Predicting changes in landscape-scale organic C following the implementation of minimum tillage.

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Abstract

We have assembled an interdisciplinary team to address the issue of how much C may be sequestered in soil of minimum tillage systems in CA agriculture. Our main research goals are to identify and quantify the underlying mechanisms and processes controlling the rate of CO_2 emissions versus soil C stabilization as affected by tillage operations. A landscape research approach is used to increase our mechanistic understanding of the biotic and abiotic processes that govern C dynamics under conventional and minimum tillage practices.

We have selected an irrigated, laser leveled agricultural site in the CA Central Valley for this study. The 70-acre site, located approximately 10 miles northwest of Davis, has been split into two fields. One field will be managed under conventional tillage and the other under minimum tillage. After harvest of a wheat crop in July 2003, the soil profile has been sampled to the 1-m depth in a grid and transect sampling scheme at 140 locations across the two fields in order to establish baseline soil physical and chemical properties including a soil C inventory. Each field has been instrumented with 1) an eddy-covariance mast to measure field-scale CO_2 fluxes, 2) with a 0.62-m^2 chamber with the capability of assessing the temporal pattern of CO_2 and N_2O fluxes, and 3) with 20 113-cm^2 chambers in order to evaluate the spatial characteristics of CO_2 and N_2O fluxes. Some of the gas flux data collected so far is presented here.

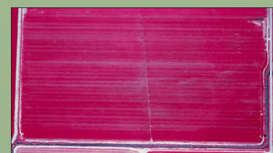
Results will be used to modify existing C models to predict the impact of minimum tillage on soil C sequestration. The research will also provide a realistic assessment of the role CA agriculture can play in C sequestration when land is converted from conventional to minimum tillage. Future research will also include a cost-benefit analysis of the two tillage systems.

Objectives

- To identify underlying mechanisms that control the quantity of C input from below and aboveground crop components across a typical CA agricultural landscape.
- To determine and quantify the processes that control the rate of CO_2 evolution as affected by minimum versus conventional tillage.
- To improve and validate existing C models in predicting soil C across farmers' fields following the implementation of minimum tillage.

Aerial Imagery of Field Site

Prior to initiation of the experiment, full color and infrared aerial photos were taken of the field site to observe patterns of yield, water, and nutrient distribution.



Background

Terrestrial ecosystems play a critical role in global C cycling. They are considered to be potentially major future sinks of C, and could partially offset the increases in atmospheric CO_2 seen in the last century. As most agricultural soils under conservation tillage practices have the capacity to sequester additional C, these soils have the potential to contribute to the mitigation of global climate change.

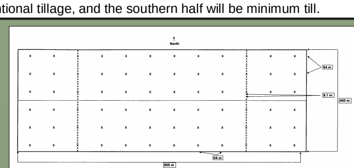
Estimations of the net amount of C that can be sequestered by U.S. cropland range from 0.07-1.7 Pg C y^{-1}. Tillage has a major impact on soil C storage; it has been estimated that the concentration of C in the Great Plains of North America decreased between 28% and 59% following 30 to 43 years of cropping history, respectively. Zero or minimum tillage most often does not directly change C inputs, but improves soil structure and increases aggregate stability, resulting in more protection of SOM (soil organic matter) from microbial degradation. The C that is consequently stored below ground is more permanent than C stored above ground in plant biomass.

Spatial variability in yield, and subsequent SOM input to the soil, vary considerably across the landscape. Different amounts of plant residue input in combination with different bio-physical properties of the soil that control the rate of decomposition appear as distinct spatial patterns across a field. However, the presence of a strong spatial pattern of a bio-physical property becomes a powerful tool in landscape-scale studies.

Data on the capacity of U.S. agricultural soils to sequester C has been varied in conclusion and based largely on experiments in the Midwest. Unique conditions of irrigated agriculture in the hot, semi-arid environment of CA's Central Valley warrant research directed specifically at modeling the potential for C sequestration in these intensively managed and productive systems.

Sampling Scheme

Our samples are collected from 140 sites across the field. 72 of these sites are spread in a grid across the entire field. The remaining sites are in two dense transects running N-S. This dual sampling scheme allows analysis of landscape-scale changes in soil C in addition to smaller-scale analyses. The northern half of the field will be managed with conventional tillage, and the southern half will be minimum till.



Materials and Methods

Intensive Soil Sampling with a Geoprobe

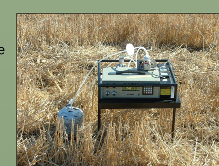
Each of the 140 sites across the field were sampled in August 2003, prior to tillage operations. Each site was sampled down to a 1 m depth with a Geoprobe, capable of hammering our core sampler into the dry, compacted, and clayey soil of the field site. Soil samples were divided into 5 depths (0-15, 15-30, 30-50, 50-75, and 75-100 cm) and will be analyzed for physical properties as well as C and N content.

Micrometeorological Towers

There are 2 towers on the field, one in the middle of each treatment, along the western transect. The towers measure CO_2 flux, as well as wind speed and direction, radiation from the ground and sky, relative humidity, air temperature, and soil heat flux. The towers provide frequent, field-scale measurements of gas flux. Their data will be compared to the smaller-scale data measured in the gas chambers.

Portable Gas Flux Chambers

These chambers are used to measure the flux of soil gases at the soil surface. The chambers are connected to an infrared gas analyzer (IRGA) and monitored for instantaneous concentration of CO_2 for five minutes. The chambers remain in the soil and are sampled for N_2O with a syringe, to be measured on a gas chromatograph. Repeated measurements in the small chambers across the entire field will reveal the spatial variability in gas flux measurements. We measured the flux of CO_2 and N_2O as part of our baseline measurements before implementation of the tillage operations, and found no significant fluxes at the soil surface. This is likely due to the very dry conditions of the field (see Table 1), which has received only rainfall for the last year.



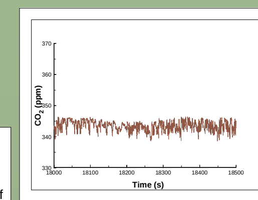
Automated Gas Flux Chambers

There are 2 large chambers located in the conventional tillage treatment and 1 in the minimum tillage treatment, all near the eddy covariance masts. These chambers are programmed to close their lids and measure the CO_2 concentration every half hour. They are also connected to IRGA's, which record the CO_2 and H_2O concentration at each reading. The automated chambers allow analysis of the temporal variability of gas flux in the field.

Initial Results

Micrometeorlogical Towers:

These figures are examples of data collected from some of the fast response sensors on the towers. CO_2 flux is calculated based on these second-by-second measurements.



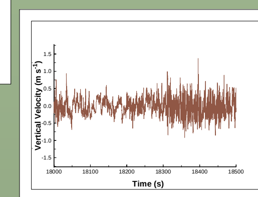


Table 1. Water content of soils at 5 depths near the eddy covariance masts. North tower conditions reveal the effects of irrigation spill-over from the neighboring field.

Percent Water

Sample Depth	S. tower	N. tower
0-15 cm	**1.87**	**4.21**
15-30 cm	**2.56**	**6.49**
30-50 cm	**7.74**	**12.16**
50-75 cm	**10.02**	**18.69**
75-100 cm	**14.66**	**26.88**

Future Plans

•Measure gas flux and soil physical parameters within 2 weeks following tillage operations, and periodically throughout the rainy season.

•Implement intensive soil, crop, and gas flux measurements during the next growing season (field corn is likely to be planted).

•Monitor C, N and ^{13}C dynamics in the soil and relate them to particle size, soil moisture, soil temperature, etc. across the field.

•Adjust existing models to predict the effects of tillage on CO_2 and other greenhouse gas emissions.

•Analyze and monitor changes in the data on varying spatial and temporal scales that can be more broadly applied to characterize the potential for C sequestration in CA's Central Valley.