FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Big Sky Carbon Sequestration Partnership
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Principal Investigator	Lee Spangler
Field Test Information: Field Test Name	Cropland Field Validation (+ remote sensing work)
Test Location	North central Montana
Amount and Source of CO_2	Tons Source: atmosphere
Field Test Partners (Primary Sponsors)	Washington State University, Montana State University, Los Alamos National Lab

Summary of Field Test Site and Operations:

Cropland Field Validation

The cropland field validation test is being conducted in north central Montana which consists of 2+ million ha of cropland (the most representative cropping region in Montana), and in other select locations in the region. The predominant land use for the region is small grain agriculture (i.e, wheat, barley, peas). The region has been under cultivation since the early 1900's with soil management progressing from intensive moldboard plowing to less intensive cultivation to no-till or direct-seed management. The adoption of direct-seed management in MT is not well documented and as a part of Phase II we are utilizing satellite imagery to better document land management in the region.

Soil carbon sequestration in the region is being researched in 1) controlled sites to develop regional estimates of carbon storage rates as a function of management and 2) measuring, monitoring, and verifying (MMV) carbon change using proximal sensing methods at sites enrolled in a pilot carbon trading mechanism. During the cropland field validation test, existing field trials at six controlled sites (farms, with multiple fields) with a range of management practices (till vs. no till and alternate year fallow vs. continuous cropping) will be extended over the duration of the project. Several MMV techniques (lab-based and "on-the-go" visible and near infrared spectroscopy (VisNIR), laser-induced breakdown spectroscopy (LIBS), and combined VisNIR – LIBS spectroscopy) will be evaluated at eight independent enrolled sites.

Based upon the results of the controlled and enrolled cropland field tests, BSCSP will prepare a Cropland Terrestrial Project Planning Handbook that details cropland sequestration project design and best management practices.

Remote Sensing Validation Group

The project area for the MMV Field Validation Group is located within the Golden Triangle Region in North Central Montana. This region is roughly includes land between Havre, Shelby, Conrad, Great Falls, and Fort Benton with the actual project area constrained to land falling within Landsat image scenes 39-26 and 39-27.

Field locations for data collection were determined by applying a random point generator to a Landsat Thematic Mapper (TM) Image set following an image masking process to remove non-agricultural areas. A file containing road spatial reference area was then overlaid onto the imagery and all generated points located away

from a road structure were removed, resulting in 500 semi-random field reference locations. These sites were physically visited June 2007. Data collected included cropping status (vegetated or fallow), crop type, and tillage management (tillage vs. no-till). A portion of the sites visited included rangeland, as we were unable to obtain rangeland information for the image masking process. The resulting reference field data included 421 cropland sites and 101 rangeland sites. These locations included 220 fields under no-till management and 201 fields under conventional tillage management. 112 of these sites were fallowed and 309 were vegetated. Data for over 500 conservation reserve sites were provided by the Montana Farm Service Agency.

An image-object or object-oriented (O-O) approach is being used for cropland classification. In this approach raster-based satellite imagery were segmented to generate vector-based data representative of cropland fields. The field-based spectral data associated with the field reference locations were incorporated into a Breiman Cutler CART-based (Classification and Regression Tree) model (presented as randomForest). The final result will be a trained model capable of accurately classifying no-till, tillage and conservation reserve land using Landsat satellite imagery representative of cropland within North Central Montana. The resulting model will also accurately predict vegetation status (cropped vs. fallow). Change detection analysis will allow image classifications from multiple years to be evaluated to also determine cropping intensity on a per-field basis. Classification accuracy will be assessed using both an out-of-bag approach generated within the randomForest model. An independent assessment will also be conducted. These results will be presented as total and class accuracies and associated kappa-based statistics.

Research Objectives:

The overall goal of this project is to demonstrate that terrestrial sequestration in cropland is a safe and permanent method to mitigate greenhouse gas emissions. The Partnership's objectives for this project are to quantify and determine cropland management practices that optimize carbon sequestration (controlled site field validation) and develop MMV protocols to evaluate carbon sequestration for enrolled farms (enrolled farm field validation). Remote sensing, using Landsat imagery, will be evaluated as a cost effective verification tool for monitoring enrolled acreages and to provide the areal extent of potential C sequestration for the region.

Remote Sensing Validation

The objective of this component is to determine if remote sensing can be used to accurately identify agricultural practices specified in carbon contract agreements as specified by the National Carbon Offset Coalition. This will include using remote sensing techniques to identify no-till, crop intensity, and conservation reserve lands. Crop intensity is defined as the proportion of years a field includes crop cover as opposed to summer fallow; conservation reserve indicates the use of perennial crop cover as opposed to annual cover. We have hypothesized that these management practices can be classified with > 85% accuracy through the object-oriented (O-O) classification of Landsat satellite imagery. The resulting land use data will also be used to calculate cropland carbon sequestration attributed by current cropland management trends, thereby estimating regional carbon intake contributed by no-till, conservation reserve, and crop intensity. The potential for increased sequestration given universal adoption of these management practices was also assessed.

Summary of Modeling and MMV Efforts: (Use the table provided for MMV)

Standard carbon measurement, employing dry combustion and modified pressure calcimeter analysis for total carbon and inorganic carbon, respectively, is a well documented and accepted method. This method relies on efficient sampling designs to measure SOC temporally and spatially. 2008 fall soil sampling will provide critical look at effects of management practices on SOC after 6 years, often regarded as the first checkpoint where delta C can be reliably measured against background TOC. It will likely be 1st quarter 2009 before those results are available.

Visible and near-infrared diffuse reflectance spectroscopy (VisNIR) spectral signatures of materials are defined by their reflectance, or absorbance, as a function of wavelength. These signatures are due to electronic transitions of atoms and vibrational stretching and bending of structural groups of atoms that form molecules and crystals. SOC and SIC are both molecular components of soil and VisNIR has been shown to semi-quantitatively estimate SOC and SIC in soils. "On-the-go" VisNIR has the advantage of quickly collecting large amounts of spatial VisNIR data to map soil variability within fields.

Laser-induced breakdown spectroscopy (LIBS) is fundamentally an elemental analysis technique. LIBS involves directing a focused Nd:YAG onto the surface of the target material The focused laser ablates a small amount of surface material from the surface producing a supersonically expanding plasma of electronically excited ions, atoms, and small molecules. These excited species emit light as they relax back to lower electronic states at wavelengths indicative of the identity of the elements present in the sample. Some of this emission is directed into a dispersive spectrometer and the resulting spectrum is detected with a charge-coupled device (CCD) detector.

Combining VisNIR and LIBS sensors should theoretically provide quantitative determination of SOC and SIC.

Remote Sensing Validation

The Remote Sensing Validation Group has obtained all necessary satellite imagery for the cropland land use classification study. The resulting imagery includes six Landsat Thematic Mapper paired scenes (39-26 and 39-27) and two Landsat Enhanced Thematic Mapper scenes. Image pre-processing efforts which include geometric correction, cloud masking, conversion from scaled pixel values to top-of-atmosphere reflectance, and non-agricultural masking have been completed for these image sets. Image segmentation has been completed for the May 2007 image scene; it is expected that segmentation will be completed for all scenes by early December 2007. All reference field data has also been collected for this study.

Preliminary modeling efforts have been completed for the classification of tillage, no-till, vegetation status (cropped vs. fallowed), and conservation reserve land using a randomForest model. Extensive literature review has validated that the randomForest model remains the best option for image classification in the context of this study due to its robustness in handling unbalance data sets, a tendency to not overfit, and an ability to provide a within-model estimate of classification accuracy.

Attempts to build a classification model based on the May 2007 imagery resulted in poor class accuracies. A large source of error was attributed to rangeland being misclassified as cropland (30% misclassification rate). Rangeland data recently obtained from the Montana Farm Service Agency should allow the Remote Sensing Validation Group to remove a substantial portion of rangeland from the project area. Further model refinement will occur following the rangeland masking procedure.

Measurement technique	Measurement parameters	Application
Controlled site benchmark sampling locations	Standard soil organic carbon (SOC) measurement (bi-annually): TC-IC=SOC, where TC = total carbon by dry combustion, IC = inorganic carbon by modified pressure calcimeter	Track temporal changes in SOC associated with tillage and cropping intensity.

Visible and infrared imaging from satellite or planes	Spectral imaging of land surface	Document acres under current soil management types (i.e. tilled, direct-seed) Document crops and crop rotations
Visible and infrared ("on-the-go")	Spectral imaging of *in situ* surface soils	Mapping soil carbon and soil variability in agricultural surface soils
Visible and infrared (lab-based)	High resolution spectral imaging of soil samples in the lab and simulated *in situ* using intact soil cores. This is currently a semi-quantitative, molecular spectroscopic method.	Build predictive models using visible and near infrared reflectance spectra to estimate soil organic and inorganic carbon.
Laser-induced breakdown spectroscopy	High resolution spectral imaging of soil samples in the lab and simulated *in situ* using intact soil cores. This is currently a semi-quantitative to quantitative elemental spectroscopic method.	Build predictive models using visible and near infrared reflectance spectra to estimate total soil carbon.
Combined visible and infrared - laser-induced breakdown spectroscopy	High resolution spectral imaging of soil samples in the lab and simulated *in situ* using intact soil cores. This is theoretically a quantitative elemental and molecular spectroscopic technique.	Build predictive models using combined visible and near infrared reflectance and laser-induced breakdown spectra to quantitatively estimate soil organic and inorganic carbon.

Accomplishments to Date:

- Initial measurements using standard methods and "on-the-go" VisNIR have been completed.
- "On-the-go" VisNIR has shown spectral patterning within enrolled fields; however, those patterns are currently not correlated with SOC.
- Initial results from simulated *in situ* SOC measurements using VisNIR and LIBS have been very encouraging with low bias (1.8 and 0.7% of MSEP, respectively), and R^2 values of 0.62 and 0.64, respectively).
- All satellite imagery for the Remote Sensing Cropland Verification Study have been purchased and pre-processed as of this report. This includes the following:
    - Image geometric correction
    - Cloud masking and radiometric correction
    - Conversion from scaled pixel values to atmospheric reflectance
    - Generation of Tasseled Cap Components
    - Generation of Normalized Difference Vegetation Indices
- All cropland field reference data has been obtained for this study. This includes over 500 field data points reflecting tillage, no-till, fallow, crop, and conservation reserve.
- Image segmentation has been completed for the May 2007 image. The Definiens professional Multi-resolution Segmentation algorithm was used to facilitate the segmentation process. The results are presented as vector-based field-level data.

Summarize Target Sink Storage Opportunities and Benefits to the Region:

- Results from standard and proximal sensing SOC measurements are applicable to within the defined study area.

- All methods are applicable to terrestrial sequestration projects globally.

Cost:

Total Field Project Cost: $1,050,384

DOE Share: $811,531 77%

Non-Doe Share: $238,853 33%

Field Project Key Dates:

Baseline Completed:

Drilling Operations Begin:

Injection Operations Begin:

MMV Events:

Field Test Schedule and Milestones (Gantt Chart):

Task 7.0 - Cropland Field Validation Test	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	FY 2006				FY 2007				FY 2008				FY 2009			
Task 7.1 - Planning																
Selection of enrolled farms				Tm1												
Task 7.2 - Controlled Test Soil Carbon Sampling and Calibration																
Analysis of MT cropland controlled test soil and vegetation field sampling - 1st round of sampling							Tm4									
Analysis of MT cropland controlled test soil and vegetation field sampling - 2nd round of sampling											Tm8					
Analysis of MT cropland controlled test soil and vegetation field sampling - 3rd round of sampling															Tm13	
Task 7.3 - MMV on Enrolled Sites/Farms																
Analysis of MT cropland enrolled farm field soil sampling and MMV - first round of sampling									Tm6							
Complete validation of 1st iteration of remote sensing model for MT cropland enrolled farm MMV												Tm11				
Complete remote sensing model for MT cropland enrolled farm MMV																Tm15
Analysis of MT cropland enrolled farm field soil sampling and MMV - second round of sampling																Tm16
Task 7.4 - Cropland terrestrial Project Planning Handbook																
Publication and submission of Project Planning Handbook																Tm17

Additional Information