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Deep soil carbon sequestration under no-tillage cropping systems in tropical and temperate climates

Rodrigo S Nicoloso(1), CW Rice(1), TJC Amado(1), JE Fiorin(2)
(1) Kansas State University, 2004 Throckmorton Plant Science, Department of Agronomy, Manhattan, KS, USA.
(2) Fundacep, Cruz Alta, RS, Brazil

No-till is an option to increase soil carbon (C) stocks with benefits to soil quality and environment. The soil carbon sequestration rates are also affected by fertilization, crop rotations, time of no-till adoption, climate, soil type and the depth of the soil layer sampled. The main objective of this study was to evaluate soil carbon sequestration rates under long-term no-till in a Mollisol from Kansas, USA and an Oxisol from Southern Brazil.

The Mollisol was a moderately well-drained Kennebec (Cumulic Hapludoll) with an average annual precipitation of 800 mm and a mean temperature of 11.4 ºC. The experiment was initiated in 1990, with tillage (conventional tillage 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 Oxisol was a clay Rhodic Hapludox with a predominance of 1:1 kaolinite and iron and aluminum oxides. The experiment was initiated in 1985 with tillage systems as main plots (conventional tillage and no-tillage) and crop rotations as sub-plots (R0: soybean/wheat; R2: soybean/oat+vetch/corn/radish/wheat/soybean/oat), with 4 pseudo replications. Soil samples were taken in 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 grounded and analyzed for total C by dry combustion using a C/N Elemental Analyzer (Flash EA 1112 series ThermoScientific). Soil C 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 showed for the 0-0.30, 0-0.60, and 0-1.20 m soil depth. The soil carbon sequestration rates were calculated by three different methodologies (1 and 3 for Mollisol and 2 for Oxisol), as following:

(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 conventional tillage 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 soil carbon sequestration rates calculation methodologies.

For both soils, the main differences between treatments were noted at 0-0.05 m depth (Fig 1 A and D). The shallow depth was influenced by tillage treatments and C inputs from crop residues (Oxisol and Mollisol) and manure (Mollisol). For the Mollisol, the 0.90-1.20 m soil layer showed a consistent reduction of carbon content in all treatments. This effect could be explained by the shallow root system in agricultural systems compared with grasslands. In the Mollisol (B), only the no-till showed soil C sequestration regardless of the soil layer analyzed, while the conventional tillage showed a loss of C at depth (0-1.20 m). The higher soil C sequestration at the surface in no-till compensated for the loss of soil C at depth. The real-net soil carbon sequestration (C) by no-till ranged between 0.28 and 0.76 Mg ha^{-1} y^{-1} at 0-0.30 m and between 1.12 and 2.18 Mg ha^{-1} y^{-1} at 0-1.20 m according to the N source. In the Oxisol, the apparent soil C sequestration (E) for no-till using conventional tillage with monocropping (R0) as the baseline ranged between 0.02 and 0.38 Mg ha^{-1} y^{-1} at 0-0.30 m and between 0.11 and 0.56 Mg ha^{-1} y^{-1} at 0-1.20 m for the R0 and R2 treatments, respectively. In conclusion, the results show that the investigation of soil C sequestration rates should be performed deeper than the tillage zone to assess the importance of agricultural systems as a soil C sink.

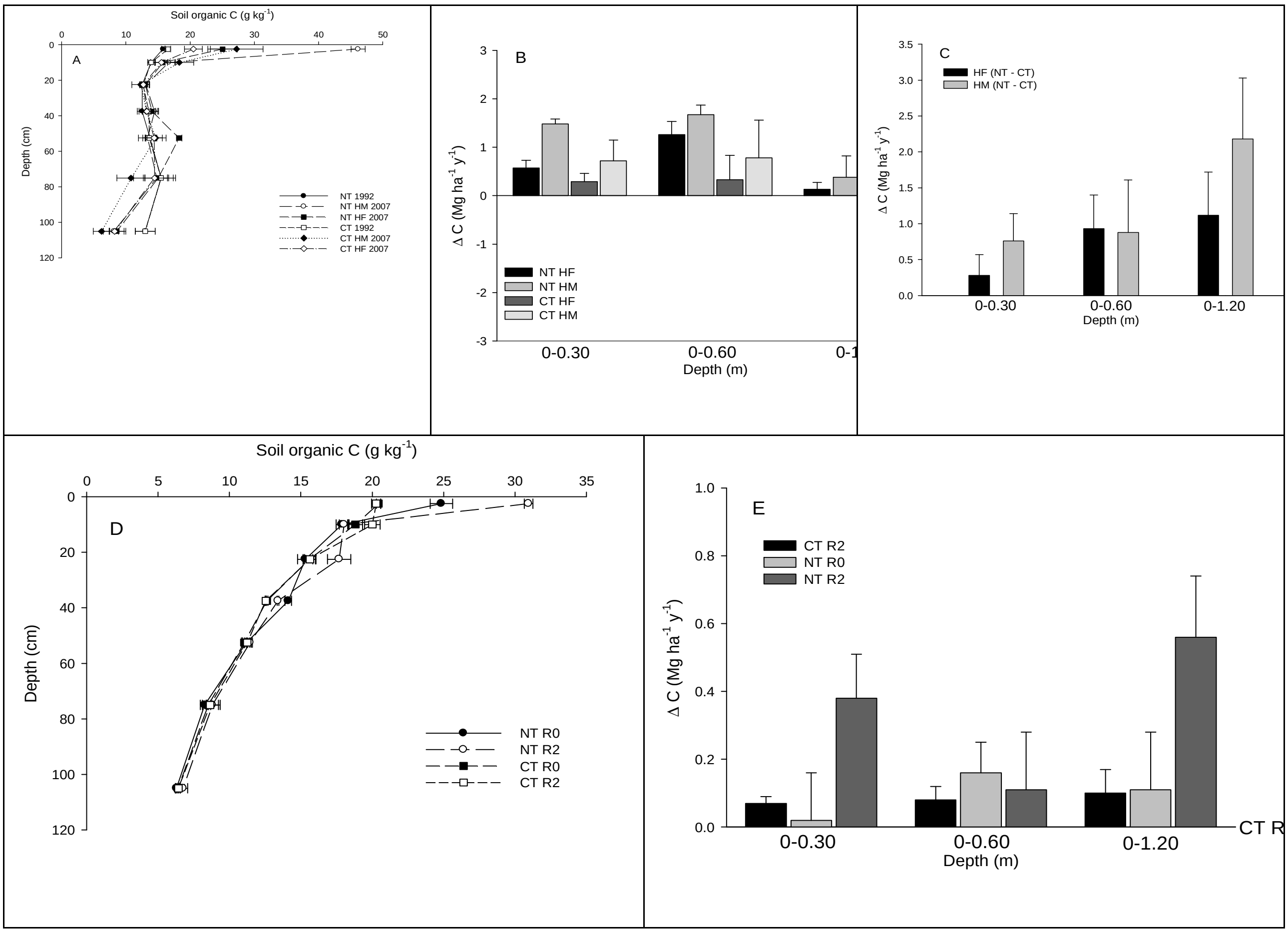

Figure 1. Soil organic C content in a Mollisol from Kansas, USA (A) and an Oxisol from southern Brazil (D). Real (B) and net-real (C) soil carbon sequestration rates in the 0-0.30, 0-0.60, and 0-1.20 m in the Mollisol. Apparent soil C sequestration rates in the 0-0.30, 0-0.60, and 0-1.20 m in the Oxisol.