SOIL CARBON MEASUREMENT USING INELASTIC NEUTRON SCATTERING TECHNIQUE: SOIL MOISTURE AND SAMPLING DEPTH EFFECT

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Introduction

To lower the risk of trading sequestered soil carbon (C) credits, an accurate assessment of soil C stock is needed. Sequestered soil C stock must be easily verifiable at a relatively low cost. Current procedures that are used to evaluate soil C are invasive, labor intensive, and costly. Emerging technologies including the Inelastic Neutron Scattering (INS) procedure have the potential to significantly reduce the problems associated with current soil C measurement techniques. The INS system used here is a rapid, noninvasive, in-situ, and a field deployable system that has shown great promise for soil C assessment; it can be operated both in static and dynamic modes. In the static mode, the INS has the potential to assess soil C for individual measurement positions, and also to integrate across large areas to give a mean value for an entire field when operated in the dynamic scanning mode. Limited laboratory and field experiments have indicated that the INS has the potential to be a rapid procedure for soil C assessment relative to conventional dry combustion method (Wielopolski et al., 2000, 2003). However, the effects of soil properties e.g. texture, moisture, and bulk density on INS-measured C are largely unknown.

Objectives:

Our objectives were to assess the effects of soil moisture and sampling depth on INS-measured C relative to dry combustion method.

Materials and Methods

Principle of INS Technique:

The INS technique is based on fast (14 MeV) neutrons emitted from a neutron generator, undergoing inelastic neutron scattering reaction with C nuclei that subsequently emit characteristic 4.44 MeV gamma rays detected by NaI detectors. The recorded gamma ray spectra are analyzed for peak intensities proportional to the C abundance in the soil. An INS system in static and scanning modes are shown in Figs. 1 and 2, respectively.

Laboratory and Field Experiments:

Moisture Effect on INS signal and consequent soil C counts was determined in the laboratory using a composted topsoil (4.2% SOC). Field water holding capacity (FC) for the dry soil was determined and subsequently equilibrated with water at 0, 25, 50, and 75 % of FC, prior to experimentation. INS C, oxygen (O) and hydrogen (H) counts were then measured for each of the moisture levels. At each moisture level gravimetric moisture contents were also determine before and after INS measurement.

Field experiments were conducted at the Clemson Pee Dee Research and Education Center, Florence, South Carolina. Static INS C measurements were carried out at seven measurement positions along a 200 m transect that included different topographic positions, soil types, and drainage conditions (Fig. 3). At each measurement position, five individual soil cores were taken at 0-5, 5-10, 10-20, 20-30, and 30-40 cm depth intervals from within a 1m² area that was centered on the INS neutron generator. In the laboratory, the samples were analyzed for gravimetric soil moisture content, and for soil C using dry combustion method (LECO). Based on the laboratory and field moisture data, INS C yield were corrected for moisture and the results were compared to soil C values that were obtained by the dry combustion procedure.

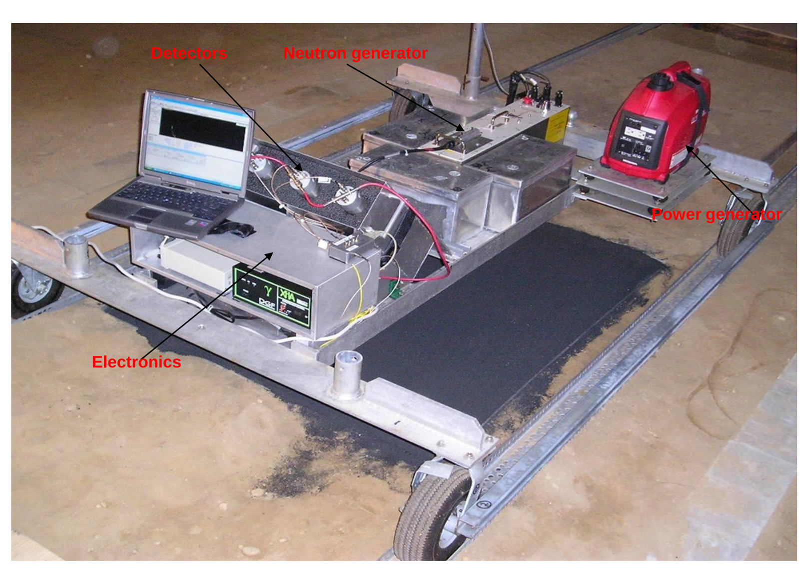

Figure 1. INS in Stationary Mode.

Figure 2. INS in Scanning Mode.

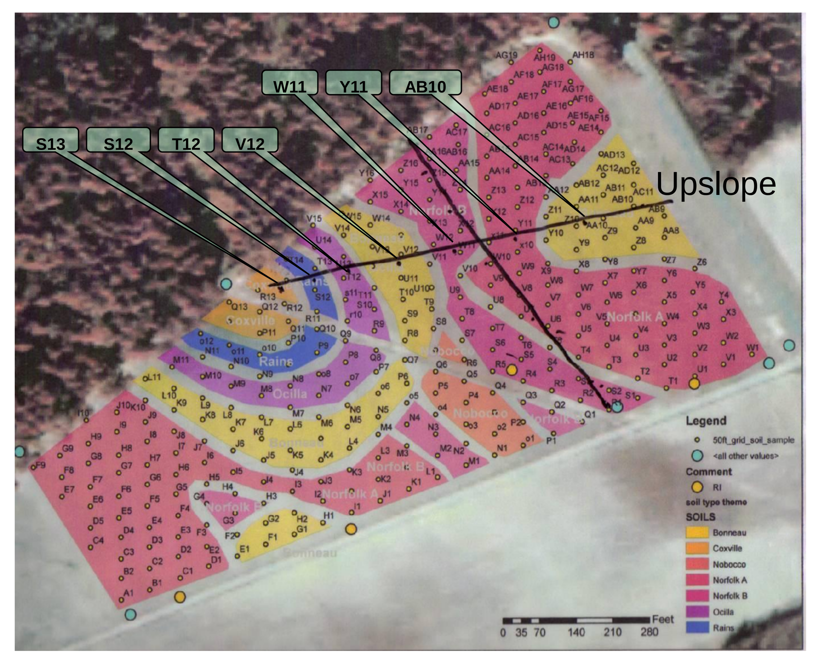

Figure 3. Soil types and Measurement Positions at the PEE DEE, Research Field, South Carolina.

Table 1. Selected Soil Characteristics of Experimental Field

Location ID	Soil type	Soil Moisture	Bulk density	Soil C (g cm^{-2})		
		Gravimetric	(0-5 cm)	Depth (cm)		
		%	g cm^{-3}	0-5	5-10	0-30
AB	Bonneau	5.6	1.53	0.59	0.56	2.30
V12	Bonneau	6.0	1.50	0.54	0.56	2.39
W11	Norfolk	5.4	1.47	0.45	0.56	1.88
Y11	Norfolk	5.4	1.57	0.36	0.50	1.84
T12	Ocilla	4.8	1.40	0.80	0.61	3.05
S12	Rains	5.6	1.47	0.74	1.04	3.34
S13	Coxville	11.3	1.49	1.04	0.86	3.66

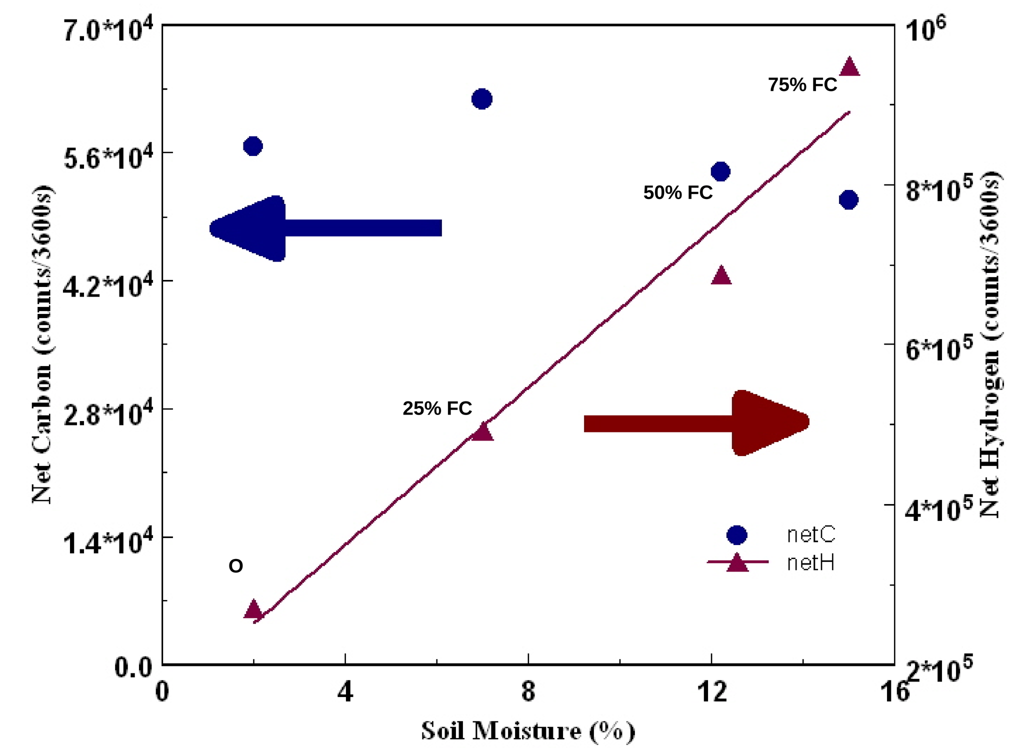

Figure 4. Moisture Effect on INS Carbon and Hydrogen Counts

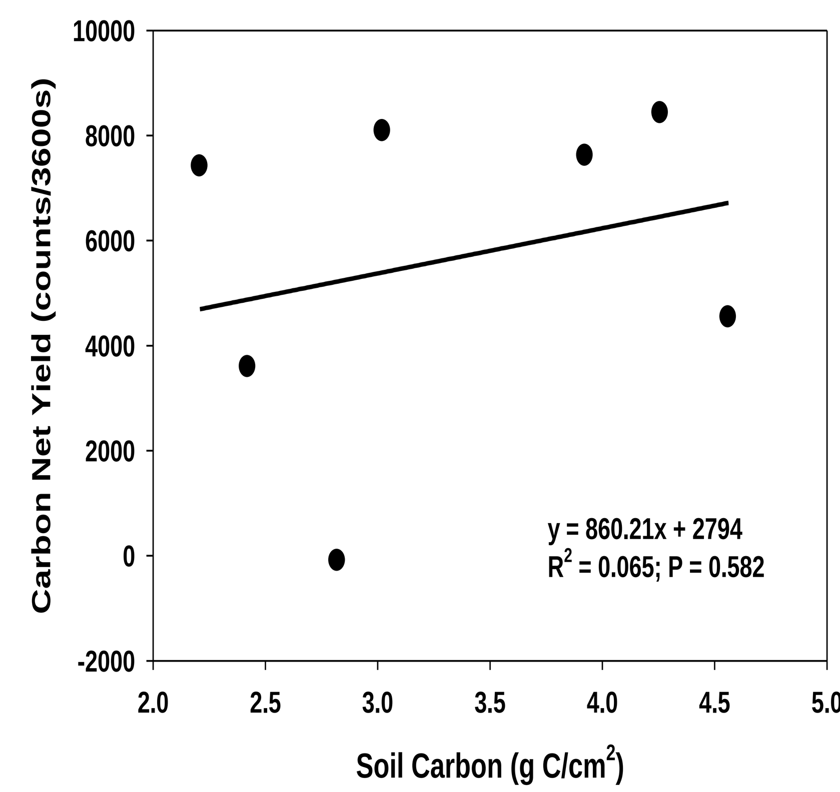

Figure 5. Moisture Uncorrected Carbon Yield vs. Dry Combustion

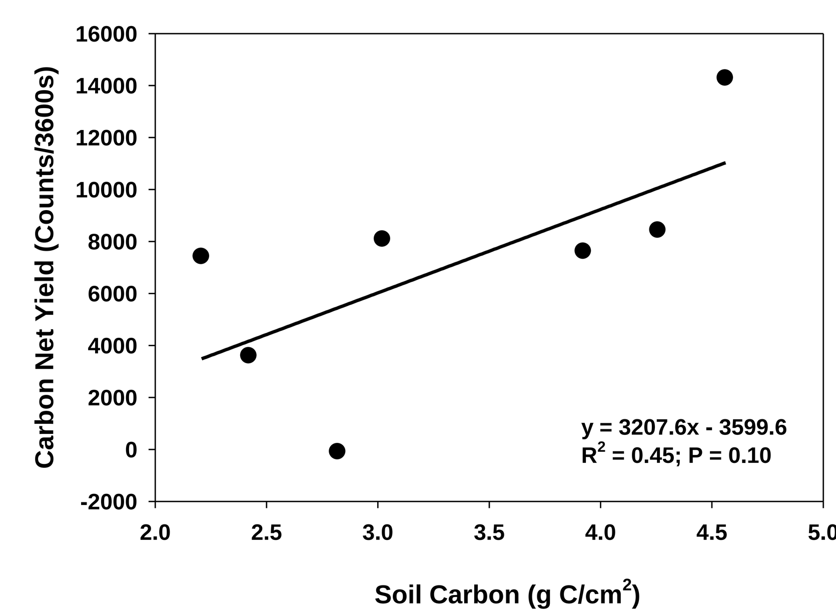

Figure 6. Moisture corrected Carbon Yield vs. Dry Combustion

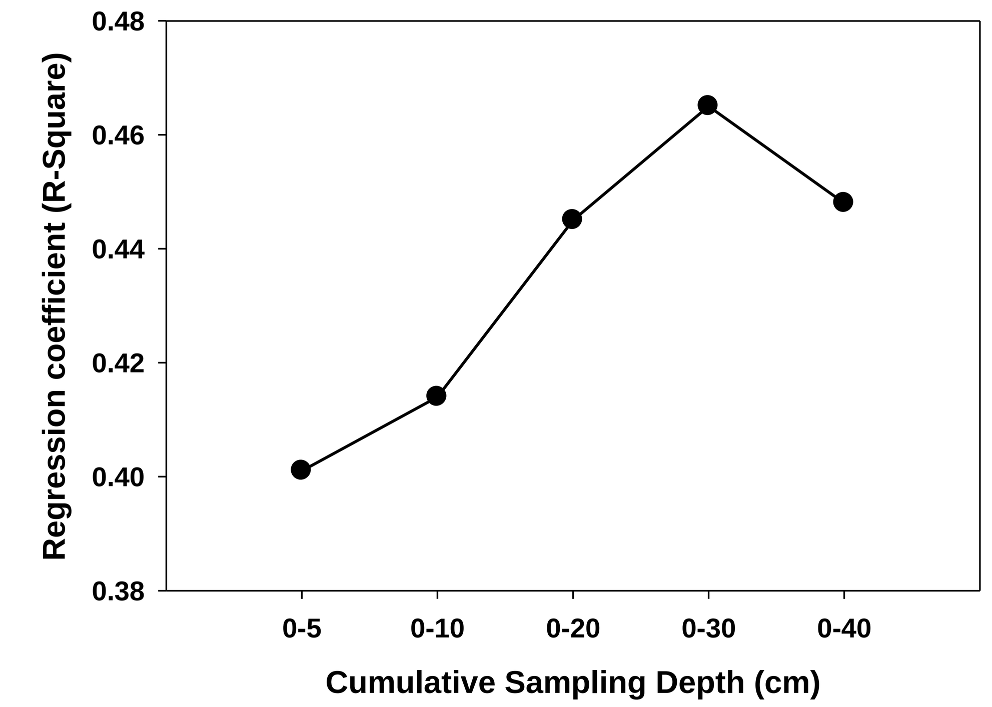

Figure 7. Relationship between INS Carbon Yield and Dry Combustion with Soil Depth

Results

Laboratory experiment showed that H count was a better indicator of soil moisture levels than O. Hydrogen counts increased linearly with soil moisture (Fig. 4). Oxygen counts showed a lower sensitivity to changes in soil moisture, possibly due to the extensive presence of O in silica component of soils.

INS C signal increased with soil moisture up to 25% FC and decreased as moisture contents increased above 25% FC. A decrease of nearly 20% in the C signal was observed at moisture level of 75% FC.

Soil C, moisture, and bulk density measured for the experimental field are presented in Table 1. Soil C and moisture were generally low except at the S13 measurement location which was probably due to its footslope topographic position.

Preliminary calibration results indicated a low but positive (r = 0.25) relationship between soil C estimated by the INS (C net counts) and dry combustion, when soil moisture effect was not considered (Fig. 5). However, correlation between INS and dry combustion-estimated C was significantly improved (r = 0.67) when INS C counts were adjusted for soil moisture (Fig. 6). The difference in soil C estimate was attributed in part, to differences in C pools measured by both procedures; INS measures total soil C (including C in roots and inorganic C).

Estimated by cumulative depth increment, relationship between INS C count and dry combustion increased as cumulative sampling depth increased up to 30 cm (r^2 = 0.47), but decreased with further sampling depth (0-40 cm depth: r^2 = 0.45) (Fig. 7).

Conclusion

- INS soil C measurement appeared to be affected by soil moisture.
- Relationship between INS and dry combustion-measured C was depth dependent and was strongest in the surface 30 cm.
- More laboratory and field characterization data would be needed to further calibrate INS C relative to the dry combustion procedure.

References

Wielopolski, Lucian, Itzhak Orion, George Hendrey, and Hugo Roger, A. Tobert, and S. Prior. 2003. Non-destructivem in situ soil carbon analysis: principle and results. Proceedings of the Second Annual Conference on Carbon Sequestration. May 3-5, Article No. 225

Wieopolski, Lucian, Itzhak Orion, George Hendrey, and Hugo Roger. 2000. Soil carbon measurements using inelastic neutron scattering. IEEE Transactions on nuclear science: 47:914-917.