Field scale greenhouse gas emissions in a furrow-irrigated field under standard and minimum tillage

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ABSTRACT

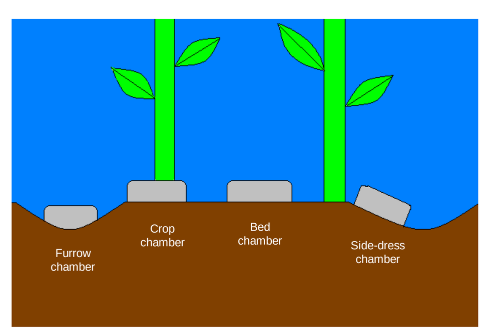
This study aimed to quantify CO_2 and N_2O release from an irrigated field in California's Sacramento Valley in an effort to determine greenhouse gas mitigation potentials through minimum tillage (MT) practices. The 30 ha, laser-leveled field site was monitored with portable static chambers for CO_2 and N_2O flux from the soil surface in standard tillage (ST) and MT treatments from September 2003 through August 2006. The field was also equipped with 2 eddy-covariance masts and 2 continuously sampling auto-chambers, to estimate total C budgets at the field scale and temporal changes in soil CO_2 flux, respectively. The crop grown on the field was different each year; the first year it was wheat, then corn, sunflower and chick peas. Overall, there was very little difference in CO_2 flux between the two tillage treatments. Flux numbers were highly spatially variable, well-correlated with air and soil temperature, and dependent on soil moisture and the degree of soil disturbance in the 2 tillage systems. Chambers placed over the crop roots showed higher CO_2 flux during the growing season due to root respiration, but did not differ significantly between the 2 treatments. The N_2O flux was negligible in both systems until a fertilization and irrigation event occurred in each growing season, at which point the MT treatment showed slightly higher fluxes. The CO_2 and N_2O data from this site are being used in several models that will enable us to predict greenhouse gas emissions from similar agricultural systems in the California landscape. Soil respiration results from this site indicate that short-term MT may not significantly decrease the contribution to global warming by irrigated agroecosystems and thus may not be a beneficial strategy for greenhouse gas mitigation. A complete C budget for the system will determine net sequestration potential.

INTRODUCTION

This greenhouse gas study is part of a multi-disciplinary study of C sequestration potential in CA agricultural systems. The 30 ha field site was split in half in the fall of 2003. The N half was converted to standard tillage (ST) and the S half continued in its third year under minimum tillage (MT) management (Figure 1).

MATERIALS AND METHODS

The field site was equipped with 3 suites of instruments for measuring CO_2 at multiple scales:



Portable PVC Chambers for CO_2 and N_2O

The portable chambers are made of 10" PVC rings permanently installed at locations that span both fields, and a portable PVC end-cap lid, which is attached to a Licor infrared gas analyzer (IRGA) for CO_2 measurement. N_2O is sampled with a syringe from the vented chambers and brought back to the lab for analysis on a gas chromatograph. There are a maximum of 4 chambers at each sampling location, as shown here. Chambers are sampled regularly throughout the year.

Automated Chambers

There are 2 chambers in the ST and 1 in the MT fields. They close for 1 minute every half hour, when fans mix the air in the chamber, and measure soil CO_2 flux with a Licor IRGA. They cover a 0.62 m² area, and are used to evaluate **temporal patterns** of CO_2 flux and soil temperature in the fields.

Eddy Covariance Towers

There is a tower in 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 net gas flux in the fields.

Field Site and Experimental Design

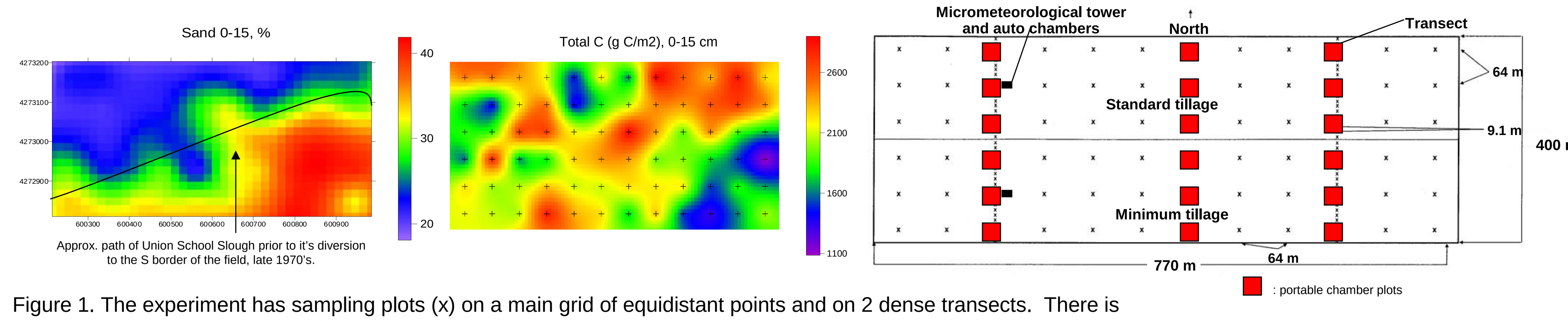


Figure 1. The experiment has sampling plots (x) on a main grid of equidistant points and on 2 dense transects. There is considerable heterogeneity in soil properties such as texture and C, shown above.

RESULTS FROM PORTABLE CHAMBERS

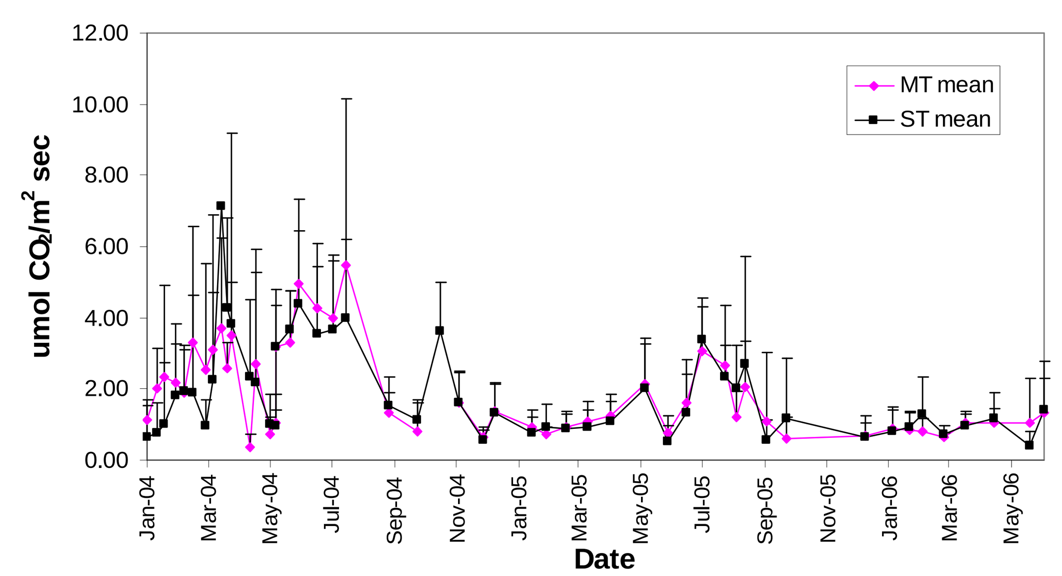


Figure 2. **CO_2 soil flux** (Jan 04 – Jun 06)

CO_2 emissions were generally very similar between tillage treatments, although in 2004 MT often had higher soil respiration rates than the ST. This may be due to the presence of actively decomposing residue on the soil surface in a field only recently converted to MT.

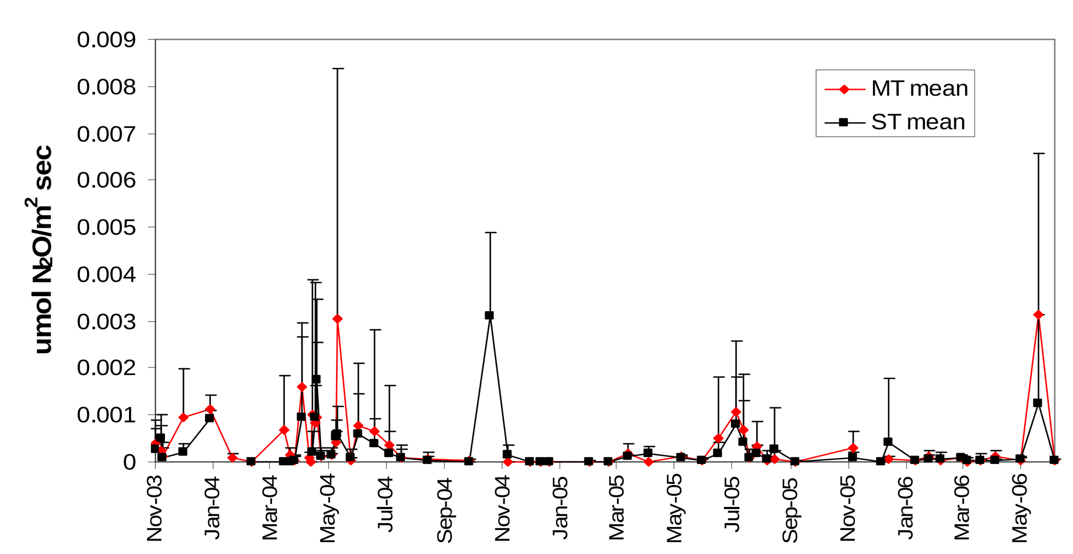
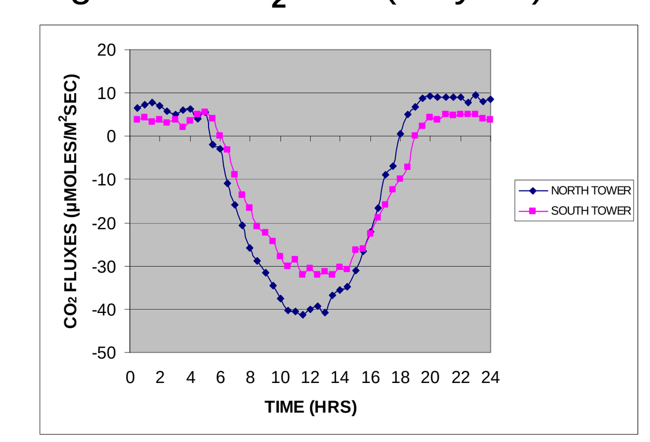


Figure 3. **N_2O soil flux** (Nov 03 – Jun 06)

N_2O emissions were generally low, but peaked when both fertilizer and irrigation water were applied. In 2004, when the MT treatment had been no-till for 3 years, MT N_2O flux was higher. In subsequent seasons the 2 treatments were very similar, although MT flux remained higher on average.

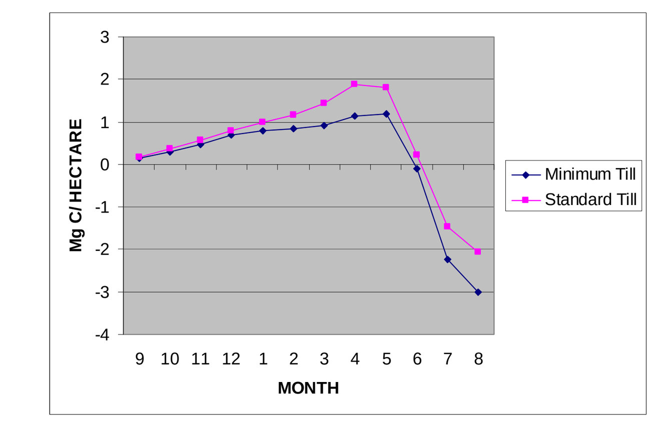
EARLY RESULTS FROM EDDY COVARIANCE TOWERS

Figure 3. **CO_2 flux** (May 04)



Decreased crop growth and subsequent yield in the MT corn crop was revealed in the net flux data, which shows the ST (North Tower) treatment taking up more CO_2 during the daylight hours. Nighttime respiration was higher in the ST treatment at this time.

Figure 4. **Net ecosystem exchange** (Sep 03 – Aug 04)



This shows that the MT treatment (which had been no-till for 3 years at this point) did sequester more C, despite it's decreased yield compared to ST and higher measured soil flux rates.

PRELIMINARY CONCLUSIONS:

- Surface soil respiration is not significantly different between tillage treatments unless the standard and minimum tillage operations are substantially different, as was the case in 2004, when MT flux rates exceeded those of ST.
- Given the very high global warming potential of N_2O, even minor fluxes must be taken into account, and these are generally higher in the more anaerobic environments of minimum tillage fields.
- Net flux measured from the eddy covariance towers reveals that differences in crop growth patterns between tillage treatments can play a major role in the total C sequestration potential of each treatment. Future analyses will determine if the net ecosystem exchange shows any treatment differences in the 2005 or 2006 seasons.

Acknowledgements

This research is funded by the Kearney Foundation of Soil Science. Thanks to our grower cooperator, Emily Sharp, George Lu, Heather, Jessica and Aaron Louie, Jeremy Kidwell, Jason Bartlett, Hyuisun Yoo, Tinsum Ching and Sonia Lund for their assistance.

Timeline of field operations