C-LOCK: AN ONLINE SYSTEM TO MAXIMIZE THE VALUE OF AGRICULTURAL CARBON SEQUESTRATION FOR PRODUCERS AND PURCHACERS

Patrick R. Zimmerman[1], Maribeth Price[2], Karen Updegraff[1] and William J. Capehart[1]

(1) Institute of Atmospheric Sciences
(2) Department of Geology,
South Dakota School of Mines and Technology
501 E. St. Joseph St., Rapid City, SD 57701-3995

Introduction

Many industrial and energy firms are interested in lowering their future exposure to financial risk, in the event that greenhouse gas emission caps are implemented. Emissions offsets generated by landowners who retire cropland or move to less intensive tillage, thereby increasing the amount of organic carbon (SOC) stored in soils, have good investment potential. However, soil carbon trades to date have been idiosyncratic events associated with large uncertainties and therefore low prices for the sellers. Institutional deficiences, issues of measurement, monitoring and verification (MMV), and compliance enforcement all conspire to raise offset costs for buyers and lower payments to sellers (1,2).

By standardizing the estimation of SOC sequestered on individual parcels, and subjecting each estimate to rigorous uncertainty analysis and validation, the C-Lock system reduces the risk associated with trades of carbon emission reduction credits (CERCs). Because of reduced dependence on field-level sampling to determine changes in SOC, the system facilitates low-cost performance-based MMV of sequestration projects. This helps to reduce transaction costs and increase the value of soil carbon sequestration for landowners.

An overview of C-Lock and a demonstration application to a South Dakota farm highlights its MMV advantages and potential cost savings compared to sampling-based protocols.

The C-Lock System

C-Lock is comprised of a web interface, a client database, a GIS database and the CENTURY soil carbon model (3), which are linked by a system of Shell and Perl scripts. A Monte Carlo-based repeated simulation procedure is used for uncertainty analysis.

C-Lock will ultimately be licensed to a private entity who will provide administrative and certification services. This entity will need to populate soil, climate and crop history databases and possibly calibrate CENTURY for states other than South Dakota in which the system is applied.

Process Summary. The client creates a private account via a secure web interface. The spatial coordinates of the registered parcel link client data to GIS databases. The client selects management options for defined time blocks between 1900 and 1989 via drop-down menus. For 1990 to the present he is required to specify annual crop and management parameters, including tillage and fertilizer schedules, although default parameter values are available for common crops. The client may specify a future date to which he would like to estimate carbon sequestration. Management parameters specified for 1990-1999 are recycled to create future scenarios.

The location of the client parcel links it to a GIS database of climate (monthly temperature and precipitation) and soil data. Generalized management data for historical time blocks are selected based on the climate zone (MLRA) in which the parcel is located.

The client-specific and general management data, climate and soil parameters are used to create parameter and event-schedule files for CENTURY, which models SOC dynamics over a specified period as a function of substrate, climate, cover type and management. A 3000-year base run is used to establish a stable pre-agricultural SOC pool. Agricultural disturbance begins around 1900. The degree of disturbance is specified through client-selected management options. Sensitivity testing has indicated that specific crops or tillage schedules have less impact on long-term SOC depletion than does the fact that annual tillage occurs.

Based on client input and the GIS-derived soil, climate and management parameters, the CENTURY model produces estimates of soil C that allow the calculation of credits for net C sequestration. However, because of the uncertainty inherent in the estimation of many input parameters and in the modeling process itself, the CENTURY model is run for a given parcel not just once but at least 200 times. Monte Carlo sampling of the most uncertain input parameters, such as soil texture or of parameters describing cultivation impacts, allows the construction of well-defined confidence intervals for credits estimated on a given parcel.

An important advantage of the model-based approach is that it can ensure that the additionality criterion for carbon offset projects is met. While most offset or emissions reduction projects use a simple mean (e.g. 1985-89) emissions rate as the emissions baseline, this approach has shortcomings in a terrestrial C sequestration project. Preliminary tests have indicated that the use of a baseline emissions rate is likely to bias calculated CERCs, since terrestrial emissions are subject to the vagaries of weather. Atypical growing conditions during the baseline period could result in unrealistically high or low estimates of C sequestration..

Therefore, in order to factor out all non-anthropogenic effects on soil C dynamic, the client-defined scenario is modeled in parallel with a business-as-usual (BAU) scenario. Through 1989 the client and BAU scenarios are identical; beginning in 1990 the client scenario is defined by management parameters specified for each year by the client, but the BAU scenario recycles the management option selected by the client for the 1982-1989 time block. Thus, rather than establishing a baseline emissions rate C-Lock establishes a baseline management scenario. The client and BAU scenarios are both subjected to Monte Carlo analysis, using exactly identical "random" weather and parameter files. Consequently any difference in soil C between the two scenarios is due exclusively to management effects.

The client report summarizes trends in soil C resulting from the client-defined CENTURY run, and cumulative CERCs for each decade of the specified contract period. The reported CERCs are based on the 200-iteration Monte Carlo run. Likely ranges of accrued CERCs are defined by the 95 percent confidence intervals for Monte Carlo output, as described below.

Certification of CERCs. C-Lock produces two independent distributions of Monte Carlo output, which are used to define a pool of marketable CERCs associated with a high degree of confidence. These are CERCs that fall between the upper 95th percentile of the BAU output range and the lower 95th percentile of the client output range. These represent the minimum level of CERCs that can be guaranteed at the 95 percent confidence level. A reserve pool of CERCs is based on the upper 95th percentile of the client scenario and the lower 95th percentile of the BAU scenario.

C-Lock verification, measurement and monitoring protocols

The basic C-Lock system incorporates three levels of data verification.

I. Data quality control limits trap or flag unreasonable input values. In addition, routine audits may entail, for example, comparison of producer inputs with remotely-sensed or satellite data regarding land use, or the comparison with FSA records for that field. This type of verification is applied to all registered parcels.

II. A subset of registered parcels will be submitted to a third party auditor, who will re-estimate CERCs.

III. Comparisons of CENTURY outputs with regional data published in the literature. Measured results from long-term study areas subject to systematic sampling, monitoring and analysis provide higher-quality data for model calibration than could be expected from sporadic, site-specific soil sampling.

Quantifying SOC changes. Project guidelines for soil C sequestration typically base MMV protocols on soil sampling to quantify total carbon stocks and stock changes, The focus of C-Lock is on the accurate quantification of incremental changes in SOC, rather than absolute SOC for a site. The C-Lock system uses regional carbon research data to calibrate and validate CENTURY. By taking advantage of comprehensive, systematic regional soil sampling, this approach reduces the need for field level soil samples to define incremental SOC stock changes. Only minimal soil sampling is required to verify the status of the soil carbon reservoir..

Soil sampling is one of the most costly components of sequestration project MMV. A study by Mooney et al (4) estimated aggregate costs per soil sample at $16.37 for Montana farms. At conventionally-recommended sampling rates of 2 samples per ha, each round of soil sampling will cost $33 per contract hectare. To quantify carbon stock changes, this sampling must be repeated regularly, e.g. every 5 years. High sample variability will generally result in significant discounting of potential CERC value. Therefore each reduction in sampling frequency by 1 represents a total cost reduction of over $6,500 for a 400-ha (about 1 section) parcel.

In the last decade, improved atmospheric sampling approaches have estimated regional fluxes of a wide range of trace gas species, using integrated systems of surface observation sites, tall towers and aircraft sampling. The use of such a network to monitor regional carbon balances could serve to provide data for an independent validation of regional soil carbon sequestration.

The C-Lock system requires the producers to periodically update management data used to estimate current and potential C sequestration. Each time the C-Lock client database is updated, CENTURY is re-run for that parcel, and new estimates of certified and reserve CERCs are produced.

If the most recent CERC estimates fail to correspond to the producer's contract commitments, he may be allowed to use his pool of reserve CERCs to temporarily make up the deficiency. At the same time, he would be required to modify his future management scenario to increase the projected rate of C sequestration for contract compliance.

C-Lock and carbon sequestration contracting

The use of project-based (per Mg soil C sequestered) rather than activity-based (per contract hectare) was found to be more economically and socially efficient by Antle et al (5) in the likely event that fields are spatially heterogenous. The main constraint to project-based contracting is the cost of measurement and monitoring, relative to activity-based contracts. The use of a system like C-Lock reduces the need for field sampling, thereby reducing costs and facilitating project-level contracting.

Because of the perceived non-permanence of carbon sequestered in biomass or soil organic matter, the idea of CERC leasing as embodied, for example, in the concepts of "carbon tonne years" and "temporary certified emissions reductions" (6) has gained some popularity. C-Lock is ideally suited to leasing arrangements because of its relatively low MMV overhead and requirement for regular management updates.

Example Application

The C-Lock system was applied to a hypothetical 400-ha farm in eastern South Dakota. We simulated a change from conventional tillage management of a wheat-corn-soybean rotation to no-till management. Assuming a 40-year contract and a price of $10 per Mg C, the guaranteed CERCs generated over the entire parcel would be worth a total of $57,207, or $1430 per contract year.

Apart from costs incurred to shift to no-till, the producer bears the time opportunity cost of initial registration and biannual updates. Based on a 2002 average farm income of $65,757 (7), the time invested in registering and updating parcel information (e.g., 3 hours initially and 1 hour for each update) is worth about $632 to the farmer. Initial and final soil samples, using the assumptions stated above, would cost to $13,096 for the entire parcel.

A contract that relied on soil sampling every 5 years would incur measurement/monitoring costs of $58,932 over the duration of the contract described above. Further, because the samples are less frequent than the producer updates to C-Lock would be, there is less immediate feedback with respect to the impact of management strategies, and hence less opportunity to correct undesirable trends.

Acknowledgement This material is based in part upon work supported by the National Science Foundation/EPSCoR Grant #EPS-0091948 and by the State of South Dakota.

References

(1) Sonneborn, C. Overview of international activities in emissions trading. In*: New Zealand Sustainable Energy Forum 2000* Conference. Dunedin, 7-9 July **2000**, 25p.

(2) Vine, E. and Sathaye, J. *Mitigation and Adaptation Strategies for Global Change*, **1999**, 4,1, 43-60.

(3) Parton, W.; Schurlock, J.; D. Ojima; D. Gilmanov; T. Scholes; R. Schimel; T. Kirchner; J.-C. Menaut; T. Seastedt; E. Garcia Moya; A. Kamnalrut; and Kinyamario, J. *Global Biogeochem. Cycles* **1993**, 7, 785-809.

(4) Mooney, S. and J. Antle and S. Capalbo and K. Paustian. *Contracting for soil carbon credits: design and costs of measurement and monitoring*. **2002**, Department of Agricultural Economics and Economics, Montana State University, Bozeman, MT. Staff Paper 2002-01. 42 pp.

(5) Antle, J. and Mooney, S. *Designing efficient policies for agricultural soil carbon sequestration*, **2001**, Montana State University, Department of Agricultural Economics. http://www.climate.montana.edu/.

(6) Phillips, G. *LULUCF Projects in the CDM: Accounting regimes and proposals for simplified rules and modalities*, Discussion Paper 02-02, **2002,** International Emissions Trading Association Toronto, Canada. 14 pp.

(7) USDA Economic Research Service. *Agricultural Income and Finance Outlook*. Electronic Outlook Report AIS-81, **2003**, Available online: http://jan.mannlib.cornell.edu/reports/erssor/economics/ais-bib/2003/ais-80.pdf.