PROGRAM **facts**

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Carbon Sequestration

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TERRESTRIAL SEQUESTRATION PROGRAM

Capture and Storage of Carbon in Terrestrial Ecosystems

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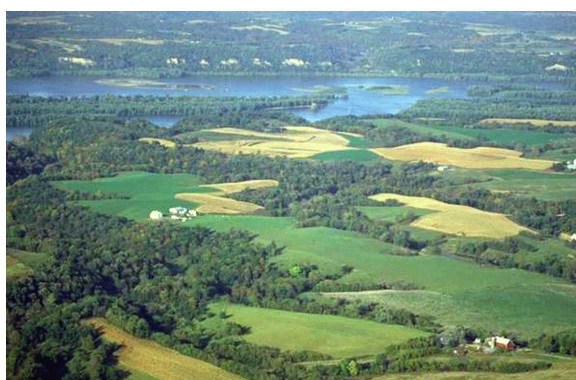
Background

Clean, affordable energy is essential for U.S. prosperity and security in the 21st century. More than half of the electricity currently generated in the United States comes from coal-fired boilers, and there is little indication that this percentage will diminish through 2020 and beyond. In addition, the use of coal for electricity generation is projected to more than double in developing nations by 2020. This ever growing demand for fossil-fuel-based power and the consequential rise in atmospheric carbon dioxide (CO_2) concentrations requires innovative methods to capture and store CO_2.

Terrestrial ecosystems, which include both soil and vegetation, are widely recognized as a major biological "scrubber" for CO_2. Terrestrial sequestration is defined as either the net removal of CO_2 from the atmosphere via photosynthesis by vegetation or the prevention of CO_2 emissions from terrestrial ecosystems. In addition, terrestrial sequestration can be enhanced in four ways: (1) reversing land use patterns, (2) reducing the decomposition of organic matter, (3) increasing the photosynthetic carbon fixation of trees and other vegetation, and/or (4) creating energy offsets using biomass for fuels and other products. The terrestrial biosphere is estimated to sequester about 2 billion tons or 2 gigatons (Gt) of carbon annually, while the total amount of CO_2 stored in soils and vegetation throughout the world is estimated to be about 2,000 Gt +/- 500 Gt.



Description

The United States Department of Energy's (DOE) Office of Fossil Energy (FE) and the Office of Science (SC) are jointly conducting research on carbon capture and storage in terrestrial ecosystems. DOE's current activities, which are managed by its National Energy Technology Laboratory (NETL), focus on enhancing the productivity of terrestrial ecosystems through the application of soil amendments, such as coal-combustion byproducts. The program's goal is to provide economically competitive and environmentally safe options for offsetting the projected increase in CO_2 emissions. These efforts are based on fostering partnerships between landowners, government agencies, and energy producers, such as coal and utility companies. This partnership will help develop the best approaches for increasing the amount of carbon that can be sequestered in soils and vegetation. Successful implementation of this program would result in net sequestration costs in the range of $10/ton of CO_2 avoided.

Current Project Summaries

Application and Development of Appropriate Tools and Technologies for Cost-effective Terrestrial Carbon Sequestration

The Nature Conservancy is working with U.S. based companies (including General Motors and American Electric Power) and non-governmental organization (NGO) partners to study how CO_2 can be stored more effectively by changing land use practices and investing in forestry projects. This project focuses on the long-term potential of obtaining cost-effective, verified measurements for various carbon sequestration and land–use carbon–emissions avoidance strategies. The project employs newly developed aerial and satellite-based technologies to study forestry projects in Brazil and Belize in order to determine their carbon sequestration potential and to test new software models that predict how soil and vegetation store carbon at sites in the United States and abroad. To date, this project has achieved two milestones. The first milestone is the development of new allometric equations for terrestrial carbon storage. This model relates the height and diameter of trees to their carbon storage potential. It also collects and applies data to improve the general biomass equation for the Atlantic forest biome and estimates more accurately its carbon storage potential. The second milestone is the development of an Euclidean-based deforestation model, which quantitatively assesses historical deforestation and reforestation trends.

Assessing Fossil and Recent Carbon Pools in Reclaimed Mined Soils

This ongoing project, conducted by the Ohio State University Research Foundation, includes mining sites, reclaimed cropland with a recent corn crop, and reclaimed grassland at various locations across a 300–400 km transect spanning the Northern Appalachian coal basin in Ohio, West Virginia, and Pennsylvania. The project objectives are to develop and test a carbon13 (13C-based) procedure to determine the fraction of coal-carbon (Coal-C) present in reclaimed soils; evaluate a chemo-thermal procedure to partition organic carbon in reclaimed soils into coal-derived and newly deposited carbon fractions; and establish an optimum sampling protocol to produce an accurate assessment of the sequestered carbon. For this project, two analytical chemical methods were employed for selective removal of recent carbon in mine soils. Analyses of soil-coal mixtures indicate that both analytical methods were effective in removing recent carbon from soils with little effect on the soil-coal carbon content at experimental sites.

In-Field, Continuous, Non-Invasive Soil Carbon Scanning System

Brookhaven National Laboratory developed an instrument for soil carbon analysis based on inelastic neutron scattering (INS), a non-invasive means for continuously monitoring the soil carbon inventory over small, specific plots, as well as over large areas. The anticipated benefits from such a system are the ability to (1) monitor below-ground carbon balances without disturbing the soil and (2) continuously scan large areas, thus providing a true mean carbon concentration in soil. Field tests were conducted on state and private lands in Alabama, Maryland, Missouri, North Carolina, and South Carolina. The following project goals were achieved:

- An INS alpha prototype system for non-destructive, in-field soil carbon analysis, in both static and scanning modes, has been constructed and tested.

- The multi-elemental capability of the INS system to measure hydrogen (H), carbon (C), oxygen (O), nitrogen (N), silicon (Si), potassium (K), and calcium (Ca) has been demonstrated.
- Initial calibration of the INS against soil carbon determination using core samples and chemical analysis by dry combustion has been published.
- Field measurements were performed in both static and scanning modes of operation.
- A complete model for the INS system has been derived and used to investigate effects of soil moisture, density, and carbon profile on this system. An initial system calibration for moisture was performed.
- A beta prototype using 16 detectors reached an advanced stage of construction and will be deployed in the summer of 2008.

Carbon Sequestration in Reclaimed Mine Soils of Ohio

Conducted by the Ohio State University's Department of Chemical Engineering, this project is aimed at assessing the soil organic carbon (SOC) sequestration potential of reclaimed mined soils (RMS) in sites mined between 0 and 50 years ago. Data are being collected in regions with similar topography, climate, vegetation, and soil types. This research focuses on: (1) assessing the sink capacity of RMS to sequester SOC in selective soil chronosequences; (2) determining the rate of SOC sequestration; (3) developing and validating models for SOC sequestration rates; (4) identifying the mechanisms of SOC sequestration in RMS; (5) assessing the potential of different methods of soil reclamation on SOC sequestration rates, soil development, and changes in soil mechanical and water transmission properties; and (6) determining the connection between SOC sequestration rates and soil quality in relation to soil structure and hydrological properties. Soil samples have been collected from 0 to 15 cm and 15 to 30 cm depths and analyzed to determine SOC concentration, total soil nitrogen concentration (TN), pH, and electrical conductivity for each sampling location.

Past Project Summaries

Through the cooperation of various participants, the Terrestrial Carbon Sequestration Program's past accomplishments include the following:

- Development of innovative Laser Induced Breakdown Spectroscopy (LIBS) to rapidly measure carbon in soils.
- Establishment of a fundamental understanding of how changes in a plant community are reflected in changes in terrestrial carbon inventories and the development of a detailed economic analysis of terrestrial carbon sequestration at reclamation sites.
- Use of DNA-based methods to "fingerprint" soil bacteria and identify their role in nutrient recycling in terrestrial ecosystems.
- Development of new field-deployable, laser-based instruments for measurement and characterization of soil carbon.
- Completion of a report for a re-forestation project.
- Development of a carbon sequestration model for calculating the amount of carbon stored in various quality soils in the Appalachian region.
- An enhanced forest carbon model, which includes economic data to estimate the cost of sequestration and helps determine the optimum tree harvesting schedules to maximize carbon sequestration and profits for land owners.

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The Global Carbon Cycle

The figure above presents a simplified version of the global carbon cycle. The arrows represent natural paths of carbon exchange and the human, or anthropogenic, contributions to the carbon cycle. The flow of carbon is measured in gigatons.

The locations where carbon is stored are called "sinks." These carbon sinks are immense. The atmosphere contains about 778 Gt of CO_2, the ground contains about 2,190 Gt of CO_2, and the intermediate and deep ocean contains about 38,100 Gt of CO_2.

The oceans absorb 92 Gt of CO_2 from the atmosphere, which is slightly more than the 90.3 Gt of CO_2 released by the oceans. These are the main flows, or "fluxes," of carbon that occur in nature.

The anthropogenic flux of carbon arises from two major sources. The larger of the two is the burning of fossil fuels for electricity and industrial processes at 6.3 ± 0.4 Gt of CO_2 per year. The smaller of the two sources is the release of CO_2 from land use changes, resulting in 0.7-1.6 Gt of CO_2 being released to the atmosphere. Finally, some 2-4 Gt of CO_2 are absorbed by soils, resulting in a net terrestrial uptake of 1.4 Gt of CO_2 per year.

Concurrent Benefits

Terrestrial sequestration also offers significant additional benefits including:

- Creating wildlife habitat and green space
- Preventing soil erosion and stream sedimentation
- Boosting local and regional economies
- Reclaiming poorly managed lands
- Increasing recreational value of lands