(Patent Pending)

A method for Maximizing Carbon Sequestration in Agricultural Ecosystems

Patrick R. Zimmerman, Maribeth Price, William Capehart, Lee Vierling, Changhui Peng,
Elaine Baker, Genet Duke, Fred Kopp, Patrick Kozak , Henry Mott, Chandan Das,
Karen Updegraff, and Craig Groseth

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Background

An accelerating rate of change in the amounts of trace gases in the earth's atmosphere has the potential to modify the earth's energy balance, which may result in a variety of potentially negative consequences. These trace gases are often referred to as greenhouse gases and include carbon dioxide. Although there is disagreement concerning the potential threats or benefits of this change, there is widespread agreement in the global community that it is prudent to enact policies to attempt to slow down the rate of change. At the same time, research is underway to predict the consequences of increasing greenhouse gas concentrations and to develop the technology to economically limit those increases. The Kyoto Protocol (UNFCCC 1998) established national emissions reduction targets as fractional percentages of emission rates during 1990.

The increasing concentration of greenhouse gases in the atmosphere is a global issue. For example, carbon dioxide emitted from a power plant into the atmosphere has a lifetime of approximately

100 years and may be distributed globally. As a result, the geographic location where the greenhouse gases are removed from the atmosphere is less important than the fact that they are removed.

One of the key provisions of many national strategies to limit the rate of growth in the amounts of atmospheric greenhouse gases is the concept of emissions trading. Emissions trading is a process whereby specific target emission rates of certain greenhouse gases are set for specific industries. A member of the industry who achieves measured emissions below the target rates may trade the difference on the open market to another who exceeds, or forecasts that it will exceed, its own emission targets. An entity responsible for measured emissions above its target rates may be subject to fines or other sanctions. The objective is to reduce the overall emission of greenhouse gases to the atmosphere, even if the emissions of one particular source are not decreased, or indeed are increased.

The unit of measure of tradable carbon emissions that has been generally accepted is commonly known as the Carbon Emission Reduction Credit, or CERC, which is equivalent to one metric ton of carbon dioxide gas (or other greenhouse gas equivalent) that is not emitted into the earth's atmosphere due to a human-caused change. That is, a CERC can be generated for human activities that have occurred since 1990 that have resulted in a reduction of business-as-usual emissions of greenhouse gases.

For example, CERCs can be generated through energy efficiency gains, substitution of biofuels for fossil fuels, or removal of greenhouse gases from industrial gas streams. CERCs also can be generated by sequestration of atmospheric carbon dioxide (CO_2) into land or water, e.g., by reforesting land or through implementation of agricultural practices that increase the storage of organic matter in the soil.

A market is emerging for trading CERCs. One type of CERC trading involves an industrial consortium, where each industrial entity determines a rough estimate of the number of CERCs generated by its activity or needed from others due to its activity. If an individual entity has generated CERCs by changing its business-as-usual activity, e.g., by reducing the amounts of greenhouse gases emitted, it can trade the CERCs to others in the consortium.

There also have been entities involved specifically in CERC trading based on increasing the storage of carbon in soil. For example, in 1999 a consortium of Canadian power companies hired an insurance company to contractually obligate a group of Iowa farmers to management contracts that specified no-till farming (www.gemco.org/Iowa_Farm_Project.htm). Based on research and modeling results from the ongoing Prairie Soils Carbon Balance Project, a broker estimated that this land management practice would result in sufficient sequestration of carbon into the soil to generate CERCs. The power companies also purchased an insurance policy for protection against the possibility that no CERCs, or insufficient CERCs, would be generated by this arrangement. This trade was designed by the consortium of power companies to minimize the price that the farmers were paid. The difficulty and uncertainty of predicting these CERCs, obtaining indemnification or insurance, and banding together a sufficiently large number of farmers to generate a pool of potential CERCs large enough to overcome substantial baseline transactional costs, coupled with uncertainty whether the CERCs generated would meet current, pending, or future regulatory requirements operated to drive up the costs incurred by the potential CERC purchasers, drive down the price paid to the producers, and generally make it difficult to establish and engage in a market for CERCs.

Existing methods (Fig. 1 below) for CERC accounting and trading generally share a number of shortcomings. Typically, the contracts specify certain land management practices, but do not require a specific number of CERCs to be generated. The estimated CERC values are highly variable and minimized due to uncertainties caused by using general regional data to try to estimate CERCs and by high transaction costs. Without a reasonably accurate method of quantifying CERCs generated, it is difficult for all to place a fair value on the trade. Also, trades generally have been designed and instigated by a potential CERC purchaser, or an entity representing one, and not by the CERC producer, such as a farmer or landowner. In addition, each trade must be individually designed by the CERC purchaser to be consistent with current and anticipated legislative requirements and to maximize the likelihood that CERCs will be generated. Competition is also limited by the requirement of projects large enough to achieve economies of scale. As a result, the price paid to CERC producers is driven down, the market for trading CERCs is limited, and incentives to induce landowners to utilize management practices that will maximize carbon sequestration are minimal.

In the absence of an accepted process to generate, quantify and standardize CERCs, especially

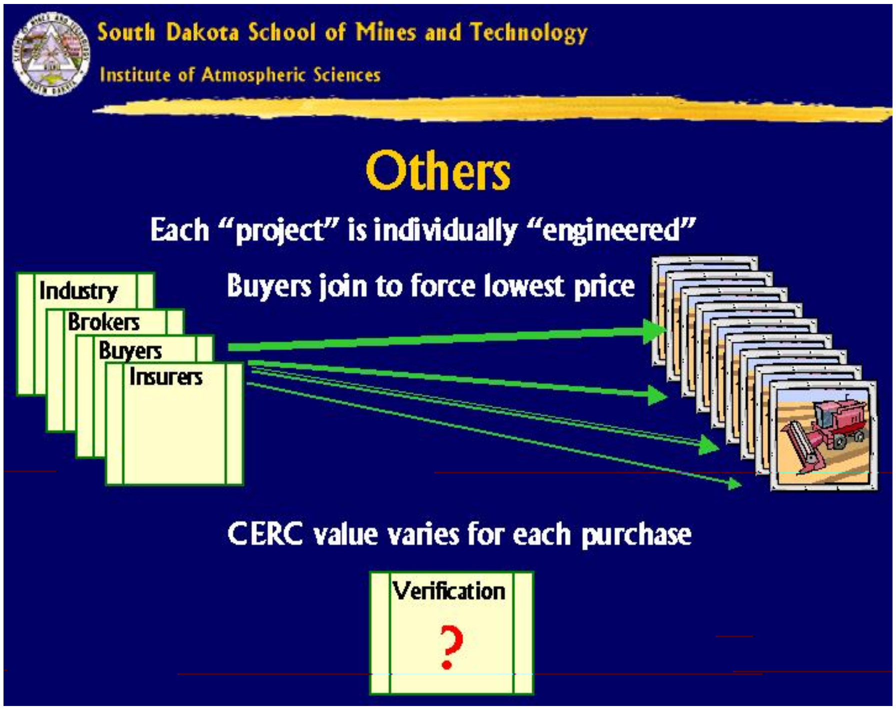

Figure 1. Typical carbon credit trading schemes

CERCs generated or projected to be generated by carbon sequestration in land or plants, the market for such CERCs remains relatively primitive, inefficient, and uncertain. The existing attempts to identify and trade CERCs suffer from difficulties in quantifying accrued and projected CERCs, high administrative costs , and the lack of a market for individuals and individual entities to effectively engage in CERC trades. These problems particularly restrict the ability of an individual landowner, or groups of landowners, to efficiently generate, quantify, standardize, market, and trade CERCs.

As such, a need exists for an improved method of generating, quantifying, and standardizing CERCs, particularly so that a relatively smaller producer of CERCs, such as an individual landowner or group of landowners, may be able to participate in a market for CERCs by generating and quantifying standardized CERCs in a transparent and verifiable manner.

In general, the establishment of a CERC is contingent upon demonstration of the following six principles: 1) a baseline rate of emissions of specific greenhouse gases as a result of business as usual (BAU) activities must be defined; 2) additivity or surplus sequestration above BAU must be demonstrated; 3) sequestered carbon must have a reasonable expectation of permanence; 4) creation of a carbon pool cannot result in leakage of CO_2 or other greenhouse gases somewhere else; 5) ownership must be documented; and 6) CERCs must be verifiable by an independent third party.

The business as usual baseline generally refers to the level of greenhouse gas emissions from continuing current management practices in that particular industry. In the case of farmers, business as usual typically is defined as conventional tillage agriculture, but may be specifically determined for each land parcel based on the land management history. Further, the business as usual baseline may be defined as an average of a larger community, rather than a business as usual for an individual or a single entity. The United States has yet to legislate policies defining BAU for agricultural land.

The second element is additivity, which generally refers to human activity that causes a reduction in business as usual emissions. That is, the change between the fluxes of greenhouse gas emissions under the business as usual baseline and the lower level of emissions must be caused by human intervention. In the case of farmers, this typically means changing land management away from the business as usual practice of conventional tillage agriculture. Even with crops removing carbon dioxide from the air, conventional tillage agriculture typically results in a net release of carbon dioxide into the air due to oxidation of carbon compounds contained in the soil. In general, as tillage intensity decreases, thereby decreasing the amount of soil exposed to the oxygen in ambient air, carbon turnover also decreases, resulting in a decrease in the net carbon dioxide emissions into the atmosphere. A change to minimum tillage, or to no tillage at all, typically results in less carbon dioxide emitted or even a net sequestration of atmospheric carbon (Kern and Johnson 1993). A change from cropland to grassland can result in the sequestration of substantial amounts of carbon dioxide in the form of organic carbon compounds that can accumulate in grassland soils. Human activity other than, or in addition to, changing land management away from conventional tillage agriculture may also be employed to cause a reduction in business as usual emissions.

The third element is permanence. The general objective of emissions trading is to reduce atmospheric concentrations of greenhouse gases to allow time to develop the technology to decrease emissions into the atmosphere directly from the source. In this case, permanence typically is defined as the storage of carbon dioxide in the form of biomass or soil organic carbon for a time period specified by regulation, typically twenty or thirty years. Generally, residence times for carbon removed from the atmosphere by forests can exceed decades, whereas soil carbon can have residence times that exceed hundreds to thousands of years.

The fourth element is absence of leakage, which generally means that the changed human activity intended to generate a CERC does not result in an undesirable increase in greenhouse gas emissions in any part of the biogeochemical cycle. In the case of carbon sequestration, CERCs are more valuable if the landowner can demonstrate that the changed human activity that resulted in generation of the CERCs does not result in increased emissions elsewhere or of other gases, such as nitrous oxide or methane, compared to business as usual emissions.

Another element to maximize the value of a CERC is documentation of ownership. That is, the entity offering to trade or sell a CERC must demonstrate that it is the owner of rights to the CERC. Although this typically will be the landowner-operator in the case of soil carbon sequestration, other scenarios are possible, for example, whereby agreement or law another has rights to use all or part of the land.

Yet another requirement is verification, which generally refers to the ability of a third party to verify the generation of the CERC through an approved accounting process (Vine and Sathaye 1999). Verification typically requires that the process employed be transparent, i.e., the process is documented so that a third party may review, analyze, understand, and replicate it. For example, verification may include audits of data to ensure accuracy. The CERC value generally will be maximized where the process employed to establish the CERC directly corresponds to the method of verification.

Direct measurement of the absolute amount of carbon sequestered in a given parcel of land is difficult and expensive. Further, the absolute amount of carbon in a specific soil sample may be highly variable for samples collected at individual points within the parcel of land, due to the mean residence time of organic matter in soils often being on the order of 1,000 years and due to soil characteristics often being quite spatially variable. Therefore, it may not be practical to obtain an accurate, precise, reproducible, cost effective, direct measurement of the relatively small amount of carbon added to, or subtracted from, a land parcel over a period of several years to decades, the time periods required by current and pending legislative protocols.

The C-Lock system (discussed below) was designed to estimate field-specific incremental soil carbon changes that can qualify to generate CERCs. Although the total amount of carbon in a specific soil sample may be quite variable, the incremental carbon stored as a result of specific land management practices over periods of decades is much less variable, particularly since most soils have been tilled in the past, at least in the United States and much of the industrialized world. This is because previously tilled soils contain levels of organic carbon that are much lower than their organic carbon saturation levels and therefore carbon storage over periods of decades is relatively insensitive to soil carbon variability. Therefore CERCs may be generated and quantified by estimating the incremental carbon stored in the soil over time, e.g., since 1990. Since greenhouse gas reduction is a national issue, validation of carbon sequestration in soils is not required for individual land parcels. Rather, validation can take place regionally by comparing numerical model results with those of intensive research sites as published in the scientific literature. Indirect atmospheric methods such as isotopic analysis of atmospheric carbon and oxygen in carbon dioxide can also provide evidence of regional and continental scale carbon flux balances. That is, by compiling CERCs from a number of landowners, one may more readily generate and quantify accrued and future CERCs with reasonable accuracy for the compilation than for a single or smaller group of landowners. Therefore, the allocation of CERCs from the compilation to individual land parcels need not be precisely accurate. However, to be fair to the individual landowner, the quantification system used should be relatively accurate, transparent, reproducible, traceable, and verifiable.

C-Lock Description

C-Lock is a process for converting soil carbon, accrued as a result of agricultural management practices, into standardized carbon emission reduction credits. C-Lock technology creates a "certified pool" of CERCs and a " reserve pool" of credits in order to produce standardized carbon emission reduction credits and reserve carbon emission reduction credits that are of equal value regardless of where they are generated.

C-Lock Elements

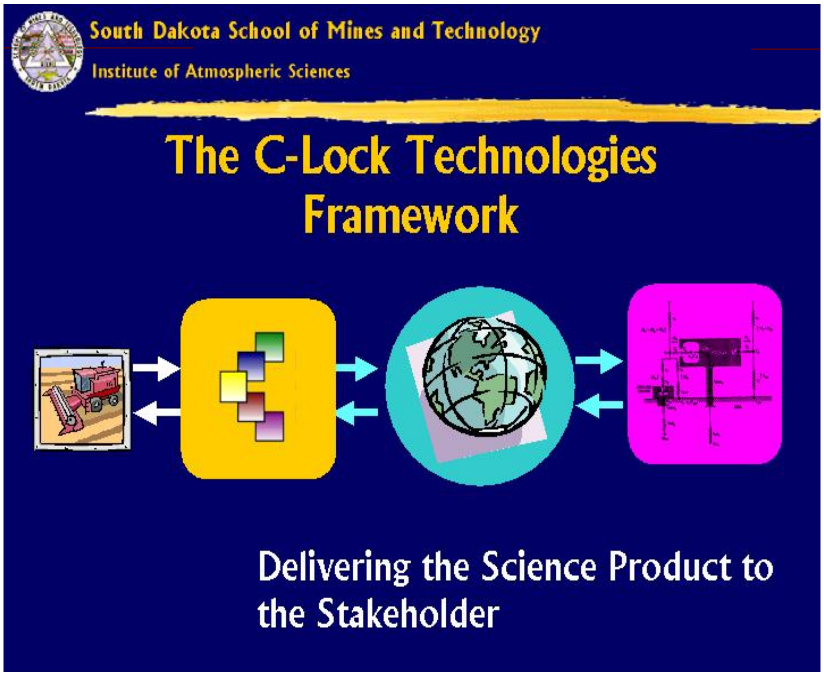

Figure 2. Major C-Lock elements

C-Lock was designed to solve the problems that currently plague the CERC market. C-Lock consists of the following building blocks:

- A web-based public interface that provides public information and web links about carbon sequestration science and policy
- A Geographic Information System (GIS) that includes specific information needed in order to accurately quantify accrued carbon
- Land parcel registration tools with secure data handling capabilities, and

- Producer land registration, data assimilation, and advisory tools.
- Reporting tools that provide the registrant with an accounting of certified and reserve credits for each land parcel
- Marketing tools accessible by potential buyers that report on pooled CERCs and reserve CERCS available
- A quality control system that provides three levels of CERC verification

C-Lock Public Interface

C-Lock can be accessed at: http:// beta.hpcnet.org/clock. The home page (Fig. 3) includes links to other websites that discuss carbon sequestration science, websites that discuss relevant policy and links to recent C-Lock presentations.

Figure 3. C-Lock Home Page

C-Lock Geographic Information System

The C-Lock GIS (Fig. 4) has been completed using South Dakota as an example. The GIS is populated with all of the data required to assess carbon sequestration for individual land parcels and to predict potential carbon sequestration. Typical data include geo-referenced climate variables gathered from weather reporting stations, digital elevation maps, high-resolution soil-type maps, and a county-level database of land use history that extends back to 1990. The GIS system is in residence in an off-line computer and is not directly accessible by the public.

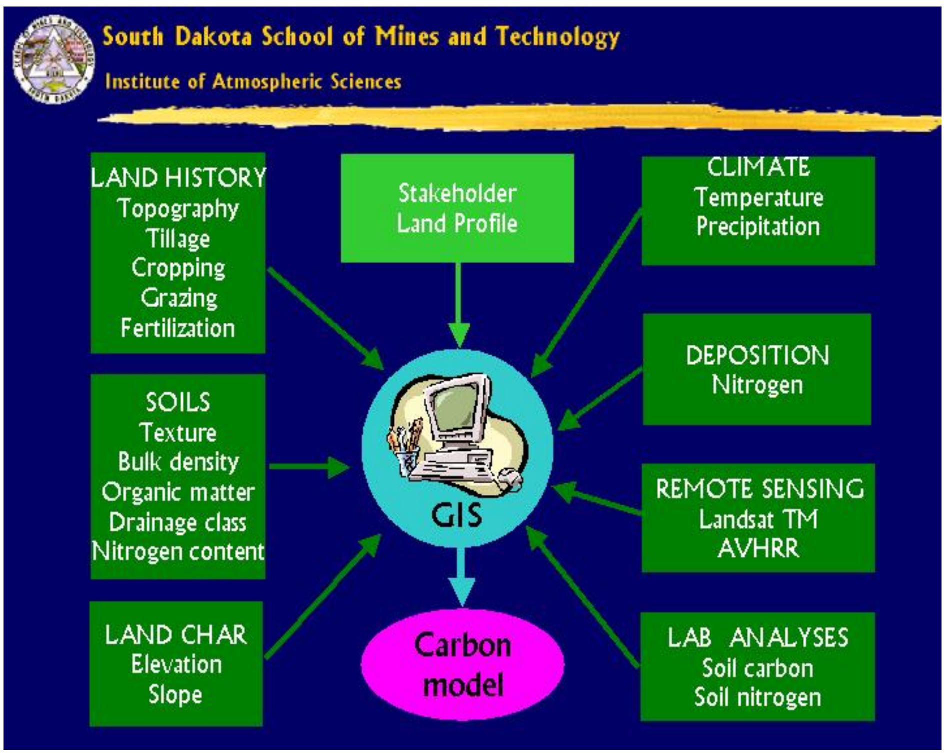

Figure 4. C-Lock GIS components

C-Lock Producer Interface Tools

Producer interface tools provide interactive data forms that facilitate land parcel registration and data entry. Producers are able to identify the location of a land parcel and then are directed to a series of questionnaires that have been pre-populated with data for that specific region concerning specific management practices. Through a series of sensitivity analyses, we have determined the relevant time blocks and the level of detail required in order to minimize uncertainty and maximize simplicity. The forms request information about tillage practices, fertilization and irrigation regimes, and crop rotation in a manner that was designed to parallel information provided by farmers to the Farm Services Agency (FSA) so that they may enroll in farm programs. Contingent on the results of data quality controls, the producer data are forwarded to the numerical model for the calculation of CERCs and reserve CERCS. In this part of the C-Lock process, a landowner can also access a carbon sequestration advisory tool. This tool is comprised of an online look-up table of relative carbon sequestration potentials determined for various land management and crop rotation scenarios relevant to the region. The C-Lock forms are dynamically served and consist of a series of roll-down menus from which a producer may select the appropriate answer.

Each page is also linked to a help file. After the producer has completed the relevant forms, data is submitted and the C-Lock interface routes the data to a computer where the numerical model (in this case CENTURY IV [Parton *et al.* 1993]) is resident.

At this point CERCs and reserve credits are calculated. Reserve credits are determined through an uncertainty analysis. Although an analysis of uncertainty can be accomplished in many ways, we have chosen to utilize a Monte-Carlo approach whereby the variables to which the model is sensitive are randomly and independently varied across a defined range and distribution of potential values (Robert and Casella 1999). CENTURY is run with each combination of values for a at least 200 iterations or until necessary to produce meaningful output statistics. Typically C-Lock will certify the existence of the CERC s quantified at the 95 percent confidence level, although other confidence levels could be chosen. For example, C-Lock might identify a total of 150 CERCs to exist on a land parcel. If only 120 CERCs fall within the 95 percent confidence limits, these would be certified while the other thirty credits would be placed in the reserve or indemnification pool. The important point is that the procedure for determining CERCs and Reserve CERCS is simple, logical, scientifically defensible, transparent, and reproducible. In addition the pools are flexible and can be adjusted as new scientific data warrants.

C-Lock Reporting Tools

The CERC reporting tools include a confidential report to an individual landowner that specifies certified CERC credits and CERC reserves for the individual land parcel. The landowner then has the option of several methodologies to market these credits. It is envisioned that credits from individual land parcels will be pooled to produce blocks of certified credits in units that are attractive to buyers. One possible scenario is to hold periodic on-line auctions so that credits can be purchased by competitive buyers, therefore resulting in the highest return possible to producers. The C-Lock marketing page will allow potential CERC buyers to register relevant information to qualify them to bid on C-Lock certified CERCs.

C-Lock Quality Control

C-Lock has built-in several levels of quality control to prevent and detect invalid data. Level I data quality control includes flagging of any producer-entered data that falls outside of the bounds of reasonable expectations compared to county-level generic data. Every land parcel registered is automatically subjected to this analysis. In addition, a subset of registered land parcels will be subjected to routine auditing. This procedure involves comparisons of producer data with selected satellite data for specific years. Auditing can also include a request for documentation of the data entered. This documentation may include a comparison of producer data with FSA reported data for the same land parcel. As the FSA moves to an all-digital system, this approach will become easily implemented. Level II quality control will send a subset of registered parcels to an independent third party to confirm that they arrive at the same values through an independent analysis. Level III data quality control will compare CENTURY model output with the best regional data published in the scientific literature. Therefore Level III data analysis links the best science to C-Lock in a way that will maximize its credibility to regulatory agencies and minimize risks to buyers. This three-level data analysis system is preferable to soil sampling in order to determine incremental carbon for several reasons:

- Intensive soil sampling is required to overcome the spatial variability of soil carbon. This is expensive.

- Most soil sampling protocols do not differentiate short-term versus long-term carbon pools. Incremental carbon is the important parameter…not total carbon.
- Comparisons of model output with long-term study areas where major variables are systematically measured using a broad range of technology and where the results are documented and archived in the peer-reviewed literature provides high-quality data to calibrate models. Sporadic low-cost soil sampling does not.

Performance-based versus Management-based Contracts

Currently, producers are required to sign up for individual management contracts, tailored for a region, but different for every carbon trade. Many farmers are extremely reluctant to participate in a program that will not allow management flexibility. C-Lock allows the development of performance-based contracts. In this case a producer would be able to commit to managing a specific, additive carbon pool. At selected intervals, for example, every two years, the C-Lock data could be updated with real yields, fertilization, tillage, and climate variables to monitor CERC storage performance for each individual land parcel. If a producer falls below his commitment level or rate, he would then borrow credits from the reserve pool to temporarily cover the CERC shortfall; however, he would then be required to repay this debt by initiating management practices that will put the CERC storage commitment back on track. If, however, C-Lock reanalysis (monitoring) indicates that the producer will be able to sequester a larger-than-expected carbon pool, targets could be increased. A variety of legal remedies could be implemented for farmers who fail to honor their contractual CERC commitment. Performance –based contracts have the additional advantage that they can be universal. Therefore legal fees will be minimized, further reducing transaction costs.

C-Lock Future

C-Lock provides an ideal platform to allow individual landowners to maximize income for activities that result in carbon sequestration. Although it has been developed using South Dakota as an example, it would not be difficult to adapt to other regions and agricultural practices. At this time we are working on a number of additional C-Lock modules. For example, we are working on a forestry module so that landowners are able to quantify and maximize income from afforestation. In addition, the C-Lock team is working to develop a soil conservation module so that registered producers can identify a parcel of land for which, based on coupled land-use and hydrology models, C-Lock will specify the dimensions and placement of vegetation buffer strips to reduce sedimentation. Preliminary analysis in South Dakota indicates that on the most erodable land, strategic placement of buffer strips over only five percent of the cropped area could reduce sedimentation by as much as fifty percent. The C-Lock platform can also be adapted to address emissions of additional agricultural green house gases such as methane and nitrous oxide, as well as emissions from feedlots, wetlands, and landfills. C-Lock is ideal to quantify and market the fruits of mitigation efforts in these areas.

C-Lock Summary

C-Lock solves a number of problems inherent in current soil and agricultural carbon trading schemes. The C-Lock system is designed to provide an easy-to-use interface among current and future regulators, landowners, and CERC purchasers. It results in the creation of standardized, globally-tradable CERCS that provide a maximum return to producers and maximum security to buyers with minimal transactional overhead. Because C-Lock enables land managers with even small holdings to participate in carbon storage and marketing, and because C-Lock is designed to minimize transactional, monitoring, and verification costs, the return to producers is maximized, as is CERC generation. Because producers generate parcel-specific data reports, data gathering costs are minimized and accuracy and specificity are enhanced. In addition, since C-Lock credits are, in effect, self-insured to cover a possible shortfall by a participant in the carbon pool, additional indemnification will not be required.

C-Lock CERC Certification and Marketing System

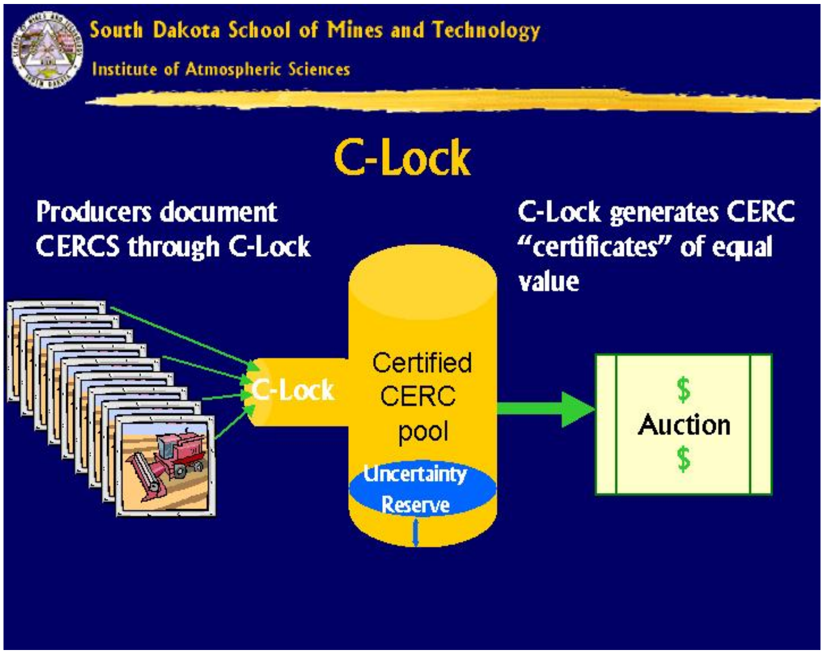

Figure 5. C-Lock certification and marketing

Although C-Lock has been developed using South Dakota as an example, it provides a flexible framework that can be easily adapted to any region of the world. The process is ready for implementation as a pilot project in South Dakota. At this time the State of South Dakota is searching for business entities interested in licensing C-Lock for use in quantifying, monitoring, and marketing CERCs.

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