Spatial Variability of Greenhouse Gas Emissions and Their Controlling Factors in an Agricultural Landscape

Juhwan Lee, Chris van Kessel, Dennis E. Rolston, Johan Six, and Amy P. King

Departments of Plant Sciences and Land, Air, and Water Resources, University of California, Davis

Introduction

- The impact of increased atmospheric CO_2 and other greenhouse gases (GHG) on global climate change is of concern.
- To mitigate the emissions of GHG from agricultural soils, direct emission reductions and terrestrial C and N sink expansions will be required.
- In the Sacramento Valley agriculture is dominated by intensively irrigated systems under a Mediterranean climate, leading to substantial GHG emissions.
- One option to mitigate GHG emissions is increasing the amount of C and N stabilized in soil organic matter (SOM) by minimum tillage (MT). MT improves soil structure, leading to more protection of SOM from microbial decomposition.
- The effectiveness of MT is however dependent on soil properties that vary across the landscape.

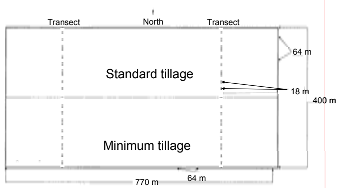
Objective

To determine the factors that are responsible for the spatial variability of GHG emissions as affected by the interaction between tillage and simulated irrigation

Materials and Methods

Soil Sampling:

- Agricultural field of 30 ha managed under MT since 2002
- Standard tillage (ST) operation only on the north side of the field in October 2003
- Two adjacent intact soil cores (5 cm X 15 cm) taken at 40 locations in April 2004



Experimental Incubation:

- 10-day incubation each at 25ºC at field moist content and 75% water holding capacity (WHC)
- Measured the headspace concentrations of CO_2, N_2O, and CH_4 at days 1, 2, 3, 5, 7, 10
- Analysis: bulk density, water content, soil texture, K_2SO_4 extracted organic C, K_2SO_4 extracted ammonium and nitrate, and total, microbial, particulate organic matter fraction (53-2000 μm) C and N

Data Analysis:

- Principal component regression (PCR) on the soil variables

Figure 1. Aerial photo of the research site, located in the Sacramento Valley, CA: Three soil types are found across this furrow-irrigated system : Myers clay (Ms), San Ysidro loam (Sh), and Hillgate loam (HdA).

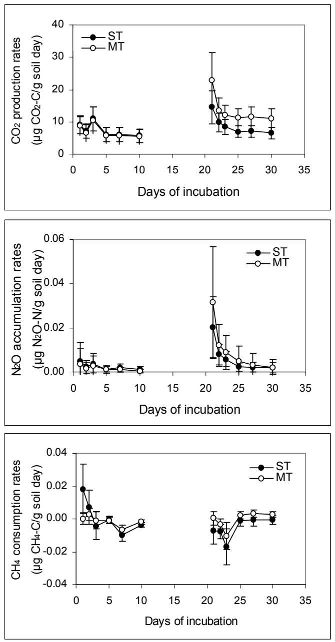


Figure 2. GHG emission rates at field moisture content and 75% WHC

Results and Discussion

Table 1. Eigenvectors, eigenvalues, and cumulative proportion of total spatial variance for the first four principal components in the data measured at field moist content

	Principal Component			
Variables	PC1	PC2	PC3	PC4
Sand	**-0.435**	0.029	0.017	0.166
Clay	**0.442**	-0.042	-0.008	-0.126
Silt	**0.425**	-0.022	-0.022	-0.182
Total C	0.128	**0.433**	0.234	0.019
Total N	0.071	**0.450**	0.215	0.012
POM-C	**0.379**	-0.138	0.096	0.297
POM-N	**0.378**	-0.148	0.094	0.306
NH_4^+	-0.075	-0.060	0.287	**0.677**
NO_3^-	0.137	0.090	-0.226	0.105
MBC	0.094	0.192	-0.444	**0.504**
DOC	0.029	-0.044	**0.728**	-0.030
BD	-0.226	**0.404**	0.060	0.088
Water content	0.115	**0.407**	-0.126	-0.005
WFPS	0.167	**0.433**	0.023	-0.097
Eigenvalue	4.699	3.826	1.557	1.250
% of total variance	33.6	60.9	72.0	80.9

Table 2. Eigenvectors, eigenvalues, and cumulative proportion of total spatial variance for the first five principal components in the data measured at 75% WHC

	Principal Component				
Variables	PC1	PC2	PC3	PC4	PC5
Sand	-0.025	**-0.559**	0.029	0.083	-0.013
Clay	0.025	**0.549**	-0.075	-0.052	-0.051
Silt	0.024	**0.554**	-0.007	-0.098	0.044
Total C	**0.433**	0.077	0.127	0.046	0.365
Total N	**0.441**	0.022	0.126	-0.036	0.335
NH_4^+	-0.037	0.025	**0.623**	0.407	-0.056
NO_3^-	-0.208	-0.051	0.118	-0.467	**0.639**
MBC	0.002	0.064	-0.256	**0.745**	0.452
DOC	-0.002	0.059	**0.698**	-0.040	-0.040
BD	**0.413**	-0.229	-0.065	-0.178	0.083
Water content	**0.425**	0.073	-0.034	0.044	-0.316
WFPS	**0.470**	-0.065	-0.037	-0.058	-0.162
Eigenvalue	4.165	3.159	1.507	1.119	1.067
% of total variance	34.7	61.0	73.6	82.9	91.8

Table 3. Principal component regression estimates of regression coefficients for GHG emission rates using g = 4 and 5 principal components at field moist content at 75% WHC, respectively.

	CO_2		Log-transformed N_2O*		CH_4	
	Field moist	75% WHC	Field moist	75% WHC	Field moist	75% WHC
Variables	(g = 4)	(g = 5)	(g = 4)	(g = 5)	(g = 4)	(g = 5)
Sand	-0.089	0.850	-0.069	0.021	0.00021	0.00073
Clay	0.077	-0.839	0.068	-0.009	-0.00022	-0.00075
Silt	0.094	-0.842	0.069	-0.026	-0.00021	-0.00071
Total C	0.164	0.007	0.028	-0.029	0.00004	0.00009
Total N	0.168	-0.011	0.022	-0.043	0.00007	0.00014
POM-C	-0.058	nd	0.036	nd	-0.00017	nd
POM-N	-0.063	nd	0.035	nd	-0.00018	nd
NH_4^+	-0.198	0.535	-0.050	0.103	0.00009	0.00004
NO_3^-	0.112	-0.112	0.040	-0.153	-0.00008	0.00033
MBC	0.158	0.736	0.045	0.104	-0.00006	0.00009
DOC	-0.197	0.060	-0.048	0.010	0.00008	0.00000
BD	0.123	0.056	-0.017	-0.051	0.00018	0.00034
Water content	0.245	-0.257	0.050	0.033	-0.00001	-0.00022
WFPS	0.240	-0.131	0.051	-0.003	-0.00001	0.00003
R^2	0.241	0.631	0.570	0.219	0.396	0.704
P-value	0.053	<.0001	<.0001	0.2555	0.0018	<.0001

*PCR models only account for the positive rates of log-transformed N_2O emission.
nd = not determined

Summary

1. Spatial variability of GHG emissions was great at the field scale, masking tillage-induced differences in the emissions (Figure 2).
2. Upon wetting the soil cores to 75% WHC, both CO_2 production rates and N_2O emission rates drastically increased, but more in the MT than ST soils.
3. Principal component analysis identified four and five PCs for GHG at field moist content and 75% WHC, respectively, with eigenvalues greater than 1 and condition number smaller than 10 (Table 1 and 2).
4. Most of the spatial variability of GHG emissions could be generally explained by differences in soil texture and soil C and N content, and to a lesser degree by differences in soil water, indicating an interaction between tillage, soil texture, and moisture content in determining GHG emissions.
5. Models obtained by principal component regression significantly account for approximately 24-70% of variation in GHG emission rates under the wide range of soil water condition (Table 3). However, the model for N_2O under 75% WHC condition was not significant due primarily to limited N_2O observation.

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