Short-term carbon cycling in a California vineyard under conventional and conservation tillage

Danielle L. Pierce[1], Kerri L. Steenwerth[2], Dave R. Smart[1]

[1] University of California, Davis, [2] USDA-ARS, Davis, CA

Objective: To gain an understanding of short-term changes in soil carbon (C) for a vineyard cover crop under conventional tillage (CT) as compared with a conservation tillage (MT) regime.

Experiment: A cover crop of barley (UC603) was planted in the fall of 2004 and 2005. Plots of the cover crop biomass were isotopically labeled with $^{13}CO_2$ in the field near the end of the growing season (late February-mid March). We tracked the label by taking static chamber measurements of $^{13}CO_2$ evolved from soil at intervals of approximately every six to eight weeks. The quantity of ^{13}C remaining in soil was estimated from these measurements using a CO_2 mixing model. The rate at which the signal declined depended upon the mow or till treatments and climate conditions.

Site description & environmental conditions

The field site is located in a vineyard in Oakville, CA (latitude 38° 25' 55" N, longitude 122° 24' 48" W).

On the days the field was mowed/tilled, the conditions were the following: March 27, 2004 the gravimetric soil moisture (gg^{-1}) was 14.4 ± 0.4 (mean ± se) and the mean afternoon soil temperature was 16.6 ± 0.5 °C (mean ± se). April 1, 2005 the gravimetric soil moisture was 17.6 ± 0.2 and the afternoon soil temperature was 14.7 ± 0.1 °C.

Bottom line: Spring 2005 was wetter and cooler than spring 2004.

Methods:

$^{13}CO_2$ Label

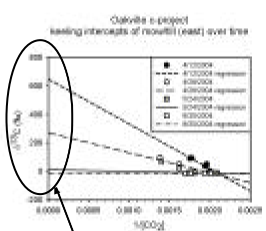
The label was applied using a large Mylar chamber, which was cooled for the duration of the labeling treatment (Left Photo). The cover crop was labeled a total of 6 times, consisting of one hour of exposure to $^{13}CO_2$ between 12:00 and 15:00. At each labeling period, the chamber was affixed to permanently established rings. One liter of 99.99 atom % $^{13}CO_2$ was injected into the chamber. The graph below is an example of the geometric mean intercepts we use to estimate the isotopic composition of the C respiration sources. The intercepts become less enriched in ^{13}C over time, indicating that less labeled C (new C) is being respired.

Mixing Lines

Carbon dioxide samples (11 ml, Exetainer) from static chambers were collected at night in 10-ml evacuated vials. The air samples from the static chambers were analyzed on a Europa Hydra 20/20 (Cheshire, United Kingdom) stable isotope mass spectrometer. The accuracy of the analyses was within 0.13 ‰. The carbon isotope ratio ($\delta^{13}C$) of the organic and air samples were calculated using equation (eq 1):

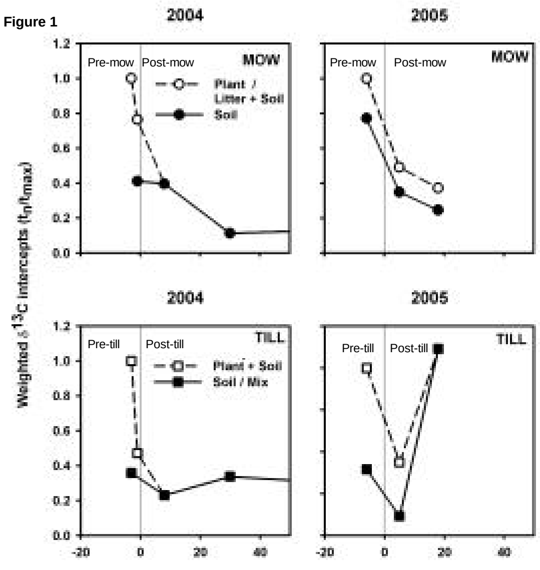
$$\delta = (R_{sample}/R_{standard} - 1) * 1000 \text{ ‰} \quad \text{(eq 1)}$$

where R is the molar ratio of the heavy to light isotopes, ^{13}C and ^{12}C, respectively for the sample and standard. The standard used for the $\delta^{13}C$ calculations was pee-dee belemnite (V-PDB).



Intercepts represent the isotopic signature of the respired CO_2. The intercepts from each plot and treatment are weighed to their initial maximum intercept value (I.e. 600 ‰) to account for labeling and biomass variation (center figures).

Figure 1



Disturbance effects on respiration of labeled carbon (^{13}C) under two different climate conditions (Figure 1):

Spring 2004 was unusually dry and warm. The belowground (soil) signal was about half that of the total plant and soil respiration in the mow and less than half (~35%) in the till. After the plots were mowed (top left) or tilled (lower left) the rate of label being respired increased in the till and decreased in the mow (see day 30).

Spring 2005 was unusually wet and cool. Pre-disturbance, the belowground signal represented 35-80% of the total cover crop respiration in the till (bottom right) and mow (upper right), respectively. Post-disturbance, the plots with mowed litter and soil alone continued to decline whereas the tilled plots increased beyond the measured pre-disturbance labeled maximum. This increase in the amount of label being respired may be attributed to the wet conditions and direct contact of the plant material with the soil. Thus making it more available to microbial decomposition. The relative amount of label being respired post-till was approximately triple in 2005 compared to 2004.

Figure 2

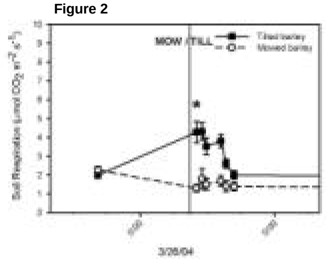
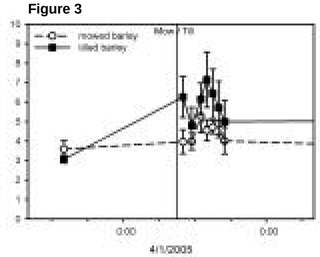


Figure 3



Disturbance effects on soil respiration rates under two different climate conditions (Figures 2 and 3):

The unusually wet spring in 2005 led to soil respiration rates that were double those from 2004. After the mow/till event, the respiration rates significantly increased (p<0.05) in the till and remained relatively constant in the mow. The increased soil moisture in 2005 led to an upward shift in overall rates while the trends between the mow and till treatments remained the same.

Cover crop biomass

The cover crop biomass was higher in 2005 relative to the previous year (Figure 4). In the till treatment it was seven times higher and in the mow it was more than double. In fall 2005 we doubled the amount of cover crop seed planted. The biomass may also be greater due to the wetter spring in 2005 (see Figure 5).

Oakville, CA precipitation

The total precipitation was higher in 2005 relative to 2004 (Figure 5). The mean amount of rain per rain event was the same between years (scatter plot, mean ± se). However, the number of rain events was greater in 2005. In our experiment this resulted in wetter soil through the mow/till event in 2005 and overall higher respiration rates.

Figure 4

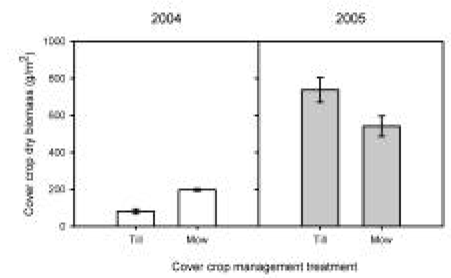
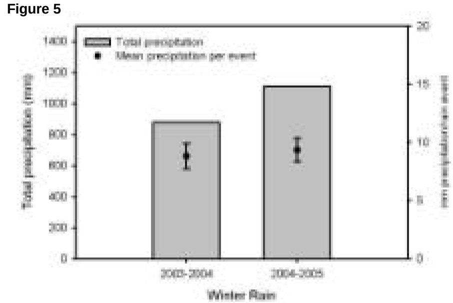


Figure 5



Conclusions

1. The isotope labeling of a barley cover crop in the field was successful. It was tracked for over a year, sensitive to both climate change and anthropogenic disturbance, and replicable.
2. Under both wet and dry soil conditions, the till treatment doubled the soil respiration rates and increased the amount of labeled cover crop decomposition.

Future Work

1. Analyze particulate organic matter (POM) samples from 2004 and 2005 to see if the mow/till has an effect of soil aggregate carbon.
2. Further investigate the role of precipitation on the carbon cycle of Mediterranean soil C by conducting a wet-up experiment in the late summer of 2005. Preliminary results indicate that soil moisture is the dominant factor driving short-term carbon cycling in this system.

Acknowledgements

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