the ENERGY lab

PROJECT FACTS

Carbon Sequestration

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

Background

Earth generates and emits an enormous amount of carbon dioxide into the atmosphere from its deep energy resources, its near-surface processes, and biotic activities. Although anthropogenic carbon dioxide emissions increase global warming, global warming is also alleviated by human activities in sequestering carbon into the terrestrial ecosystem and injecting carbon dioxide deep into geological formations, thus partly reversing the role of the earth from a source to a sink. Balancing these roles and mitigating global warming is also aided by developing bio-fuels and other modalities as alternative energy sources. A common thread underlining these changes and projections is the need for an improved understanding of the below-ground carbon processes. This, in turn, calls for advanced instrumentation to better assess various terrestrial carbon-sequestration strategies, to monitor the permanence of deep carbon-dioxide stores, and for quantifying of carbon stores for contract verification in trading with carbon credits.

Project Description

Brookhaven National Laboratory (BNL) developed a unique instrument, inelastic neutron scattering (INS), for non-destructive, *in situ,* quantitative soil analysis for carbon and other elements. It samples large soil volumes, ~0.3 m^3, in either static- or continuous-scanning modes of operation. The instrument is based on gamma-ray spectroscopy which is induced by fast neutrons under-going inelastic neutron scattering (INS) and thermal neutron capture (TNC) with soil elements. These nuclear processes afford very high elemental-specificity, not affected by the chemical state of the element. These nuclear processes being very fast enable scanning over large areas. In addition to being non-destructive, INS allows acquiring true sequential observations over a specific spot or over large scanned areas. Effective depth of soil analysis by the INS system is about 30 cm. These characteristics of the INS system and its other advantages overcome many of the limitations posed by the widely accepted standard chemical methods for soil analysis by dry combustion in current use.

The INS technique significantly improves, quantifies, and expedites the determination of the efficacy of different land-management methodologies for ensuring carbon sequestration and assuring soil quality. Its high sensitivity can detect changes in soil carbon induced by stressed vegetation impacted by the slow carbon-dioxide seepage from geological storage.

The viability of the alpha prototype INS system was demonstrated in numerous static and scanning studies in fields ranging from those with low bulk density, in pure

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PROJECT DURATION

Start Date
06/01/03

End Date
09/30/10

COST

Total Project Value
$2,295,000

DOE/Non-DOE Share
$2,295,000 / $0

PARTNERS

Brookhaven National Laboratory

organic soils, to ones with a high bulk density of overburden in abandoned mine lands. In addition, the system's capabilities were verified in forest ecosystems and at the Zero Emission Research and Technology (ZERT). This facility can simulate carbon-dioxide seepage from deep geological formation. The results of these studies were published in the open literature. A beta prototype of the system is under construction, the sensitivity of which is greatly improved in comparison with the current alpha model. The second generation of this system is expected to provide a non-destructive carbon-depth profile.

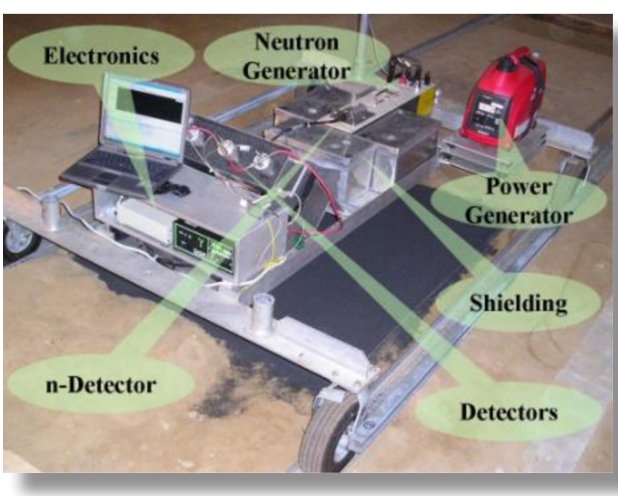
Goals/Objectives

The purpose of this project is to develop new analytical capabilities for soil analysis surpassing those attainable with current state-of-the-art chemical analysis by dry combustion. The new approach is expected to be safe, rapid, non-destructive, and provide multi-elemental data with static- and scanning-capabilities. Information obtained by the new instrument addresses terrestrial- and geological-sequestration concerns, and offer a new outlook on the belowground carbon processes.

The objectives of this project were to (1) design and construct a novel system for soil analysis with unique capabilities surpassing those currently available; (2) perform system validation in various soil types where the soil's carbon content was well characterized; And, (3) demonstrate the system's viability for monitoring carbon-dioxide seepage from deep below ground reservoirs.

Accomplishments

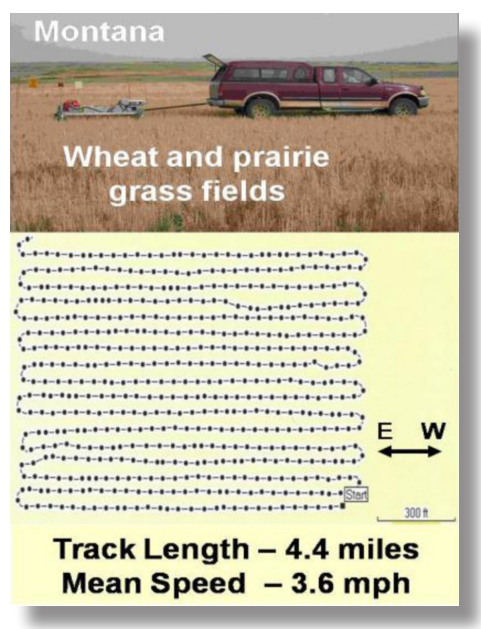
- An INS system for non-destructive, in-field soil carbon analysis, in both static and scanning modes was constructed and tested. The results demonstrated the proof-of-principle, and the feasibility of using the system as intended.
- BNL researchers partnered with scientists from several Agricultural Research Service (ARS) of the U.S. Department of Agriculture in NC, AL, SC, and OK, and with scientists from several Universities in PA, OH, and MT in conducting measurements of soil carbon using the INS system and cross correlating the findings with concomitant soil analysis by the standard method. The results showed very good agreement between these two methods.
- In addition to elemental analysis; carbon (C), nitrogen (N), potassium (K), calcium (Ca), and phosphorous (P), it was shown that the system also can measure the soil's water content.
- The alpha prototype was able, within a month, to detect the stress caused by carbon-dioxide leaks on local vegetation, and the subsequent loss of soil carbon.
- The INS beta-prototype system with new electronics is undergoing evaluation and testing. Using 16 detectors, it offers superior sensitivity for the elements mentioned above.
- Current basic spectral-analysis software was improved; however, implementing advanced spectral analysis using the least squares method and spectral libraries are planned.
- A Monte Carlo simulation of the INS system using the N-Particle (MCNP5) code needs to be finalized and validated.



INS Alpha Prototype Placed Above a Sand Pit with Synthetic soil.

Benefits

This project successfully demonstrated a one-of-a-kind, robust, flexible, non-invasive, mobile system for *in situ* carbon monitoring. The system introduces types of measurements that previously were not possible. Expectedly, this will benefit our understanding of the belowground carbon processes without disturbing the soil, and will prove adequate sensitivity to detect leaks from geological sequestration. Furthermore, the system supports the continuous scanning of large areas, thus providing the true mean carbon-concentration in the soil, which is an essential part of true sequential measurements.



INS Mobile Scanning a Wheat Field in Montana and the GPS Trace of the Scan.