FACT SHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Plains CO_2 Reduction (PCOR) Partnership – Phase II	
Contacts:	Name Organization E-Mail	
DOE/NETL Project Mgr.	Andrea McNemar, U.S. Department of Energy, andrea.mcnemar@netl.doe.gov	
Principal Investigator	Edward Steadman	
Field Test Information:		
Field Test Name	Terrestrial Field Validation Test	
Test Location	North Dakota, South Dakota, Minnesota, Montana, Iowa	
Amount and Source of CO_2	Tons N/A	Source Atmospheric CO_2
Field Test Partners (Primary Sponsors)	Ducks Unlimited, Inc.	
	U.S. Geological Survey Northern Prairie Wildlife Research Center	
	North Dakota State University	

Summary of Field Test Site and Operations:

With increasing levels of greenhouse gases (GHGs) in the atmosphere and concerns over their effects on climate and weather, a surge in interest in the various methods of carbon sequestration is occurring. Among them is terrestrial sequestration, the process of removing carbon dioxide (CO_2) from the atmosphere by plants via photosynthesis and storing the carbon in biomass and soils. Terrestrial carbon sequestration projects offer an immediate and cost-effective strategy to reduce atmospheric emissions while other methods (i.e., geologic sequestration) are advanced. Secondarily, land-use practices that enhance terrestrial sequestration generally also enhance soil, air, and water quality and improve wildlife habitat.

As part of this project, the Energy & Environmental Research Center; Ducks Unlimited, Inc.; the U.S. Geological Survey Northern Prairie Wildlife Research Center; and North Dakota State University demonstrated optimal practices for terrestrially sequestering CO_2 at multiple sites located in the Prairie Pothole Region (PPR) of North America. PCOR Partnership partners collected soil and gas samples from various age cohorts of restored grasslands, native prairie, cropland, and wetlands throughout Montana, North and South Dakota, Minnesota, and Iowa (Figure 1). In addition to carbon uptake and storage measurements, methane (CH_4) and nitrous oxide (N_2O) gas fluxes were also measured to estimate the net GHG flux of each management practice. These data have been instrumental in advancing terrestrial carbon credits from the PCOR Partnership region into the marketplace.

Terrestrial sequestration projects create carbon credits that can be transacted in voluntary or mandatory regional, national, or international carbon markets. Under a mandatory GHG reduction program, these credits provide entities with alternative compliance options, in addition to direct reductions, to reduce GHG emissions while new less carbon-intensive fuels and technologies are developed.

Many carbon market stakeholders are involved in bringing terrestrial offsets to end users, including those involved in financing, producing, generating, providing, aggregating, and/or marketing GHG emission reductions. Project results have supported the development of protocols for terrestrial carbon credit development and trading and are intended to serve as a model to promote and implement terrestrial sequestration across the PPR. The launch of the Ducks Unlimited Carbon Credit Program provides landowners with a revenue stream novel to the agricultural economy of the plains: sequestered carbon. Through this program, landowners sign perpetual grassland easements while, at the same time, they are conveying carbon rights to be bundled and sold on the open market. Results from this project have provided the science and business process framework needed for project developers and investors to advance emission reduction targets as well as achieve financial returns in this rapidly emerging market.

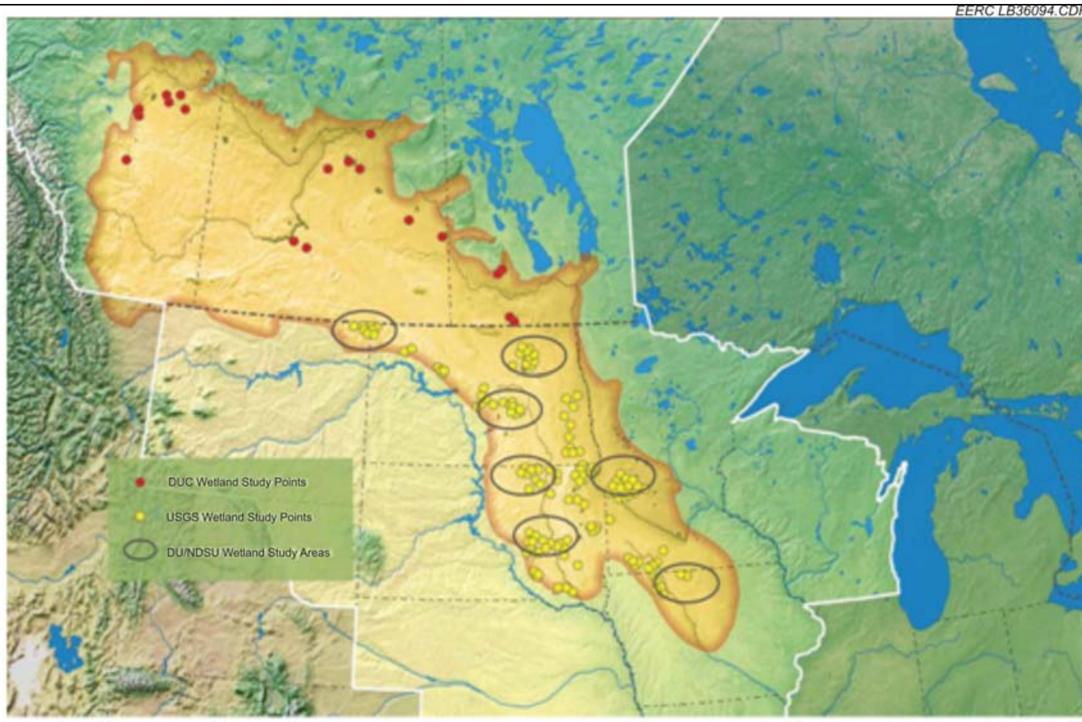


Figure 1. Terrestrial sample locations.

Research Objectives:

The objective of the terrestrial field validation was to develop the technical capacity to systematically identify, develop, and apply alternate land-use management practices to the prairie pothole ecosystem (at both a local and regional scale) that results in carbon sequestration and the monetization of carbon offsets. These reductions include emission offsets achieved by defining best management practices (BMPs) for sequestering carbon and reducing GHGs in restored wetland/grassland complexes. The field validation included assessments of both the socioeconomic and physical/chemical environment.

Summary of Modeling and MVA Efforts:

Measurement Technique	Measurement Parameters	Application
Static Chamber Approach	Measurement of fluxes of N_2O, CH_4, and CO_2	Gas exchange measurements
Various Meters/Probes and Laboratory Sampling Techniques	Volumetric water content (θ), total soil porosity (P_t), soil temperature, precipitation, and climate and soil properties	To determine influences on gas flux and carbon storage
Core Sampling (soil probe)	Soil bulk density, soil moisture, and soil analysis for carbon	Measurement of carbon in soil

Accomplishments to Date:

- Completed experimental design package, Health and Safety Plan, National Environmental Policy Act compliance document and Regulatory Permitting Action Plan, Outreach Action Plan, Sampling Protocol Plan, and Regional Technology Implementation Plan.

- Terrestrial field validation test sites were selected and instrumented for sampling.

- Gas emissions were collected from 17 wetlands in north-central South Dakota on a biweekly basis (11,625 individual gas flux samples collected).
- Soil samples were collected on 14,250 acres of native grassland, restored grassland, and cropland to date (2850 soil samples collected). Sample sites are located in North and South Dakota, Montana, Iowa, and Minnesota. These data have been instrumental in advancing terrestrial carbon credits in the marketplace.
- An Oracle software-based carbon-tracking database was officially launched for use in May 2008. This database provides carbon transaction information complete with serial numbers for unique carbon units and tons and includes business requirements generated for calculating, inventorying, and tracking offsets. These reports were used in a recent grassland carbon credit transaction.
- Project results have supported the accreditation of an Avoided Grassland Conversion project with the Climate, Community, and Biodiversity Standard (CCBS 2008). This project was the first to be certified by the standard in the United States and is the first Avoided Grassland Conversion project in the world.
- Business model/processes for aggregating and transacting carbon offsets in a voluntary market is complete. Legal documents for easements (including carbon rights) are complete.
- Evaluation of U.S. Department of Energy Technical Guidelines is complete, particularly as they relate to grassland sequestration, aggregator roles, and criteria for additionality, leakage, and permanence.
- An economic model was constructed to examine land units affected by various wetland restoration actions. This model, along with another that predicts the probability that a parcel of land will remain in a particular land use (with varying commodity prices and subsidy and conservation payments), was used in a "price point" and/or "willingness to sell/convert" analysis on private lands in the PCOR Partnership region.

Summarize Target Sink Storage Opportunities and Benefits to the Region:

Areas targeted for the terrestrial field validation test included grasslands (native and restored) and wetlands (native, restored, and cropland) throughout the PPR. These areas, when properly managed and/or restored, offer significant immediate storage opportunities.

Landowners in the PPR can benefit financially by payments received for conveying carbon rights through carbon credit programs. These payments would be in addition to traditional farm program or easement payments. The public sector will benefit by use and nonuse values of wetland/grassland areas as they pertain to recreational activities (e.g., hunting, fishing, and bird watching) and other cobenefits such as flood attenuation, water quality, groundwater recharge, sediment loading, and erosion reduction.

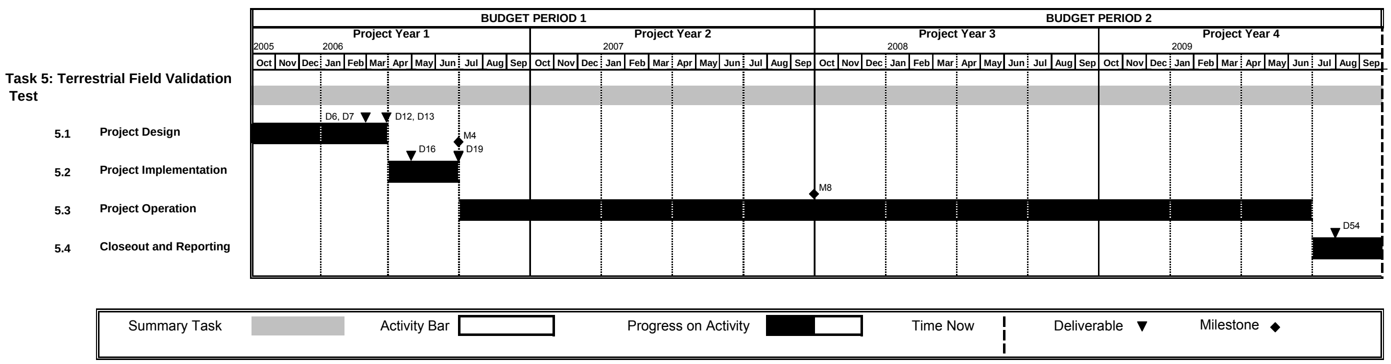
In addition to the physical/chemical validation tests, the PCOR Partnership determined the sociological and economic feasibility of terrestrial sequestration offsets. Economic feasibility was assessed based on research to determine price points for terrestrial sequestration and by modeling economic feasibility when carbon is included in the financial portfolio of a typical landowner. Spatial models were developed that integrate the physical/chemical capabilities to sequester carbon with the socioeconomic and willingness-to-participate information gleaned from other facets of the validation test.

Ducks Unlimited, Inc., continues to aggregate terrestrial carbon credits from numerous landowners, bundling and transferring them to a company that specializes in carbon credit marketing. As a result of key protocols developed under this project, approximately 130,000 tons of native grassland carbon offsets generated in the PCOR Partnership region were sold in September 2008, and negotiations are currently under way to transact an additional 600,000 tons.

Cost:	**Field Project Key Dates:**
Total Field Project Cost: $3,123,334	**Baseline Completed:** NA
DOE Share: $2,844,788 91%	**Drilling Operations Begin:** NA
Non-DOE Share: $278,546 9%	**Injection Operations Begin:** NA
	MVA Events: Through duration of project

Field Test Schedule and Milestones (Gantt Chart):

- Experimental design package completed February 2006.
- National Environmental Policy Act Compliance document completed February 2006.
- Site Health and Safety Plan completed March 2006.
- Regulatory Permitting Action Plan completed March 2006.
- Outreach Action Plan completed April 2006.
- Sampling protocols completed June 2006.
- Regional Technology Implementation Plan completed July 2009.



Key for Deliverables ▼
D6 Terrestrial Field Validation Test Site – Experimental Design Package
D7 Terrestrial Field Validation Test Site – NEPA Compliance Document
D12 Terrestrial Field Validation Test Site – Site Health & Safety Plan
D13 Terrestrial Field Validation Test Site – Regulatory Permitting Action Plan
D16 Terrestrial Field Validation Test Site – Outreach Action Plan
D19 Terrestrial Field Validation Test Site – Sampling Protocols
D54 Terrestrial Field Validation Test Site – Regional Technology Implementation Plan

Key for Milestones ◆
M4 Terrestrial Field Validation Test Site – Sampling Protocol Completed
M8 Fact Sheet 11 Completed – Best Management Practices for Terrestrial Carbon Sequestration on Private Lands in the Prairie Pothole Region

Additional Information

Measurement of Gas Fluxes

Fluxes of N_2O, CH_4, and CO_2 were measured on a biweekly basis during the growing season (approximately May–September) using a static (non-steady-state) chamber approach (Livingston and Hutchinson, 1995). In each catchment, eight (five wetland and three upland) monitoring locations were established along a transect extending from the wetland center to the catchment boundary. Five monitoring locations were established in the wetland zone by placing one chamber in the wetland center, one in the wetland–upland transition zone, and three at equal-distance intervals between the wetland center and wetland–upland transition zone. Monitoring locations were established in the upland zone by placing a chamber in the center of each of the three landscape positions: the toeslope, midslope, and shoulder slope. The placement of eight chambers along transects covered a range of soil moisture conditions (i.e., soil water-filled pore space [WFPS]) that influences emission of gases; studies suggested that the relative contribution of nitrification and denitrification to N_2O and dinitrogen (N_2) emissions varies with WFPS (Davidson et al., 2000). WFPS ranged from field capacity (60% WFPS) at the wetland–upland transition zone to saturated (100%) near the wetland center. Changes in WFPS along transects were gradual rather than abrupt because of low relief associated with depressional wetlands. Hence, soil moisture did vary more than 10% (e.g., 60%, 70%, 80%, 90%, 100%) between chambers along transects.

To start gas flux measurements, chambers were sealed to the chamber bases at dry sites, and floating chambers were deployed at wet sites. Gases were allowed to accumulate in the chamber headspace for a minimum of 30 minutes after deployment. Headspace gas samples were withdrawn from the chamber through a septum port by syringe. Samples of the initial gas concentration were obtained by drawing ambient atmosphere into a syringe at the start of the flux measurement. All syringe gas samples were immediately transferred to and stored overpressurized in 10-mL preevacuated (<10 torr) crimp-top serum bottles fitted with thick gas-impermeable septa/stoppers. Laboratory tests showed that N_2O, CH_4, and CO_2 concentrations remained stable within the overpressurized serum bottles for at least 3 weeks (University of Wisconsin – Stevens Point [UWSP] Dissolved Gas Laboratory).

Gas samples were analyzed by gas chromatography within 1 week of sampling. A gas chromatograph (SRI Model 8610) equipped with electron capture (ECD) and flame ionization (FID) detectors and two 10-port valves was used to measure N_2O, CH_4, and CO_2 with a single injection of sample. The instrument configuration and operating conditions (modified from Coolman and Robarge [1995] and Lotfield et al. [1997]) provide minimum detection levels of <3 ppbv N_2O (ECD), <10 ppbv CH_4 (FID), and <1 ppmv CO_2 (ECD and FID). Coefficients of variation for detection of the three target gases within ambient air were less than 2% (UWSP Dissolved Gas Laboratory). The gas chromatograph was calibrated with commercial N_2O, CH_4, and CO_2 air blends verified against a reference standard from the National Oceanic and Atmospheric Administration.

Measurement of Covariables Known to Influence Gas Fluxes

Water-Filled Pore Space: Along a moisture gradient from the upland zone to the center of each wetland, WFPS was expected to exert important control over trace gas production in the soil (Davidson et al., 2000). The formation of N_2O as a by-product of nitrification and denitrification reactions peaks at about 60% WFPS (Davidson et al., 2000). Below 60% WFPS, NO (nitric oxide) becomes an increasingly dominant gaseous by-product of nitrification relative to N_2O, while above 80%, N_2O tends to be converted to N_2 gas. The formation of CH_4 as a product of anaerobic soil respiration becomes increasingly favored as WFPS approaches 100%. Soil WFPS is expressed as the ratio of volumetric water content (θ) and total soil porosity (P_t):

$$\%WFPS = (\theta/P_t) \bullet 100$$

During each biweekly sampling event, θ was measured in the top 15 cm of the soil near each gas chamber along each transect using a TH_2O soil moisture meter. Total porosity (P_t) in the top 15 cm of soil was determined from bulk density (ρ_b) and particle density (ρ_s) according to:

$$P_t = 1 - \rho_b/\rho_s$$

Soil densities were mapped on a one-time basis along each transect using the core (ρ_b) and pycnometer (ρ_s) methods (Klute, 1986), respectively. Soil densities were assumed to be constant during the study period.

Soil Temperature: Microbially mediated nitrification and denitrification processes are influenced by soil temperature (Paul and Clark, 1996). During each biweekly sampling event, temperature (°C) was measured in the top 15 cm of the soil near each gas chamber along each transect using a soil thermometer. Additionally, temperature data loggers were buried in the center of each wetland to provide a continuous (e.g., hourly) record of soil temperature fluctuations.

Precipitation and Climate: A rain gauge was installed at each wetland. Precipitation was monitored weekly and after major or unusual precipitation events.

Soil Properties: Soil samples were collected to a depth of 15 cm near monitoring locations and submitted for determination of the following: extractable nitrate (NO_3) and ammonium (NH_4), total nitrogen, total carbon, organic carbon, inorganic carbon, extractable phosphorus (P), bulk density (g/cm^3), and soil texture. Methods of determination follow those described by Page et al. (1982) and Klute (1986).

Wetland and Catchment Morphometry Information: Nutrient loading and groundwater flows are influenced by catchment morphometry. A topographic field survey was conducted on all catchments. Wetland catchments were surveyed using a global positioning system total station (Trimble, 5700). Using the program ForeSight version 1.3 (Tripod Data Systems, Inc., Corvallis, Oregon), estimations of wetland and upland areas (ha), maximum depth (m), and wetland volume (ha-m) were made. Additionally, the average grade (%) and length (m) of the upland slopes were estimated.

Statistical Analysis

The analysis of covariance with repeated measures (Milliken and Johnson, 2002) was employed to test for differences in gas emissions (mass · area^{-1} · time^{-1}) with respect to land use treatment (i.e., farmed, restored, and native prairie wetlands) while controlling for covariates (e.g., WFPS, temperature).

References:

Coolman, R.M., and Robarge, W.P., 1995, Sampling nitrous oxide emissions from humid tropical ecosystems: Journal of Biogeography, v. 22, p. 381–391.

Davidson, E.A., Keller, M., Erickson, H.E., Verchot, L.V., and VeldKamp, E., 2000, Testing a conceptual model of soil emissions of nitrous and nitric oxide: BioScience, v. 50, p. 667–680.

Klute, A., ed., 1986, Methods of soil analysis—Part 1—physical and mineralogical methods, 2d ed.: Madison, Wisconsin, Soil Science Society of America.

Livingston, G.P., and Hutchinson, G.L., 1995, Enclosure-based measurement of trace gas exchange—applications and sources of error, *in* Matson, P.A., and Harriss, R.S., eds., Biogenic trace gases—measuring emissions from soil and water: London, Blackwell Science.

Lotfield, N., Flessa, H., Augustin, J., and Beese, F., 1997, Automated gas chromatographic system for rapid analysis of the atmospheric trace gases methane, carbon dioxide, and nitrous oxide: Journal of Environmental Quality, v. 26, p. 560–564.

Milliken, G.A., and Johnson, D.E., 2002, Analysis of messy data, Volume III—Analysis of Covariance: New York, New York, Chapman and Hall/CRC, p. 605.

Page, A.L., Miller, R.H., and Keeney, D.R., 1982, Methods of soil analysis—Part 2—chemical and microbiological properties, 2d ed: Madison, Wisconsin, Soil Science Society of America.

Paul, E.A., and Clark, F.E., 1996, Soil microbiology and biochemistry, 2d ed.: San Diego, California, Academic Press.