REACCH Monitoring Objective: Assessing Dynamics of Carbon Dioxide, Water Vapor, and Nitrous Oxide at Multiple Agricultural Ecosystems in the Inland Pacific Northwest

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Introduction

Local meteorology, crop management practices and site characteristics have important impacts on carbon, water, and nitrogen cycling in agricultural ecosystems. Future climate projections for regions such as the inland Pacific Northwest (iPNW) of the USA show a likely increase in temperature and significant reductions in precipitation that will affect agricultural carbon, water, and nitrogen cycles. Agriculture is highly dependent on climate, yet it is also a primary contributor of the greenhouse gases nitrous oxide (N_2O) and methane (CH_4). Agricultural fields can be net carbon dioxide (CO_2) sinks or sources depending on management practices and climatic conditions. Therefore, there is a critical need to quantify greenhouse gases (GHGs) in different agricultural ecosystems to better understand their distribution, cycles, and how they are impacted by ongoing climate change.

Our team has installed five eddy covariance (EC) flux towers to continuously monitor fluxes of CO_2, H_2O, and energy. at sites in different agroecological zones across the region. As of October 2015, we have eleven site-years of results. Two of the flux towers are also outfitted to monitor N_2O emissions, using a hybrid approach incorporating a micrometeorological gradient method and an array of automated chambers.

We found that all five sites were net CO_2 sinks over the measurement period, with cumulative sink strengths ranging from 63 to 326 g C m^{-2} yr^{-1}. However, the N_2O results indicate that emissions are 3-6 kg N_2O-N ha^{-1} yr^{-1}, roughly two to four times higher than the Intergovernmental Panel on Climate Change (IPCC) Tier 1 estimate.

Site Description

Five EC flux towers have been deployed at different agricultural sites in the iPNW region (Fig. 1, Table 1).

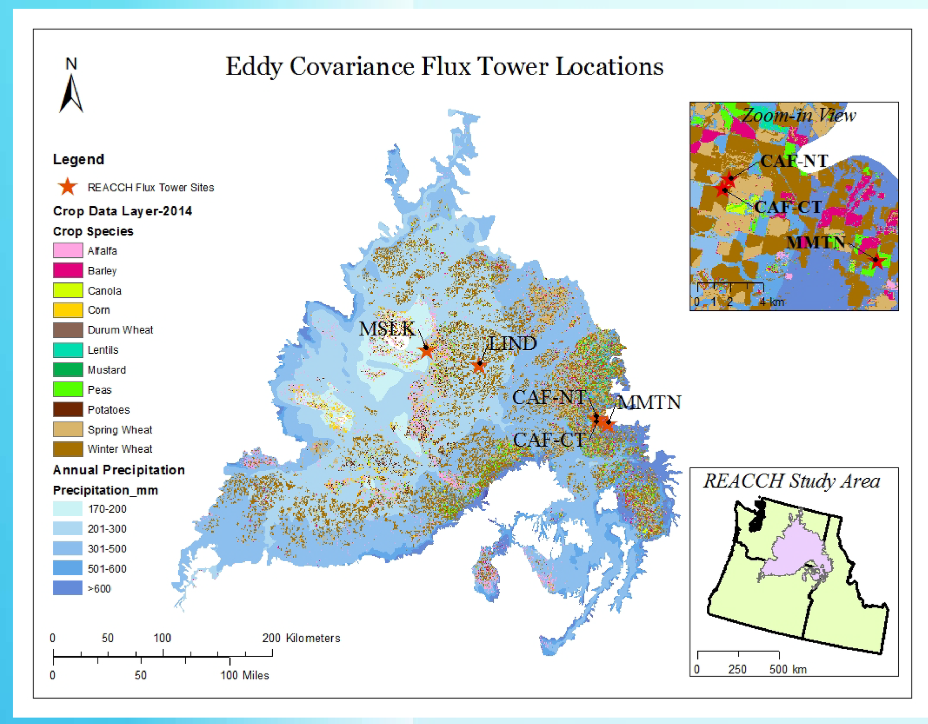

Figure 1: Location of five eddy covariance flux towers n the iPNW region of the U.S.

Table 1:Site characteristics, local meteorology and management practices.

Site	Annual Temp/Precip	Management Practices	Crop Rotation
MSLK	11°C / 230mm	conventional tillage, irrigation	spring wheat-cover crops-potato
LIND	10°C / 280mm	reduced tillage, fallow	winter wheat-summer fallow
CAF-NT†	9°C / 550mm	no-till	winter wheat-spring garbanzo
CAF-CT†	9°C / 550mm	conventional tillage	winter wheat-spring garbanzo
MMTN	9°C / 680mm	conventional tillage	winter wheat-spring crops

†Sites that are measuring N_2O emissions

Methods: Micrometeorological Techniques and Chambers

- **Eddy Covariance used to determine net ecosystem exchange of CO_2 (NEE):**

$$NEE = \overline{w'\rho_c'}$$

Where *w'* and ρ_c' are the instantaneous variations from the mean vertical wind speed and CO_2 molar density, respectively, and the overbar denotes a half-hour average.

- **Flux gradient technique used to measure fluxes of N_2O:**

$$F_{N_2O} = -K\frac{\Delta N_2O}{\Delta h}$$

Where *K* is the eddy diffusivity, ΔN_2O is the difference in N_2O concentrations over Δh, the vertical distance between the two N_2O measurement heights.

- **Automated stats chambers were also used to measure N2O fluxes:**

$$F_{N_2O} = \frac{\Delta N_2O}{\Delta t} * \frac{V}{A}$$

Where ΔN_2O is the change in the N_2O mixing ratio over the duration of the chamber closure, or Δt, *V* is the chamber volume, and *A* is the area of soil covered by the chamber.

Tower Systems: image shows the eddy covariance tower set-up. 3D sonic anemometer and infrared CO_2/H_2O analyzer on lower boom, meteorological measurements on upper boom, and solar panels to provide power.

Clockwise from left: sonic and IRGA, the moon, and a chamber line up during sunset; close up of chamber in front of flux tower, and chambers and tower shortly after tilling and sowing.

Results

- **Carbon Budgets**

Measured CO_2 flux (NEE) is partitioned into gross primary productivity (GPP) and total ecosystem respiration (R_{eco}):

$$NEE = GPP - R_{eco}$$

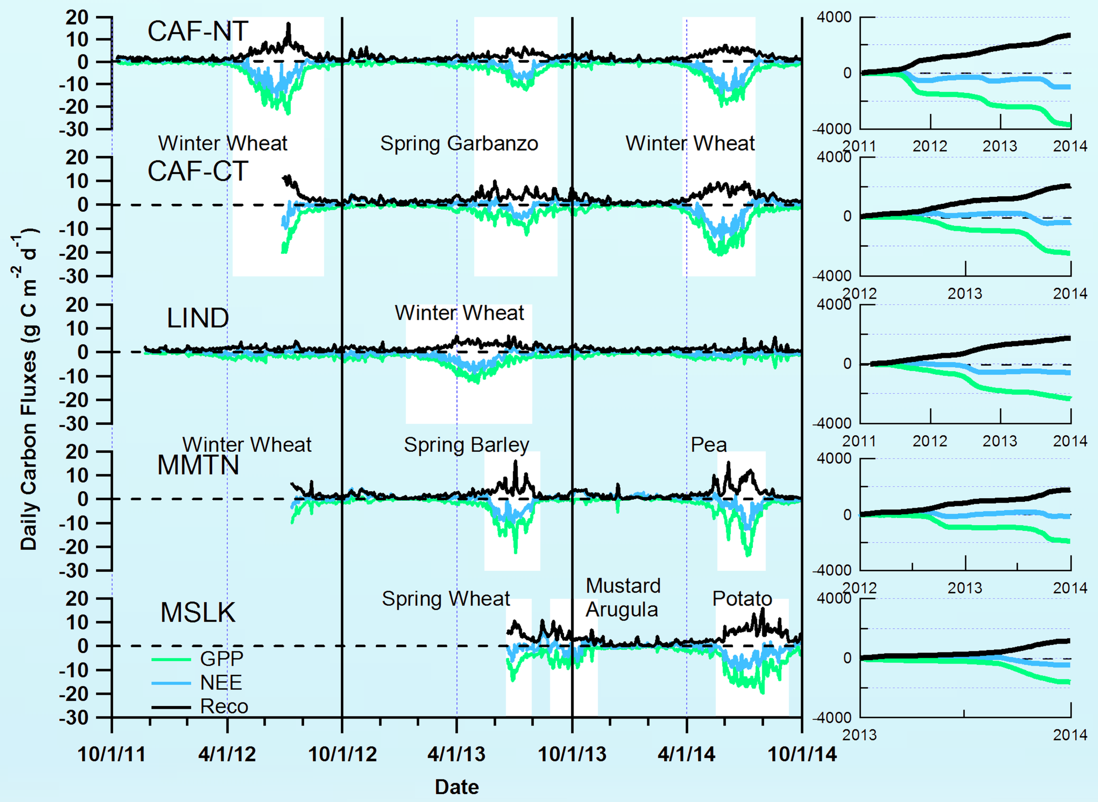

Figure 2: Daily (g C m^{-2} d^{-1}) and (right column) cumulative (g C m^{-2}) carbon fluxes at five flux tower sites. Sign convention: fluxes from the atmosphere to the surface are negative.

Results

- **Water Budgets**

H_2O flux (ET) is partitioned into transpiration (T) and soil water evaporation (E):

$$ET = T + E$$

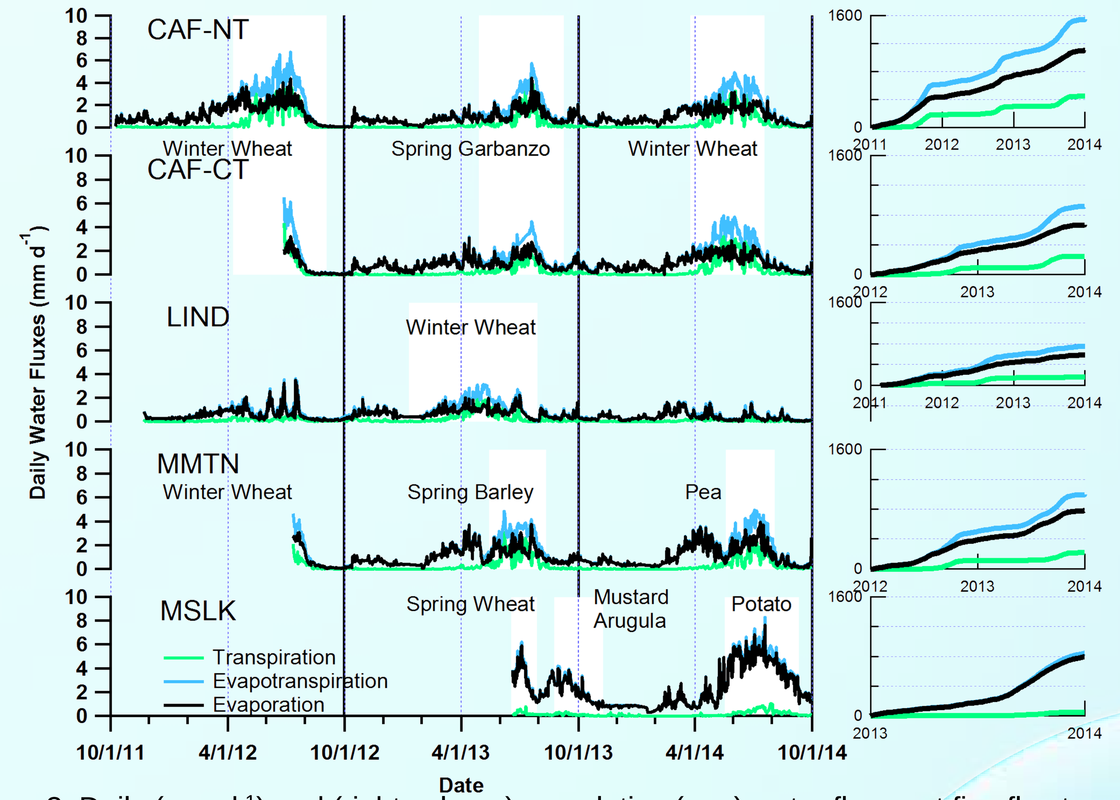

Figure 3: Daily (mm d^{-1}) and (right column) cumulative (mm) water fluxes at five flux tower sites.

- **N_2O Fluxes** were measured with two techniques: flux gradient and static automated chambers.

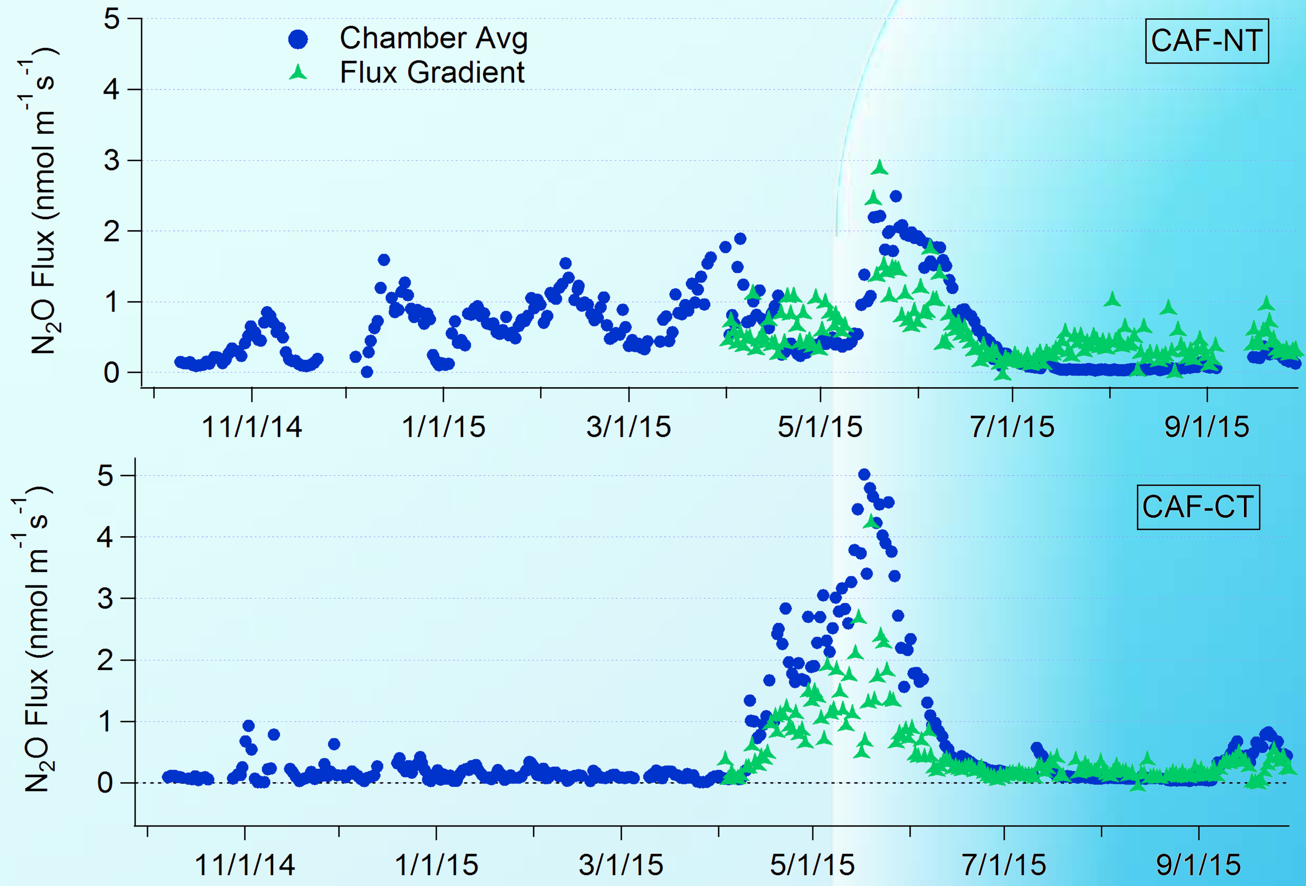

Figure 4: Daily (nmol m^{-2} s^{-1}) N_2O fluxes measured by chambers (for the 2015 canola crop year) and the flux gradient technique (for April – Sept 2015) at two different sites.

Table 2: Annual carbon and water budgets at five sites during the period of Oct 2013-Sept 2014.

Site	MMTN	CAF-NT	CAF-CT	LIND	MSLK
NEE (g C m^{-2})	-39	-450	-521	-67	-434
GPP (g C m^{-2})	-971	-1343	-1613	-549	-1615
R_{eco} (g C m^{-2})	932	893	1092	482	1181
IMP (g C m^{-2})	8	4	4	fallow	--
EXP (g C m^{-2})	21	232	269	fallow	--
NBP (g C m^{-2})	-26	-222	-256	-67	--
ET (mm)	498	507	503	166	841
T (mm)	105	151	157	24	48
E (mm)	393	356	346	142	793
Precip (mm)	-536	-455	-455	-175	-86
Net (mm)	-38	52	48	-9	755

NEE (net ecosystem exchange of CO_2); GPP (gross primary productivity); R_{eco} (total ecosystem respiration, including both autotrophic and heterotrophic respiration); IMP (import carbon content); EXP (export of harvest material); NBP (net biome production); ET (evapotranspiration); T (transpiration) and E (soil water evaporation); Precip (Precipitation).

Table 3: 2015 crop year annual and 6-month (April – Oct) N_2O emissions from the Cook Farm till and no-till sites

Site/Technique	April - Oct	Annual
	Emissions (kg N_2O-N ha^{-1})	
CAF-NT Chambers	2.4	5.2
CAF-NT Flux Gradient	2.3	4.9
CAF-CT Chambers	4.4	5.2
CAF-CT Flux Gradient	2.2	2.6
CropSyst Model		0.8
IPCC		0.5-1.5

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