in press) applied an estimate of 7 Mg ha^{-1} (3.15 tons $acre^{-1}$) to estimate potential carbon storage associated wetland plants (including algae) in restored wetlands. If we apply the 5 Mg ha^{-1} (2.25 tons $acre^{-1}$) carbon storage estimate based on emergent vegetation to the area of potentially restorable wetlands in the PPR (Table 1), an additional carbon storage benefit of 12,320,000 to 24,720,000 Mg (13.6 million tons to 27.2 million tons) would be associated with the vegetative standing crop; the GHG benefit from the plant biomass would be almost immediate.

Based on these projections, it appears that substantial atmospheric carbon can be stored in the emergent vegetation of restored wetlands. Although carbon stored in vegetation is often viewed as not being permanent and susceptible to loss from disturbances such as fire, vegetative communities quickly reestablish following fire. Given the resilient nature of wetland

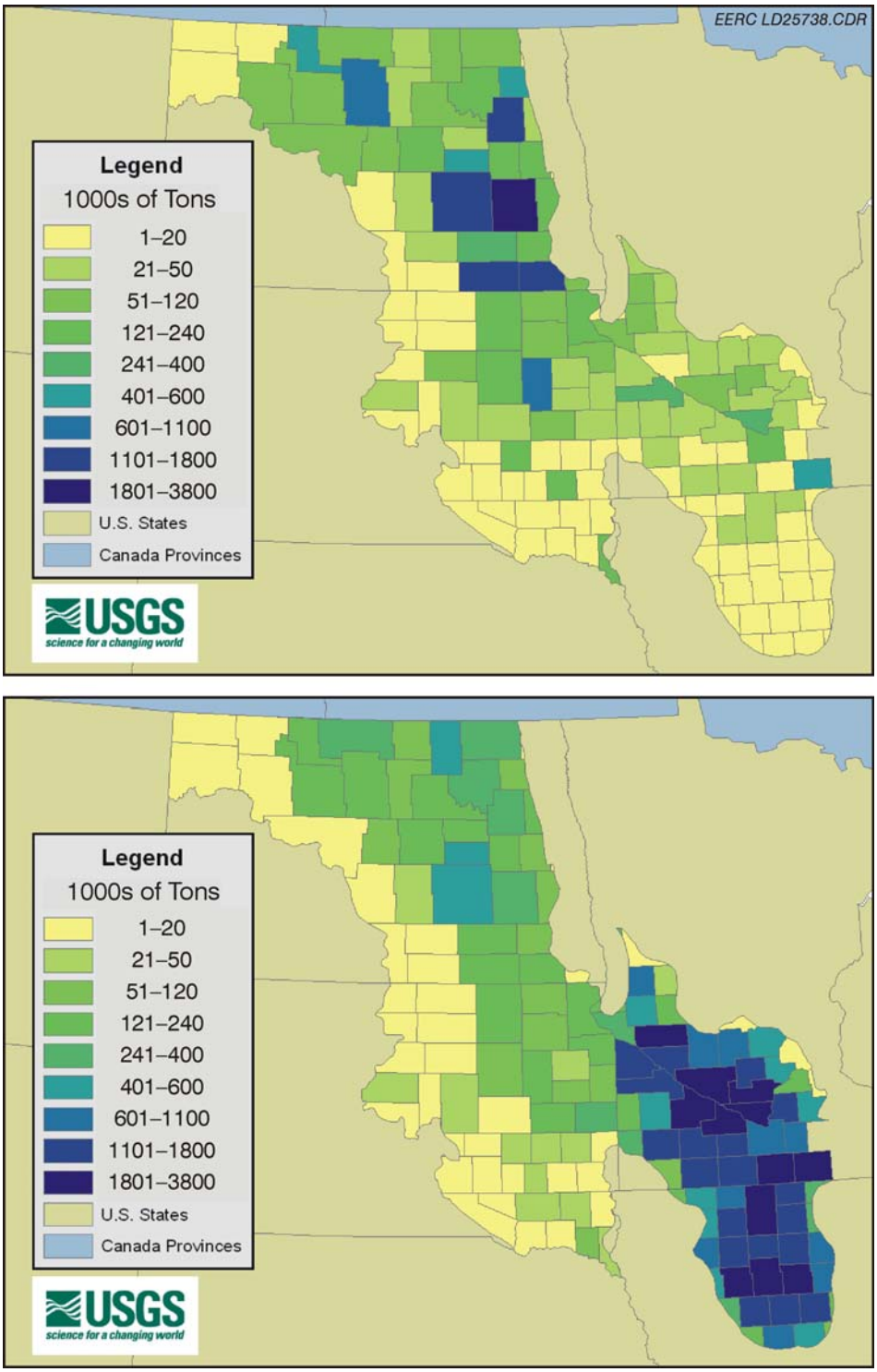

Figure 6. Carbon sequestration potential based on wetland restoration for counties in the U.S. PPR (by county) based on area of potentially restorable wetlands estimated using the NWI (top) and the NRI (bottom).

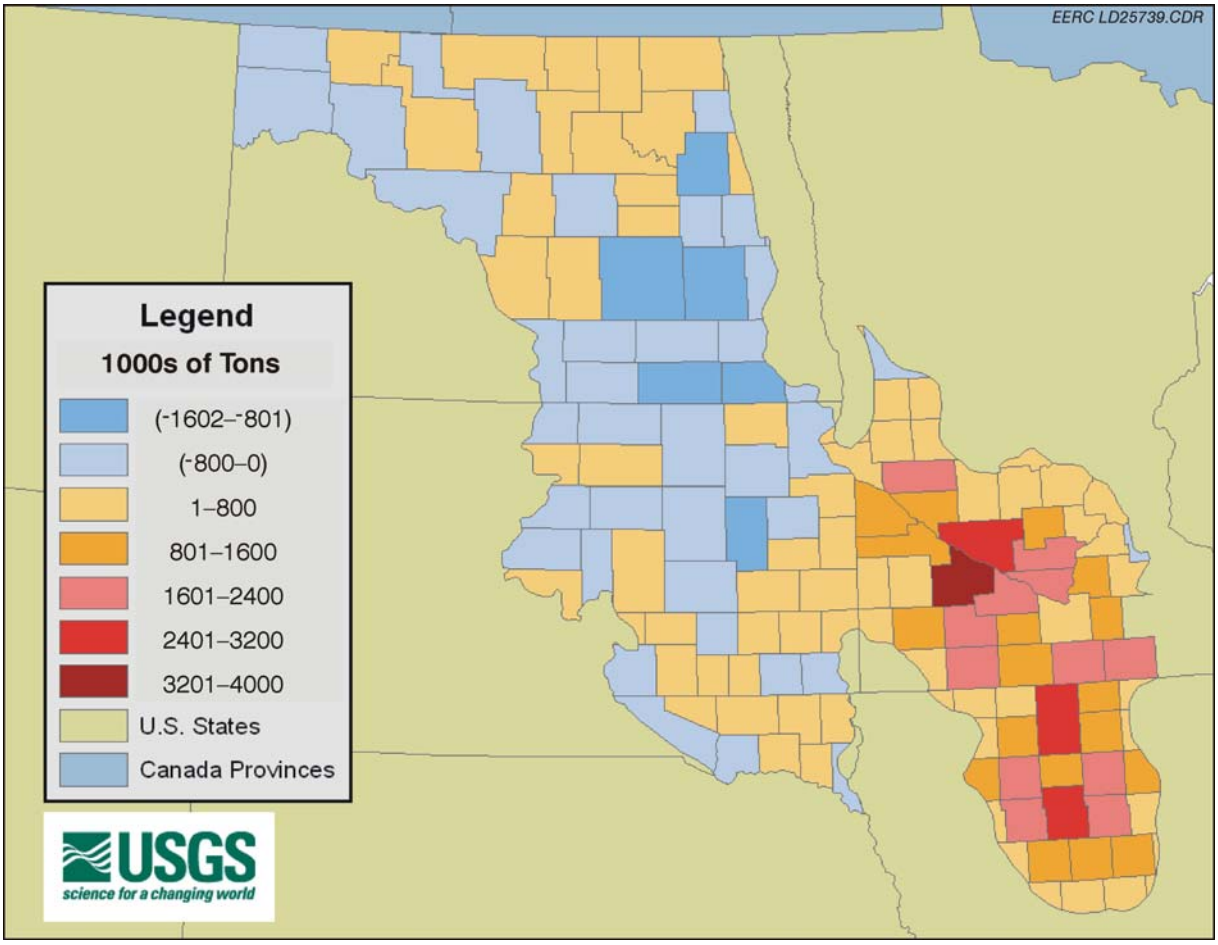

Figure 7. Difference between the NWI and the NRI estimates of wetland carbon sequestration potential based on wetland restoration for counties. Note the negative numbers indicate greater carbon storage potential based on the NWI and the positive estimates indicate greater potential based on the NRI.

plant communities, carbon storage in wetland vegetation is an almost immediate and rather constant form of carbon storage. Future research should be conducted to better quantify atmospheric carbon storage in standing crops of plants in restored wetlands. Some information on carbon stores in emergent vegetation was collected from the 270 wetlands sampled during 2004 by USGS scientists (Euliss et al., 2004). When available, these data will be incorporated into the regional database to project the potential carbon stores associated with emergent vegetation standing crops.

Other Potential Greenhouse Gas Benefits

Wetlands represent approximately 4% of the Earth's land area, yet they store almost 33% of all soil organic matter (Eswaran et al., 1993). Although wetlands are the most productive terrestrial ecosystems in the biosphere (Whitaker and Likens, 1973) and account for substantial carbon stores, concerns over emissions of GHGs such as CH_4 and N_2O slowed widespread recognition of restored wetlands as a mitigation strategy for climate change.

Methane and N_2O are very important GHGs, with global warming potentials of 21 and 310 (i.e., CO_2 equivalents), respectively (Intergovernmental Panel on Climate Change, 1996). Studies suggest that wetlands contribute 20% to 40% of the annual global atmospheric CH_4 flux; however, the lowest emissions come from temperate regions (10% of total wetland flux; Bartlett and Harriss, 1993) such as the PPR. Most studies demonstrating high emission of CH_4 are from permanently inundated marshes and peatlands (Updegraff et al., 2001; Whiting and Chanton, 2001) where the combination of organic soils and lengthy periods of soil reduction maximize CH_4 production. In contrast, most restored prairie wetlands are only seasonally inundated and have mineral soils (Order Mollisols) that in combination are less conducive for CH_4 production. Consequently, the notion that high CH_4 emissions may come from prairie wetlands has been influenced by studies conducted outside the PPR.

Although there are valid concerns over the release of CH_4 and N_2O emissions from restored wetlands, limited data suggest that restoration of previously farmed wetlands may actually reduce emission of these GHGs. Data from a glaciated region in northeastern Germany similar to the PPR suggests that enrichment of wetlands by nitrogen fertilizers and accelerated mineralization of soil organic matter elevates the emission of CH_4 and N_2O (Merbach et al., 2002). The emission of CH_4 and N_2O from German wetlands has been shown to increase up to 35-fold because of eutrophication of wetland basins by agricultural fertilizers. These findings from Germany are consistent with conceptual models and findings from field studies saying that nitrogen fertilization overloads the assimilative capacity of plants and microorganisms, resulting in enhanced emission of N_2O (Davidson et al., 2000). Most wetlands in the PPR are embedded in an agricultural landscape where they receive agricultural runoff-laden sediment and agricultural fertilizers (Gleason and Euliss, 1998). Consequently, converting cultivated cropland to permanent grass within restored wetland catchments should reduce nutrient enrichment in restored wetlands and lower emissions of N_2O and, possibly, CH_4 from wetland basins. Any reduction in emissions of CH_4 and N_2O that results from restorations would represent an additional GHG reduction benefit. Currently, there is no published literature on emission of CH_4 and N_2O from PPR wetlands. However, studies have been initiated in the United States and Canada by PCOR Partnership partners to evaluate the potential of restored wetlands to reduce emissions of CH_4 and N_2O.

CONCLUSIONS

The overarching goal of this study was to develop a database to estimate the regional potential of restoring previously farmed wetlands to sequester atmospheric carbon. We estimate that over a 10-year period, restoration of prairie wetlands has the potential to sequester 54,852,000 to 111,216,000 Mg (60.5 million to 122.6 million tons) of SOC. Additionally, we estimate that the vegetative standing crop in restored wetlands may represent an additional carbon storage benefit of 12,320,000 to 24,720,000 Mg (13.6 million to 27.2 million tons). To put this into perspective, the prairie pothole wetlands have the potential to sequester up to 25% of the transportation-related CO_2 emissions for the entire PCOR Partnership region annually (Jensen et al., 2005).

Limited data also suggest that restoration of wetlands may reduce other GHGs, especially N_2O and CH_4. It is important to remember that our estimates of carbon storage potential assume that all potentially restorable wetlands are restored. Although it is highly unlikely that wetland restoration will be fully implemented in the PPR, our results can

be used to demonstrate the potential of restored wetlands to sequester carbon relative to other terrestrial-based approaches. Euliss et al. (in press) demonstrated that restored wetlands can sequester over twice the SOC as no-till cropland on only about 17% of the total land area in the PPR. Further, on an area basis, wetlands sequester carbon at rates greater than conversion of cropland to permanent grass (Euliss et al., in press).

This work demonstrates the potential of restored wetlands to sequester carbon within the PCOR Partnership region. However, the importance of prairie wetlands to sequester carbon is a recent development, and thus far, wetland restoration has not been targeted by industry to offset emissions. It is important to remember that our approach to carbon sequestration in wetlands is based on wetlands that are restored to provide for a broad suite of ecosystem services ancillary to carbon sequestration, such as reduction in soil erosion, improved water quality, floodwater storage, and wildlife habitat (Knutsen and Euliss, 2001). Hence, restoration technology has not been developed or implemented specifically to maximize the carbon sequestration potential of restored wetlands; therefore, our sequestration estimates are conservative. The economics of maximizing carbon storage in wetlands at the expense of other economic and ecological benefits to society, while feasible, is likely not sustainable for future generations of Americans. Given the strong environmental concerns of modern society, we believe that the best approaches to carbon sequestration in wetland settings would be those that would store carbon without negatively impacting any of the other ecosystem services provided by restored wetlands.

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