Non-destructive Assessment of Belowground Carbon: Recent Observations Ranging from Organic Soils to Abandoned Mine Land

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Inelastic Neutron Scattering (INS):- *Is a new method for multi-elemental analysis of soil based on spectroscopy of gamma rays induced by fast, 14 MeV, neutrons. The INS system consists of; a neutron generator, a detection system and a power generator, which are mounted on a cart ~30 cm above the ground. The data is acquired in situ, non-destructively in either stationary or scanning modes of operation for a duration of 30 min or longer. INS uniquely analyzes large volumes, ~0.3 m^3, to a depth of ~30 cm . The measured gamma rays are expressed in units of kgC/ha.*
Results using INS alpha prototype, its unique capabilities and its suitability for NACP are presented below.

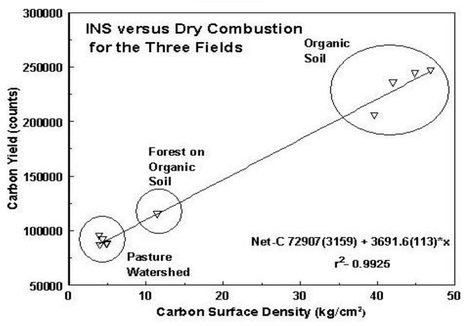
Results Using INS System

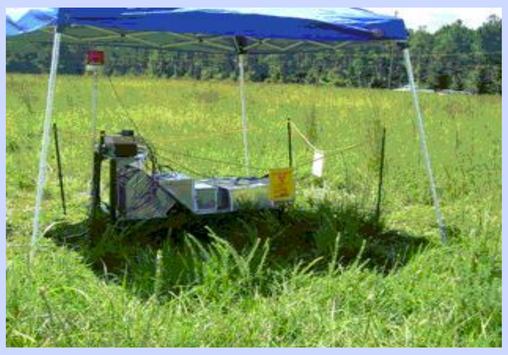
INS scanning of an organic field.

INS static measurement in a forest.

INS scanning a pasture field in a watershed.

INS Calibration of Three Diverse Fields.



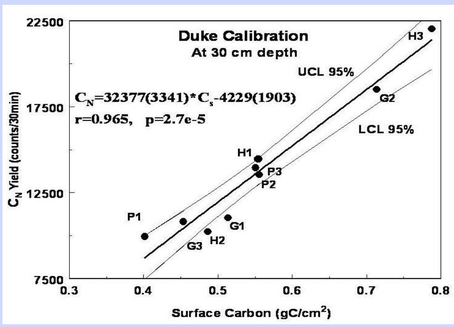


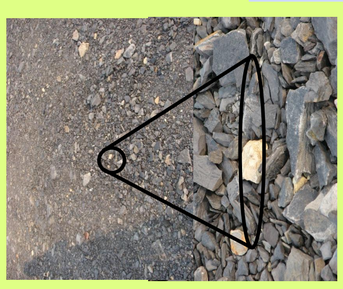
INS static measurement in a grass field (G).

INS static measurement in a pine forest (P).

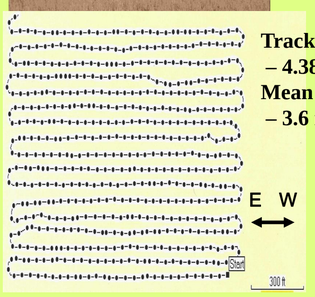
INS static measurement in an oak forest (H).

INS Calibration of Three Diverse Fields.

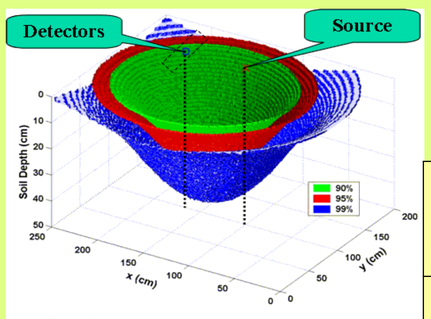




INS use in abandoned mine land.



INS scan of a wheat field and a GPS trace.



Surfaces Describing the volumes from which a 90, 95 and 99% of the detected signal.

MCNP Simulated volumes and footprints sampled by INS.

% of Total Response	Depth (cm)	Footprint (m^2)	Volume (m^3)	Mass (kg)
90	25	2.400	0.233	325.66
95	31	3.345	0.373	522.18
99	44	7.069	0.789	1105.29

INS System Performance

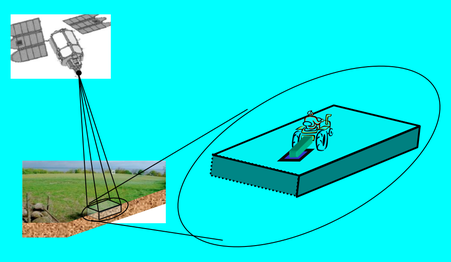
Statistics: Sensitivity 32377 counts/gC/cm^2/h MDL ~0.1 %C
Reproducibility: Long Term, 2 years: n (plastic) ~ 1%; (Cu foils) ~ 2.9%, Si ~ 2.3%, C ~ 5.0%
Error: for a single carbon analysis is between 5% to 10%. The relative error can be arbitrarily reduced as SQRT of the counting time.

INS Future Developments:

- *Development of an advanced operating system based on power over the Ethernet communications for a newly ruggedized system.*
- *Implementation of an advanced spectral analysis software based on Library Least Squares (LLS) providing superior spectral resolution and minimizing error propagation.*
- *APT – Implementation of an Associated Particle Technology to improve the system's sensitivity and enable to measure soil carbon depth profile non-destructively.*
- *Monte Carlo modeling of a complete INS system.*

New Applications of INS System:

1. *Correlating above ground Remote Sensing of soil C and moisture with INS belowground determination of C and moisture on the same pixel size.*



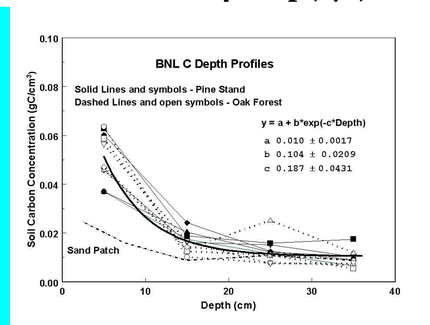
2. *Comparison of soil C assessment by Eddy Covariance Towers with soil C determination at the tower's foot print by the INS.*

C Depth Profile Physical Model (CDPPM)
CDPPM = α + β*exp(-γz)

3. *A new non-destructive approach for assessing soil C inventory on a large scale to a depth of 100 cm.*

$$\int_{100}^{0} CDPPMdz \Big/ \int_{30}^{0} CDPPMdz = K$$

$$\int_{100}^{0} CDPPMdz = INS*K$$



4. *Implementing INS in estuaries and marshlands.*
5. *Redesigning INS system for underwater measurement of sedimentation for C buildup.*
6. *Non-destructive determination of C depths profile.*

INS Relevance to NACP

- *Correlation of remotely sensed soil C and moisture over large areas with the same belowground determinations by INS.*
- *An independent novel approach for determining soil carbon inventory.*
- *Improving and enhancing soil C datasets used in climate change models.*

These characteristics would be of particular interest in the TUNDRA and permafrost regions; the new frontiers in the global climate research.