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How critical is the baseline to assess carbon sequestration in agricultural soils?

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Soil carbon sequestration is a low cost effective option to mitigate increased atmospheric CO_2. Among strategies to increase the soil C sink, no-till is a prime option. Long-term experiments are valuable tools to estimate soil C sequestration rates. However, the rates reported in the literature are variable adding doubts about the real potential of agricultural soils as C sinks. Part of this uncertainty is due to the absence of a confident baseline of the carbon stocks at the beginning of the experiments. In the absence of a initial measurement, most of C sequestration rates are just based in the difference of stocks between treatments regardless temporal changes in within each treatment. The main objective of the study was to assess the C sequestration rates by different calculation methodologies.

This research was carried out upon a long-term experiment of the Kansas State University in Manhattan, KS, USA. The soil was a moderated well-drained Kennebec (Cumulic Hapludoll), refereed in this text as a Mollisol. The average annual precipitation is 800 mm with a mean temperature of 11.4 ºC. The experiment was initiated in 1990, with tillage (conventional tillage (chisel-disk) and no-tillage) as the main plots and nitrogen sources (168 kg N ha^{-1} as ammonium nitrate or cattle manure) as sub-plots, with 4 replications. Soil samples were taken in 1992 (baseline) and 2007 at 0-0.05, 0.05-0.15, 0.15-0.30, 0.30-0.45, 0.45-0.60, 0.60-0.90, and 0.90-1.20 m. The samples were air-dried, passed through a 2-mm sieve and roots removed. A sub-sample was ground and analyzed for total C by dry combustion using a C/N Elemental Analyzer (Flash EA 1112 series ThermoScientific). The soil carbon stocks were calculated based in the soil bulk density at 1992 and 2007 and compared on an equal mass basis. For the purpose of this study, the sequestration rates are calculated to the 0-0.30 m soil depth. The soil C sequestration rates were calculated by three different methodologies:

(1) Real C-Seq-Rate= $(C_{trt}t_n - C_{trt}t_0) / (t_n - t_0)$

(2) Apparent-Net C-Seq-Rate= $(C_{NTtrt}t_n - C_{CTtrt}t_n) / (t_n - t_0)$

(3) Real-Net C-Seq-Rate= $(C_{NTtrt}t_n - C_{NTtrt}t_0) - (C_{CTtrt}t_n - C_{CTtrt}t_0) / (t_n - t_0)$

where, $C_{trt}t_n$ is the carbon stock in the treatment at time n; $C_{trt}t_0$ is the carbon stock in the treatment at time zero; $C_{NTtrt}t_n$ is the carbon stock no-till treatment at time n; $C_{CTtrt}t_n$ is the carbon stock tilled treatment at time zero; $C_{NTtrt}t_0$ is the carbon stock no-till treatment at time n; $C_{CTtrt}t_0$ is the carbon stock conventional tillage treatment at time zero. The results were compared by the means' standard error and by the significance of the correlation in the regression analysis between sequestration rate calculation methodologies.

The main differences between treatments were noted at 0-0.05 m depth (A and B) (Fig.1). The highest soil C accumulation was noted in no-tillage with manure. Although there's also a difference in the deepest layer, sequestration rates are only calculated for the 0-0.30 m depth. The C sequestration rates varied more than 100% between calculation methods. Even in the conventional tillage soil C increased over the 15 years. In the mineral fertilizer treatments (D) rates ranged from 0.23 to 0.57 Mg C ha^{-1} y^{-1} and in the manure fertilized treatments (E) from 0.71 to 1.48 Mg C ha^{-1} y^{-1}. The apparent-net (2) and real-net (3) methods are similar (C) and useful to assess the net contribution over the soil organic C stocks by an improvement in soil management, such as the option for the no tillage adoption. In this case, the baseline did not have a significant impact on the estimation of sequestration rates. The real (1) method is more appropriate to evaluate the environmental value of the C sink. In this case, the baseline is critical, since the rate of C sequestration in each treatment was greater than the difference between treatments. For example, the real C sequestration rate in no-till with manure fertilization was 0.57 Mg ha^{-1} y^{-1} between 2007 and 1992, while in the conventional tillage was 0.29 Mg ha^{-1} y^{-1} in the same period. Results from paired plots often reported in the literature could underestimate soil C sequestration rates. In conclusion, changes in soil C stocks should include a minimum of two time points to determine the full value of soil C sequestration.

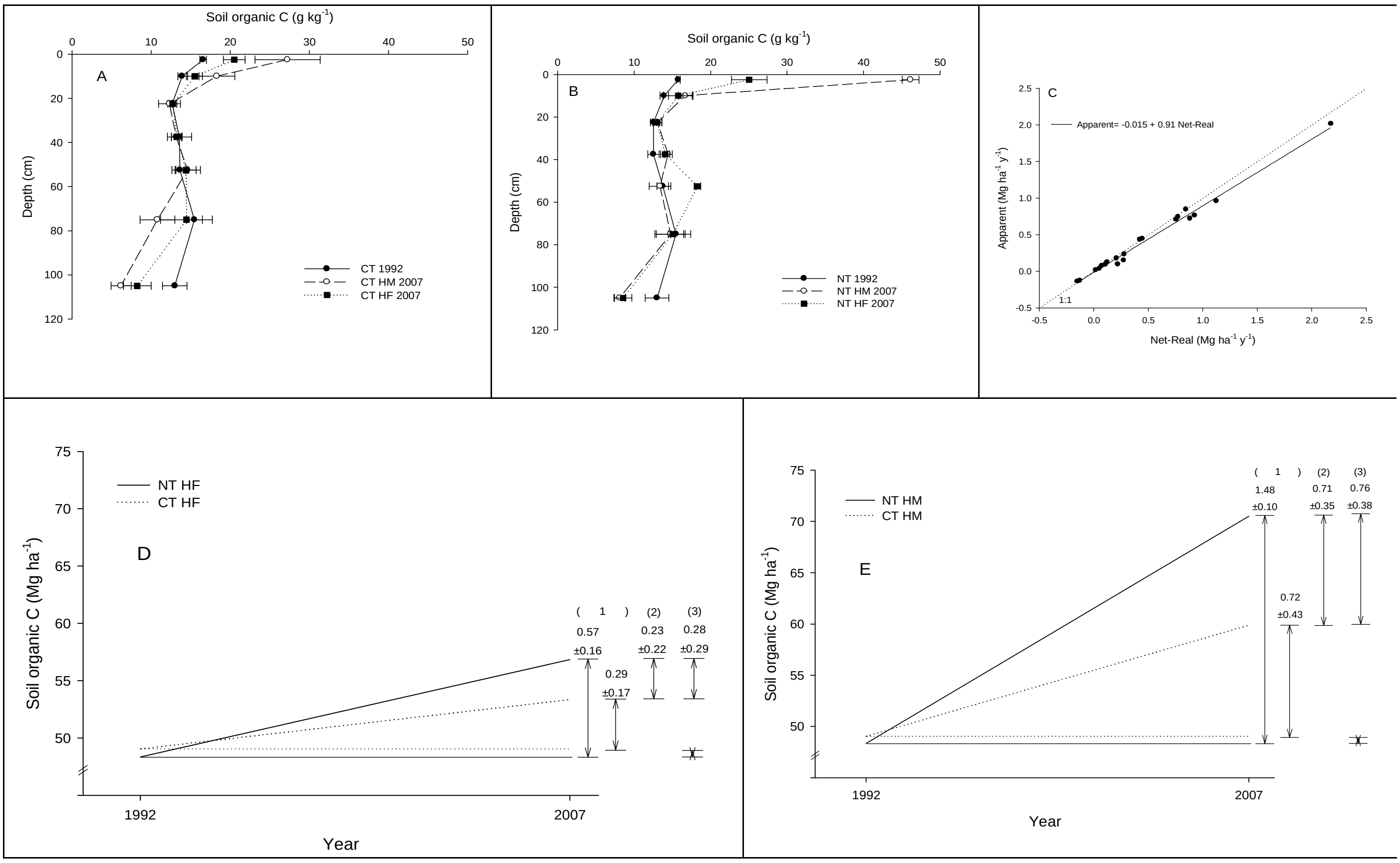

Figure 1. Soil organic C content in conventional tillage (A) and no-tillage (B) at 1992 and 2007 in a Mollisol from Kansas, USA. Relation between apparent and net-real carbon sequestration rates (C). Soil organic C and C sequestration rates calculated by different methods in the no tillage and conventional tillage with mineral fertilization (D) and manure fertilization (E) treatments at 0-0.30 m depth.