The Relationship Between C Input, Aggregation, and Soil Organic C Stabilization in Sustainable Cropping Systems

Angela Kong*, Chris van Kessel, R.F. Denison, Dennis Bryant, and Johan Six

Department of Plant Sciences, University of California, Davis

Introduction

•~ 10% of the earth's soil C is stored within agricultural ecosystems
•Sustainability, environmental impact, and potential role in mitigating rising atmospheric CO_2 concentrations associated with cropping systems must be addressed
•There is a pertinent need to quantify the mechanisms, capacity, and longevity of agricultural lands as C sinks
•Agronomic practices that influence yields and affect the proportion of crop residues returned to the soil are likely to influence soil organic C
•C-saturation implies that once the capacity for a soil to stabilize C is reached, additional C inputs will not be stabilized as SOC
•Determining the C status of a soil relative to C saturation is important to gauging the potential for C sequestration in cropping systems

Hypotheses

Hypothesis$_1$: Total soil organic C and aggregate stability increase with increasing C input

Hypothesis$_2$: Soil C is preferentially stabilized in microaggregates-within-macroaggregates

Abbreviations: Carbon (C), carbon input (C input), Large Macroaggregates (LM:>2000μm), mean weight diameter (MWD), microaggregates-within-macroaggregates (mM), small Macroaggregates (sM:250-2000 μm), particulate organic matter (POM), soil organic carbon (SOC)

Objectives

• Quantify the relationship between C input, total SOC sequestration, and aggregate stability
• Identify mechanisms of preferential C stabilization within the soil matrix

Table 1. Cropping systems at the LTRAS site (*fallow in alternate years)

Rainfed unfertilized Wheat Control (RWC)*
Rainfed unfertilized Wheat/Legume (RWL)
Rainfed fertilized Wheat/Fallow (RWF)
Irrigated unfertilized Wheat Control (IWC)*
Irrigated unfertilized Wheat/Legume (IWL)
Irrigated fertilized Wheat/Fallow (IWF)
Conventional fertilized Wheat/Tomato (CWT)
Conventional fertilized Corn/Tomato (CCT)
Irrigated Legume/Corn/Tomato (LCT)
Organic irrigated composted Corn/Tomato (OCT)

Methods

•Sampled soils (0-15 cm depth) from 10 cropping systems at the Long-term Research on Agricultural Systems (LTRAS) site in April 2003
•Soils were analyzed for total organic C content and fractionated into seven aggregate fractions
•Archived soils from the year of establishment of the long-term experiment (1993) were analyzed for total organic C content
•SOC Sequestration/Loss (10years) = SOC_{2003} - SOC_{1993}
•Aggregate fractions were analyzed for total organic C and aggregate stability

Table 2. Carbon Input Calculations

Formula
Maize stover (Mg dry wt. ha^{-1}) = 1.06 × grain dry wt. (Mg dry wt. ha^{-1}) + 0.50†
Winter wheat straw (Mg dry wt. ha^{-1}) = 1.06 × grain dry wt. (Mg dry wt. ha^{-1}) + 0.39†
Maize roots (Mg dry wt. ha^{-1}) = 0.23 × aboveground biomass dry wt. (Mg dry wt. ha^{-1})†
Wheat roots (Mg dry wt. ha^{-1}) = 0.22 × aboveground biomass dry wt. (Mg dry wt. ha^{-1})†
Tomato aboveground biomass (Mg dry wt. ha^{-1}) = 0.001(fresh wt. yield Mg $ha^{-1})^2$ + 0.05(fresh wt. yield Mg ha^{-1}) + 0.34
Tomato roots (Mg dry wt. ha^{-1}) = 0.30 × aboveground biomass (Mg dry wt. ha^{-1})‡

† Equations are adapted from S. Williams (personal communication, 2004).
‡ Aboveground biomass does not include tomato yield.

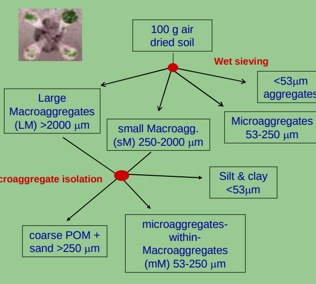


Figure 1. Soil fractionation schematic that produces seven aggregate size classes.

Results and Discussion

Figure 2. Cumulative C input levels calculated for the 10 cropping systems at the LTRAS site.

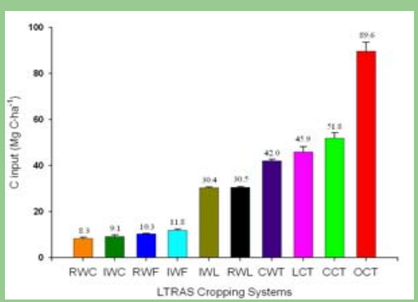
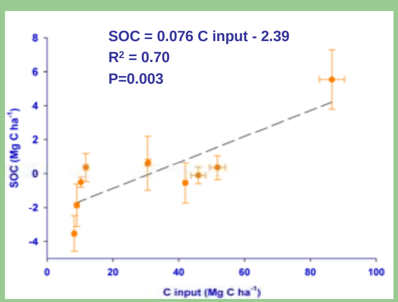


Figure 3. Linear relationship between cumulative C input and SOC change after 10 years.



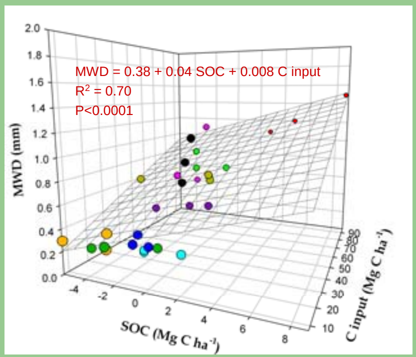


Figure 4. SOC sequestration and aggregate stability were linearly related and were each found to increase linearly with C input levels across the cropping systems.

Over the 10 years of cropping management, the low input systems lost SOC whereas the organic cropping system (highest C input level) accumulated the greatest amount of SOC.

Greater aggregate stability was found in higher carbon input levels and was also associated with higher SOC levels, thereby suggesting that soil C stabilization is associated with greater aggregation.

(*The 10 cropping treatments are differentiated by color codes, which were assigned in Figure 2.)

Soil Aggregate Dynamics and SOC Sequestration

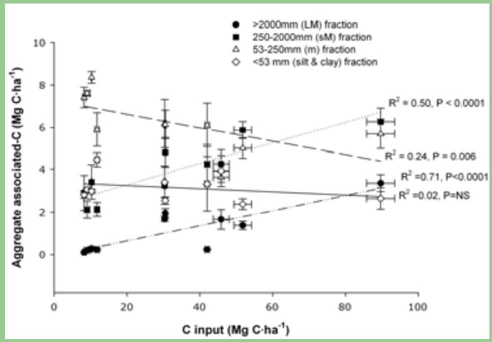


Figure 5. The relationship between C input and SOC sequestration is dominated by an increase in SOC associated with the macroaggregates, especially small macroaggregates (sM: 250-2000μm fraction).

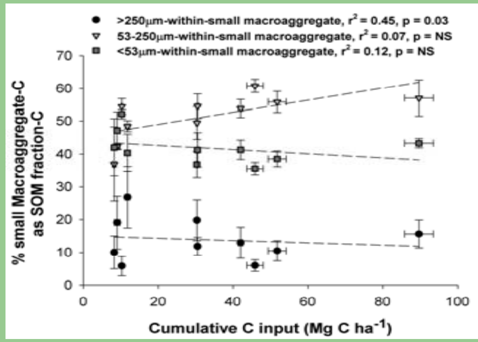


Figure 6. Relationship between C input and C associated with aggregates isolated from small macroaggregates. A preferential stabilization of SOC was associated with the microaggregates-within-small macroaggregate fraction (mM: 53-250μm; *p = 0.03*).

Conclusions

•**Our 2 hypotheses were corroborated by the results**
• **The potential of C sequestration across cropping systems is strongly controlled by C inputs and governed by the stabilization of SOC in microaggregates occluded within stable macroaggregates, especially the 250-2000μm macroaggregate fraction**
•**These cropping systems exhibit a residue-C conversion to SOC rate of 7.6% (low compared to nationwide rates)**
•**Soils at the LTRAS site are not C-saturated**
•**The mM fraction is an ideal diagnostic indicator of long-term C sequestration**

*Corresponding author (aykong@ucdavis.edu)