# Assessment of Soil Sampling Methods for Carbon Credit Monitoring

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## Background

- In 2001, the Oklahoma Legislature passed the Oklahoma Carbon Sequestration Enhancement Act,
  - Authorized the OK Conservation Commission to verify and certify carbon offsets.
- In 2007, a pilot project was designed and implemented in 2008 in conjunction with a EPA 319 targeted watershed project.
- In 2008, N. Canadian Pilot Project was initiated,
  - Western Farmers Electric Coop provided funds to purchase carbon offsets and also to initiate research on carbon sequestration in OK.
  - Prior to the initiation of this effort only 2 studies had been conducted on carbon sequestration in Oklahoma.
- Program uses expected sequestration rates in Oklahoma established by Chicago Climate Exchange,
  - 0.27 Mg C $ha^{-1}$ $yr^{-1}$ for no-till in western OK.
  - 0.67 Mg C $ha^{-1}$ $yr^{-1}$ for grass plantings.
- Preliminary, but highly variable data collected to 0-110 cm from the N. Canadian river watershed suggests an annual average sequestration rate of 0.3 Mg C $ha^{-1}$ $yr^{-1}$ in no-till field samples.
- Methodologies are needed by which verifiers can collect soil samples to monitor carbon sequestration in aggregated cropland.
- This will strengthen estimates and the carbon market in Oklahoma.

## Objectives

- Evaluate soil sample collection alternatives to a hydraulic probe that the Oklahoma Conservation district personnel can use to monitor carbon.
- Design and create a database to
  - Monitor changes in carbon content of soils under contract for carbon offset payments.
  - Utilize it to determine the impacts of soil type, management, and location on carbon sequestration.

## Materials and Methods

- Alternatives to Hydraulic probe were push probe and slide hammer (Fig.1).
- 48 fields under contract were sampled with the hydraulic probe (Fig. 2).
- 19 fields were sampled with all the three probes.

**Figure 1: Push, Hydraulic and Slide hammer probe (left to right) with cutting diameter of 2.67, 3.98 and 4.8cm respectively.**

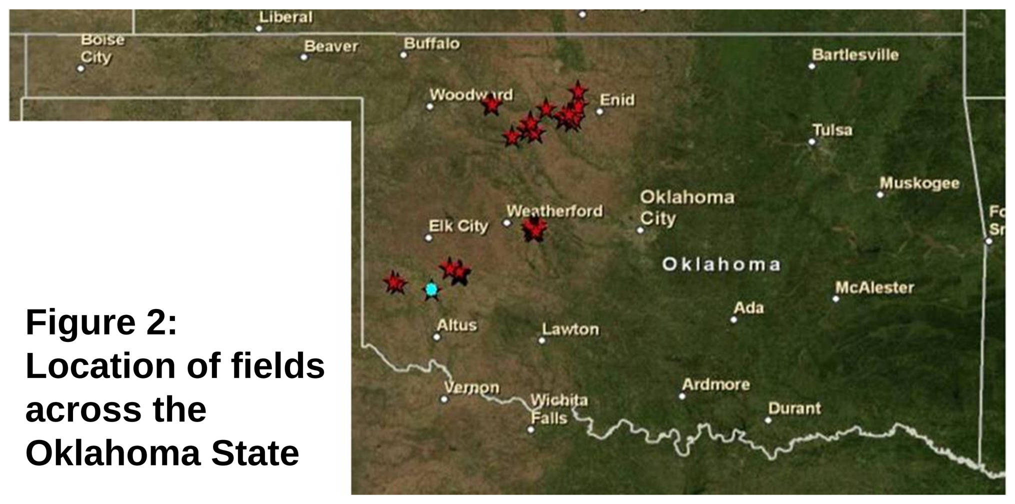


**Figure 2: Location of fields across the Oklahoma State**

- A random point was generated in each field using random point generator in ArcGIS.
- Twenty samples were collected from each field,
  - 10 belonged to hydraulic probe.
  - The other 10 belonged to push and slide hammer probe sharing 5 each.
- Samples were collected to depths of 0-10, 10-20, 20-30 cm (Fig. 3).
- Sample segments were put in to zip lock bags and stored in an ice chest until transported to and stored in a refrigerator at 4º C.
- Wet sample weight was measured.
- Moisture content at each depth was measured gravimetrically using a sub-sample dried at 110 °C.
- Bulk density was determined using the moisture content, wet sample weight cutting diameter of probe and segment length.
- Whole samples were dried at 65 °C for at least 48 hrs.
- Dried samples were ground to pass a 2mm sieve and analyzed for total carbon concentration using the dry combustion method.
- pH of the soil samples was measured using 1:1 soil to water ratio.
- Samples with pH greater than 7.2 were analyzed for inorganic carbon concentration separately using Pressure-Calcimeter method.
- Two methods were used to calculate carbon mass in the soil:
  - Fixed Depth
  - Fixed Mass
- Fixed depth: Carbon mass was determined by using bulk density readings to a fixed depth of 30cm.
- Fixed Mass: A core with minimum soil mass up to 30cm was selected (3689 Mg).
- All the cores were adjusted to this minimum soil mass and carbon mass was calculated in constant mass of soil per unit area.

**Figure 3: Hydraulic probe core being cut into segments.**

## Results

- Bulk density measured with the push probe is significantly higher than hydraulic and slide hammer probes in the surface 10cm (Table 1).
- Coefficients of variation in bulk density measured with the push probe were higher than with other probes and significantly higher at 10-20 cm.
- The carbon concentrations were significantly higher in the hand probe than in remaining probe types in the 10-20 cm depth (Table 2).
- The organic carbon mass measured by the push probe to 30 cm was significantly higher than that from the hydraulic probe(Table 3).
- Likely resulted from compaction, as indicated by increased bulk density in the hand probe treatment
- The fixed mass method of calculating carbon masses resulted in no-significant difference in carbon mass among the probe types.
- Coefficients of variation in organic carbon mass is higher for hydraulic probe in fixed depth method.
- Average number of samples required to measure expected carbon sequestered using fixed depth is higher than average number of samples required for fixed mass method (Fig. 3 and 4).

**Table 1: Measurement of bulk densities at various depth with all three probes with their percent coefficient of variation. (lsd p<0.05)**

| Depth (cm) | Probe type | Bulk Density (g/cm3) | CV (%) |
|---|---|---|---|
| 0-10 | Push Probe | 1.46a | 7.92a |
| | Slide Hammer | 1.32b | 7.73a |
| | Hydraulic Probe | 1.33b | 7.82a |
| 10-20 | Push Probe | 1.51a | 7.00a |
| | Slide Hammer | 1.55a | 4.77b |
| | Hydraulic Probe | 1.53a | 6.09ab |
| 20-30 | Push Probe | 1.56a | 6.51a |
| | Slide Hammer | 1.56a | 5.33a |
| | Hydraulic Probe | 1.53b | 5.18a |

**Table 2: Carbon concentration, Carbon as measured with Push, Slide Hammer and Hydraulic probe at 0-10, 10-20 and 20-30cm depth. (lsd p< 0.05)**

| Depth (cm) | Probe | Total OC* (g/kg) | Average OC* CV (%) | Carbon Mass (Mg/ha) | Average CM* CV (%) |
|---|---|---|---|---|---|
| 0-10 | Push | 6.9a | 14.9a | 9.9a | 14.5a |
| | Slide Hammer | 7.1a | 16.2a | 9.3a | 16.9a |
| | Hydraulic | 7.0a | 17.4a | 9.3a | 16.7a |
| 10-20 | Push | 5.5a | 18.4a | 8.0a | 19.9a |
| | Slide Hammer | 5.2b | 13.0a | 8.0a | 14.3a |
| | Hydraulic | 5.2b | 16.6a | 7.8a | 18.1a |
| 20-30 | Push | 5.3a | 18.3a | 8.0a | 19.4a |
| | Slide Hammer | 5.2a | 16.0a | 7.9a | 17.2a |
| | Hydraulic | 5.0a | 17.5a | 7.5a | 18.3a |

*Organic Carbon

**Table 3: Organic Carbon Mass (OMC) as measured with Push, Slide Hammer and Hydraulic probe in 0-30 cm depth using Fixed depth and mass (3689 Mg) method. (lsd at p<0.05)**

| Method | Probe | Average OCM (Mg/ha) | CV OCM (%) |
|---|---|---|---|
| Fixed Depth | Push | 26.2a | 8.5b |
| | Slide Hammer | 25.2ab | 10.6ab |
| | Hydraulic | 24.6b | 11.2a |
| Fixed Mass | Push | 22.2a | 9.5a |
| | Slide Hammer | 21.7a | 10.4a |
| | Hydraulic | 21.4a | 11.4a |

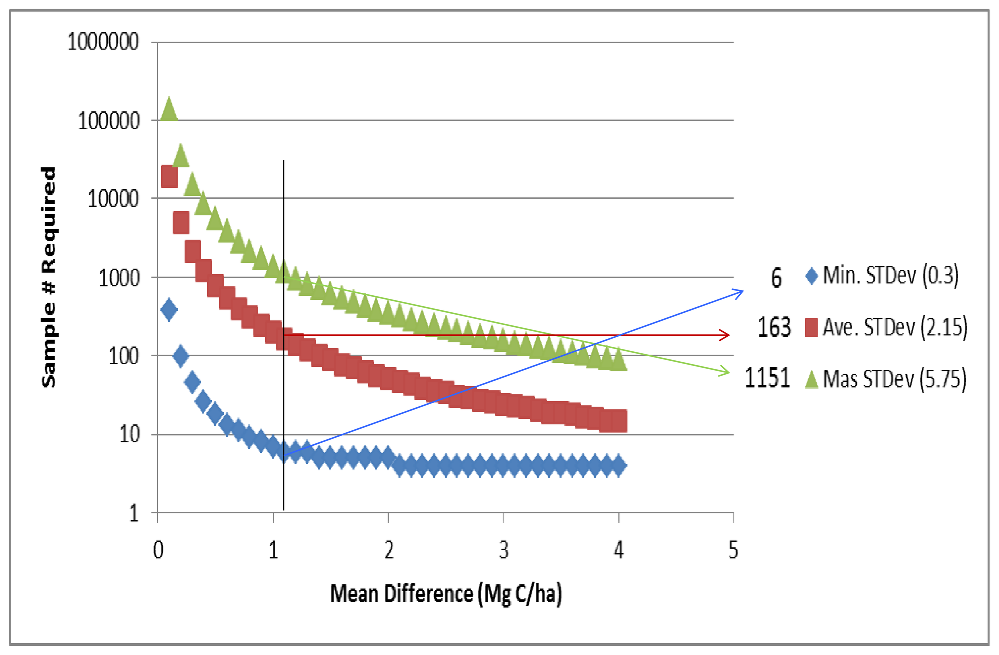


**Figure 3 : Power analysis for carbon content in surface 30 cm layer calculated using Fixed Depth method (Values left of legend are the number of samples required to measure significant difference of 1.1 Mg C $ha^{-1}$ at a single sample site)**

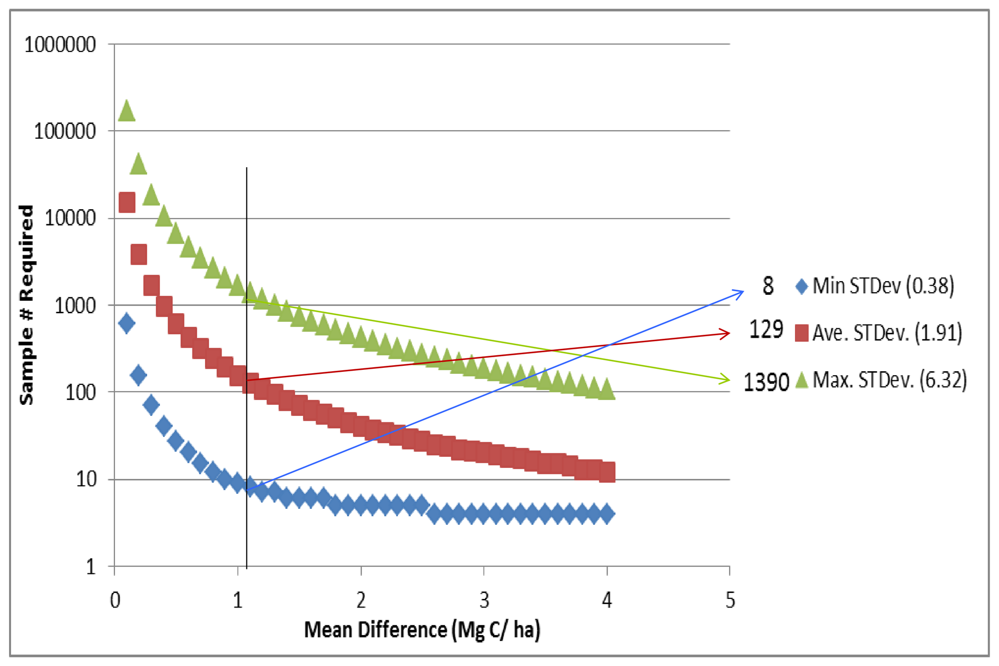


**Figure 4 : Power analysis for carbon content in surface 30 cm layer calculated using Fixed Mass method (Values left of legend are the number of samples required to measure significant difference of 1.1 Mg C $ha^{-1}$ at a single sample site)**

## Summary

- The small diameter push probe appears to compress the surface section of the core, resulting in increased bulk density.
- Variability is similar among sampling probes.
- Fixed mass method decreases variability and error resulting from the compression of soil cores.
- Number of samples required to measure expected sequestration rate is higher in fixed depth method.
- The fixed mass method reduced the average number of samples required to measure a difference, however, pooling data across fields maybe required to measure carbon sequestration in aggregated cropland.