

Evaluation of carbon saturation level of Ferrosol and Dermosol under different land uses

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Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree and qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.



Tania Khandakar

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Abstract

Fine soil particles especially silt + clay particles play important role in storing carbon (C). Thus the protective capacity of soils to store C is determined from relationship between % silt + clay content of soils and C associated on these particles. The difference between existing C content on silt + clay particles of soils and modelled protective capacity give an estimation of saturation level of that soil and are explained by using the term saturation deficit. Land use and land management influence on degree of saturation of protective capacity due to difference in C input and level of disturbance.

The overall hypothesis of the research were (i) land use and soil properties influence the C saturation levels of soils (ii) soil organic carbon (SOC) mineralization will be higher from soils having lower silt + clay content and higher level of C saturation (iii) mean residence time (MRT) of SOC pool will be higher in soils having higher silt + clay and lower C saturation level (iv) carbon will be more protected within aggregates (< 2000 μm) compared to dispersed silt + clay (< 53 μm) and clay particles (< 2 μm) (v) stabilization of applied residue C will be higher in soils where protective capacity are less saturated with C (vi) desorption of indigenous soil C will be higher from soils having higher level of C saturation (vii) adsorption of added dissolved organic carbon (DOC) will be higher in soils having lower C saturation level. The specific objectives of the research work were to determine (i) the protective capacity and C saturation level of that capacity of soils under contrasting land uses (ii) microbial decomposition of SOC and its relationship with silt + clay and C saturation deficit of soils (iii) stabilization of applied residue C in soils having different degree of C saturation (iv) desorption of indigenous soil C and adsorption of DOC in soils using initial mass isotherm approach (IMI).

To prove the first hypothesis Ferrosol and Dermosol (having different texture and mineralogy) were collected from three contrasting land uses (pasture, cropping and woodland). Protective capacity and C saturation level of that capacity (saturation deficit) was calculated by using an exponential model ($y = 6.67 e^{0.0216x}$ ($r^2 = 0.61$, $p < 0.001$) proposed by Sparrow et al. (2006). Land use significantly influenced C saturation level in Ferrosol ($p < 0.01$) and in Dermosol ($p < 0.05$). In both soils, woodland stored higher C compared to pasture and cropping. Carbon saturation deficit was observed in all the pasture and cropping soils in both Ferrosol and Dermosol. Two woodland soils in Ferrosol (Dorrigo 2 and Dorrigo 3) stored 28% and 88% more C than theoretical protective capacity. In Dermosol, one woodland soil (Kirby) stored 7% more C than theoretical protective capacity. Significant positive relationship ($p < 0.01$) of oxalate-extractable Al with TOC and silt + clay associated C in Ferrosol explained one reason for oversaturation of silt + clay protective capacity. The positive effect of poorly crystalline Al in C storage was not observed in Dermosol because of higher TOC/Al ratio (5 to 29). Significant positive relationship ($p < 0.01$) of cation exchange capacity (CEC) with TOC was observed in both Ferrosol and Dermosol. X-ray diffraction analysis showed that Dermosol was dominated by smectite minerals, having higher specific surface area. Positive relationship between CEC and clay content ($p < 0.01$) in Dermosol also supported the influence of clay minerals on CEC and SOC content. In contrast to these, CEC was not correlated with clay content in Ferrosol which was dominated by kaolinite, Al and Fe oxides. Thus organic matter itself might be the source of cations in Ferrosol that contributed to CEC, rather than influence of CEC on SOC storage.

Subsequent experiment was conducted on Ferrosol to prove the hypothesis, ii, iii and iv. A five months incubation experiment was conducted, in which 4 g of triplicate soil samples ($< 2000 \mu\text{m}$, $< 53 \mu\text{m}$ and $< 2 \mu\text{m}$) were taken in 250 ml incubation jars. The

samples were wetted at 70% of field capacity. Evolution of CO₂ was measured at time intervals. The calculated cumulative mineralization (C_{\min}) and percent SOC mineralization (SOC_{\min}) of the whole soil was negatively correlated with silt + clay content ($p < 0.001$) and C saturation deficit ($p < 0.001$) of the soils. However, significantly higher cumulative mineralization was observed from dispersed silt + clay particles than whole soil ($p < 0.01$) and clay particles ($p < 0.05$). Even percent SOC mineralization was also significantly higher in silt + clay than whole soil ($p < 0.01$) and clay ($p < 0.05$). A constrained two pool model was run to calculate the mean residence time (MRT) of active and slow SOC pool. In this experiment the slow pool consisted of slow + resistant pool, since resistant pool had not been separated by acid hydrolysis. The MRT of combined slow and resistant pool of whole soils were positively correlated with silt + clay ($p < 0.05$) and saturation deficit ($p < 0.05$) of soils. Lower SOC mineralization from soils having higher silt + clay content and with higher C saturation deficit might be responsible for higher MRT of SOC pool in these soils.

An eight months incubation experiment was conducted to test the hypothesis that stabilization of applied residue C will be higher in soils having higher C saturation deficit. Ferrosol, with different level of C saturation were incubated by mixing with grass residue with and without available nutrients. The nutrients were added with fresh residue in one set of soil to observe the influence of available nutrients on decomposition of residue and subsequent increase or decrease in soil organic C. A control experiment was also conducted where no residue was added to soils. Whole experiment was run with three replications at 25°C and of 70% of field capacity. The amount of CO₂-C produced during incubation was trapped in 1M KOH and the amount of CO₂-C trapped was determined by titration against 0.5 M HCl using TIM-850 Titration Manager (Radiometer Analytical, UK) (SMBRG, 2011). After incubation the grass residue was separated by sieving

through 2 mm sieve and TOC and silt + clay associated C (after fractionation with Na-hexametaphosphate) were determined by LECO CNS analyser. After incubation, TOC and silt + clay associated C decreased in soils where no residue was added than initial C content. The decrease in silt + clay associated C was smaller compared to TOC which indicated the maximum loss of C from silt + clay non-associated fractions. Though residue addition increased TOC and silt + clay associated C in some soils that had higher C saturation deficit, decrease in TOC and silt + clay associated C was observed in soils that had higher C saturation level. Nutrient addition increased the decomposition of residue, but it did not increase C content in some saturated soil, because of positive priming effect. Higher stabilization ($p < 0.01$) of residue derived C was observed in soils having higher C saturation deficit and proved the hypothesis that was proposed before conducting the experiment.

An adsorption experiment was conducted in the laboratory to test the hypothesis that desorption of SOC will be higher from soils having higher C saturation level, and adsorption of added dissolved organic carbon (DOC) will be higher in soils having lower C saturation level. DOC was extracted from partially senescent grass (spp. *Pennisetum Clandestinum* Chiov) with deionised water. Adsorption was conducted by preparing 6 initial solution of different DOC concentration (from 0 to 300 mg L⁻¹). Briefly, 40 ml solution of each concentration was added to 0.4 g silt + clay. The suspensions were tumbled for 18 hours in the dark at 4°C to inhibit microbial decomposition of DOC. The suspensions were centrifuged for 20 minutes at 3000 rpm and filtered through 0.45 µm nylon filter. The amount of DOC sorbed was calculated from the difference between DOC concentrations in the initial and equilibrated solutions. The results were analysed by initial mass isotherm, due to desorption of indigenous soil C. The intercept b of the initial mass isotherm was positively correlated with initial C content of the silt + clay particles

($p < 0.01$) and negatively correlated with saturation deficit of soils ($p < 0.01$) which proved the hypothesis that desorption of SOC will be higher from soils having higher C saturation level. Unlike b , the slope m of the regression (the fraction of the total reactive substance in a soil/water system that is retained by the soil) was not correlated with C saturation deficit of soils because of multiple factors affecting on adsorption. Thus the hypothesis that was proposed before conducting experiment that adsorption of DOC will be higher in soils having higher C saturation deficit was rejected.

List of Publications from this thesis

Conference Presentations

Tania Khandakar, Heiko Daniel, Chris Guppy. 2011. Soil carbon saturation: Concepts, recent findings and gaps. Poster presentation at 3rd International Symposium on Soil Organic Matter, Organic matter dynamics-from soils to oceans, 11-14 July 2011, Leuven, Belgium.

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