# Feasibility of Measuring Soil Moisture Content Using the Inelastic Neutron Scattering (INS) Carbon Analyzer


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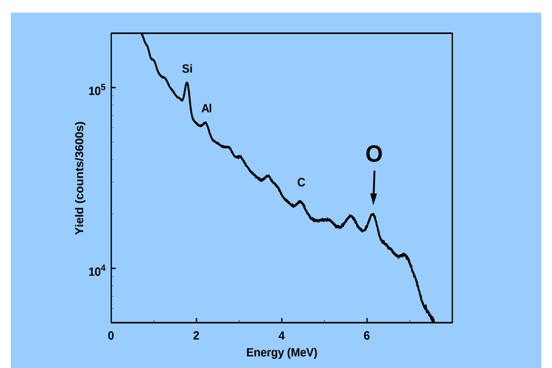
## Abstract

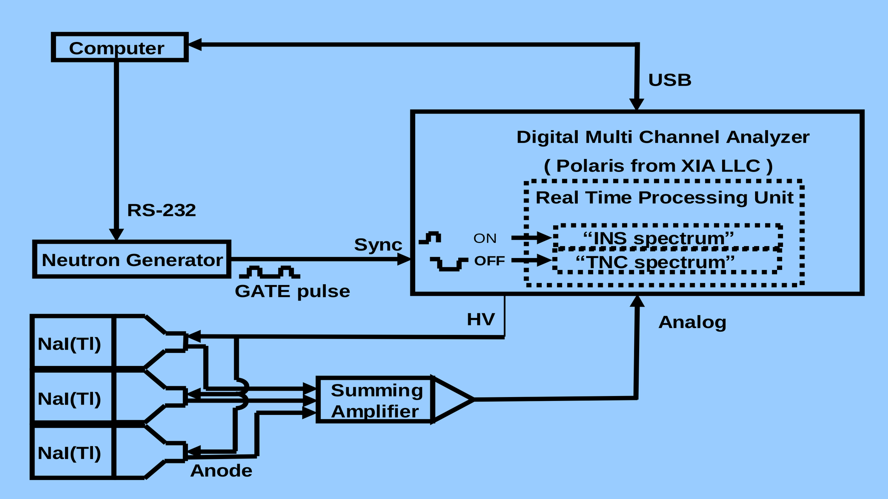
Knowledge of soil carbon (C) and moisture content is vital for crop and soil management, carbon sequestration and climate change studies. For that purpose we developed an INS system that is non-destructive and provides multi-elemental analysis in large soil volumes. Similarly, the system can also be used to measure water content in soil. Current methods for measuring these components require independent techniques that are destructive and labor intensive. Here we report our initial studies showing that (1) Hydrogen (H) rather than Oxygen (O) is a better indicator of the soil moisture and (2) since C,O and H are measured concurrently , H might be used for adjusting the carbon reading due to changes in soil moisture.


## Principle

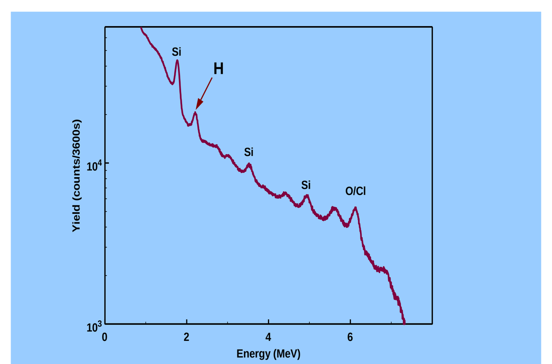
Fast neutrons from a pulsed 14 MeV neutron generator (NG) impinge on soil and interact with various elements present. During the neutron burst (ON state) they undergo inelastic neutron scattering (INS) with C and O nuclei, whereas in-between the bursts (OFF state) the neutrons slow down via elastic scattering with the soil's matrix elements and undergo thermal neutron capture reactions (TNC) with H. Both the INS and TNC processes produce characteristic elemental gamma-rays. These are recorded concurrently but separately as INS and TNC spectra. The block diagram of the data acquisition system, the INS system and the resulting two spectra are shown below.


"INS Spectrum-measure C and O"




**Data Acquisition System**




"TNC Spectrum-measure H"

## Methods

- Laboratory experiments were carried out at the Soil Analysis Facility at BNL, New York. Dry, 2% moisture, top soil was homogeneously mixed with water at 25, 50 and 75% of the Field Capacity resulting in about 7, 12 and 15 % soil moisture, respectively. The mixtures were transferred to pits 152 cm by 122 cm and 46 cm deep and analyzed with the INS system positioned over the pit. The INS and TNC spectra measurements were repeated three times and sthe oil moisture was determined gravimetrically.
- Field experiments were carried out at the Pee Dee Clemson University Research Station, South Carolina. INS and TNC spectra were acquired at ten sites along a transact. At each site (a) volumetric soil moisture content was measured using a theta probe, (b) gravimetric moisture content measured on composite samples from 8 cores collected to 30 cm depth and (c) separately, gravimetric analysis of soil moisture from 0-5, 5-10, 10-20,20-30 and 30-40 cm depth intervals of 5 individual cores.

## Results

Hydrogen yield correlation to soil moisture changes (Fig 1) was much superior to oxygen yield correlation (Fig 2) both when homogeneously and heterogeneously distributed.

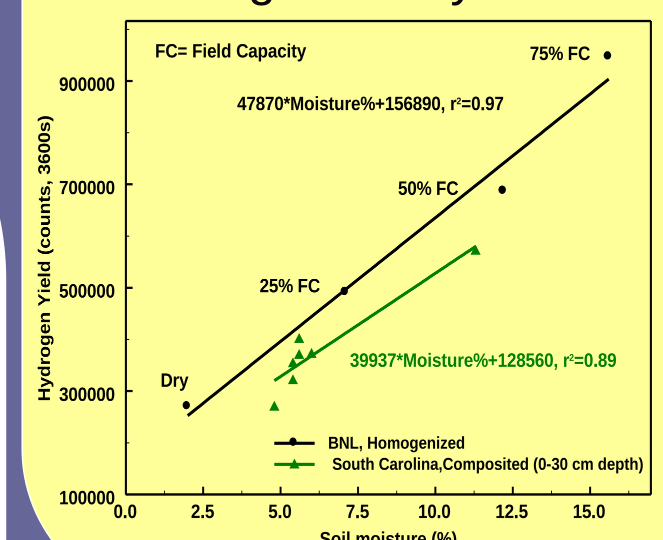



Fig.1

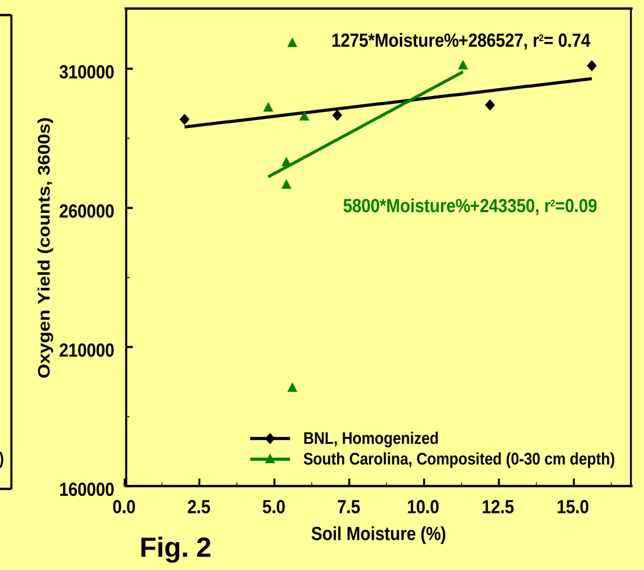



Fig. 2

The H yield correlation with Theta probe moisture measurements made to a depth of 6.5 cm (Fig.3) is poorer compared to the relationship with gravimetric moisture determination to 30 cm depth (Fig.1).

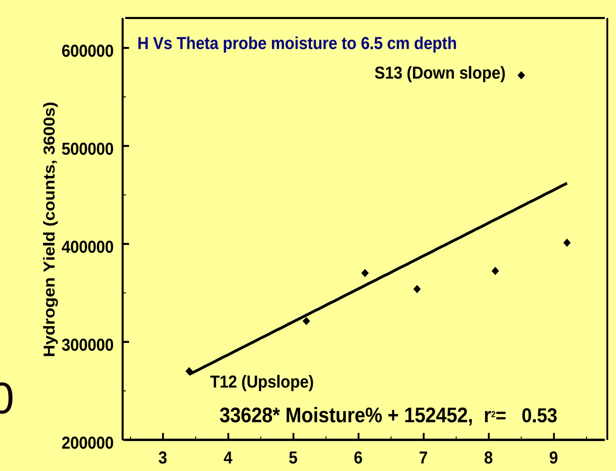



Fig. 3

- The gravimetric moisture data to 30 cm depth also have a poor correlation with Theta probe moisture values .
- The high intercept needs to be investigated (Fig. 4).

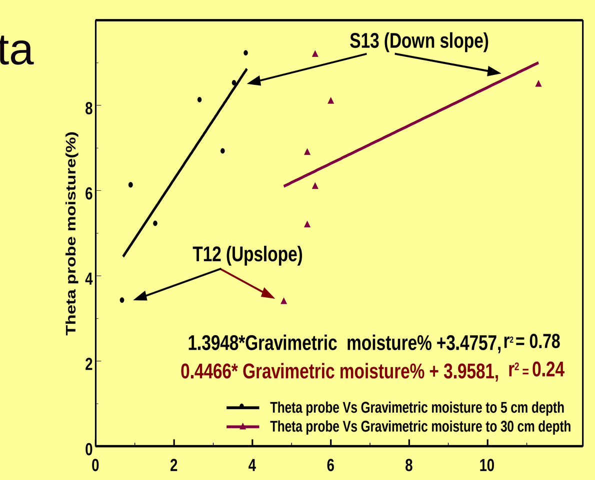



Fig. 4

- The H yield best fit the gravimetric data from 20-30 cm depth (Fig. 5). The oxygen yield correlation was much poorer (Fig. 6).
- The gravimetric moisture(%) tended to peak at a depth of 20-30 cm (Fig. 7).

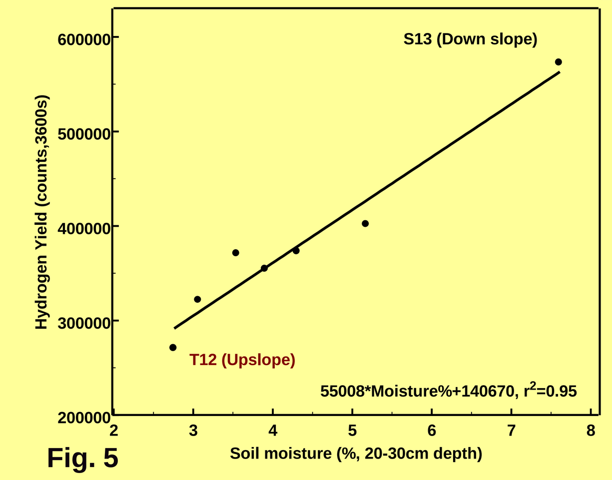



Fig. 5

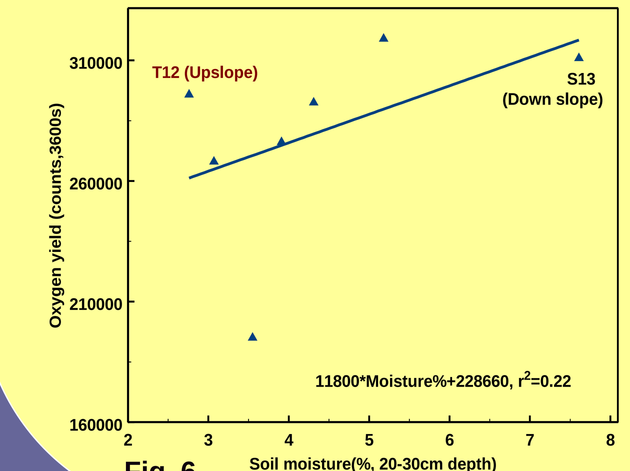



Fig. 6

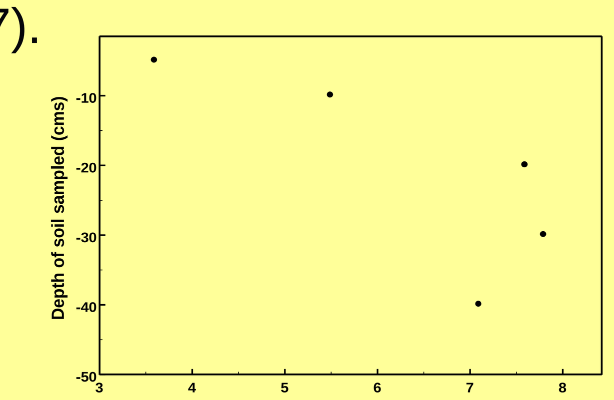
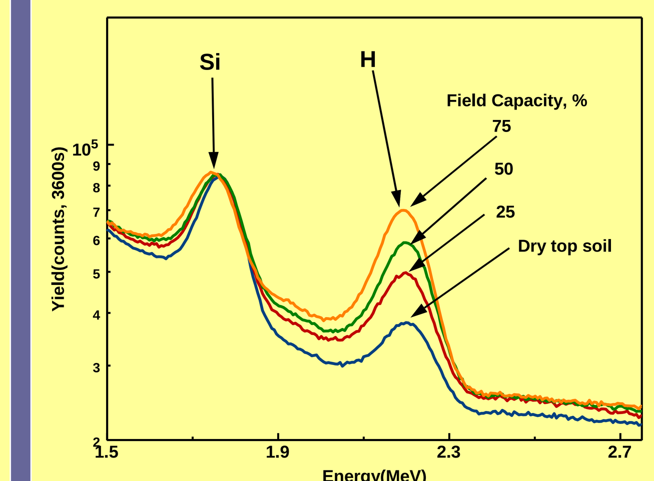



Fig. 7


Pee Dee Clemson Research Station, South Carolina

Hydrogen spectra show the sensitivity towards moisture change.




BNL Soil Analysis Facility, New York

## Conclusions

- Using an INS system we showed the possibility of measuring soil moisture concurrently with C determination.
- Hydrogen signal correlates better than O with soil moisture content.
- The high intercepts in the regression lines and the nature of the H and O outliers in the field require further inquiry.
- Based on our results we may use the H signal for C corrections that may be required due to changes in the soil moisture.
- The affect of concurrent change in soil density needs to be investigated.