Building the scientific foundation for a mountain meadow carbon protocol in California



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Plumas Corp

Sierra Foothill Conservancy
Truckee River Watershed Council
South Yuba River Citizen's League
American Rivers
US Forest Service

Stillwater Sciences

Talk Outline

- Background
- Main question
- Project structure
- Results on baseline conditions
- Implications and Next Steps
- Working together to SCALE UP

What is a meadow?

- Dominated by herbaceous plant communities (woody species can occur but not dominate)
- Rooting zone saturated for at least 2-3 weeks of growing season
- Water sources can include surface water flooding, groundwater, subsurface flows, and snowmelt

Weixelman et al. 2011

What is a Carbon Protocol?

Purpose: To create carbon offsets of known amounts and duration (uncertainty is quantified and 'contained')

For a particular type of C sequestration or output reduction:

- Rules of the game by which carbon offset projects are developed
- Project Entry Requirements
- How they estimate C sequestered
- How they assure accuracy, completeness and credibility

What are they good for?

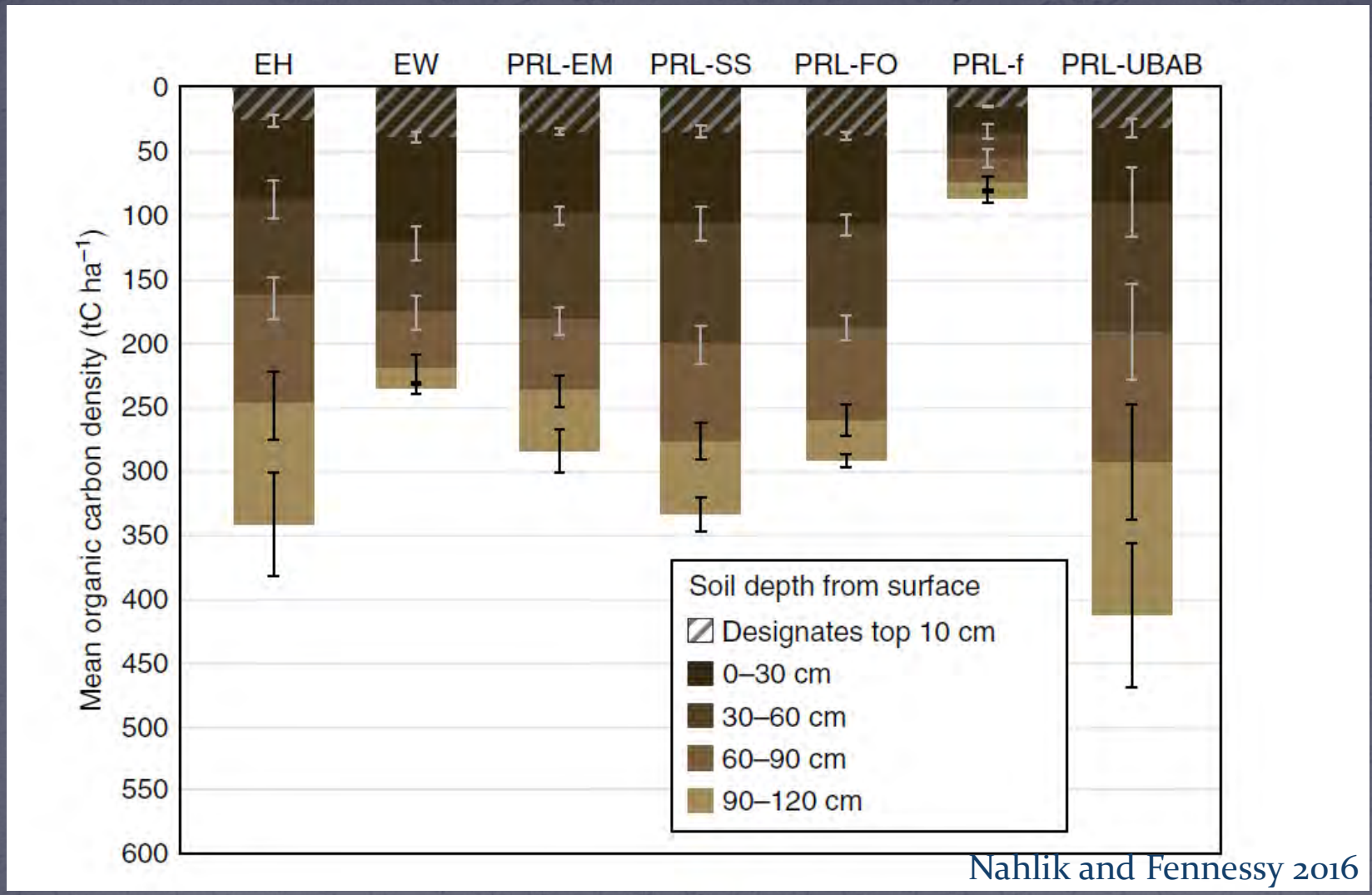
Recognize real value in nature's carbon storage.

Voluntary Market: Buyers, such as companies, public entities or individuals value and can pay that value to offset global warming impacts.

Regulatory Market: Required through regulations such as AB32. Offsets need to cost less than C reduction. AB32 allows up to 8% of required reductions to be met through offsets.

Why a **Meadow** C Protocol?

SOIL CARBON POOLS IN WETLANDS ARE LARGE



Nahlik and Fennessy 2016

EH= Estuarine emergent
EW = Estuarine woody
PRL-EM = Palustrine, riverine and lacustrine emergent
PRL-SS = Palustrine etc. with shrubs
PRL-FO = Palustrine, etc. with forest
PRL-f = Palustrine, etc. farmed
PRL-UBAB = Plaustrine etc. with unconsolidated bottom

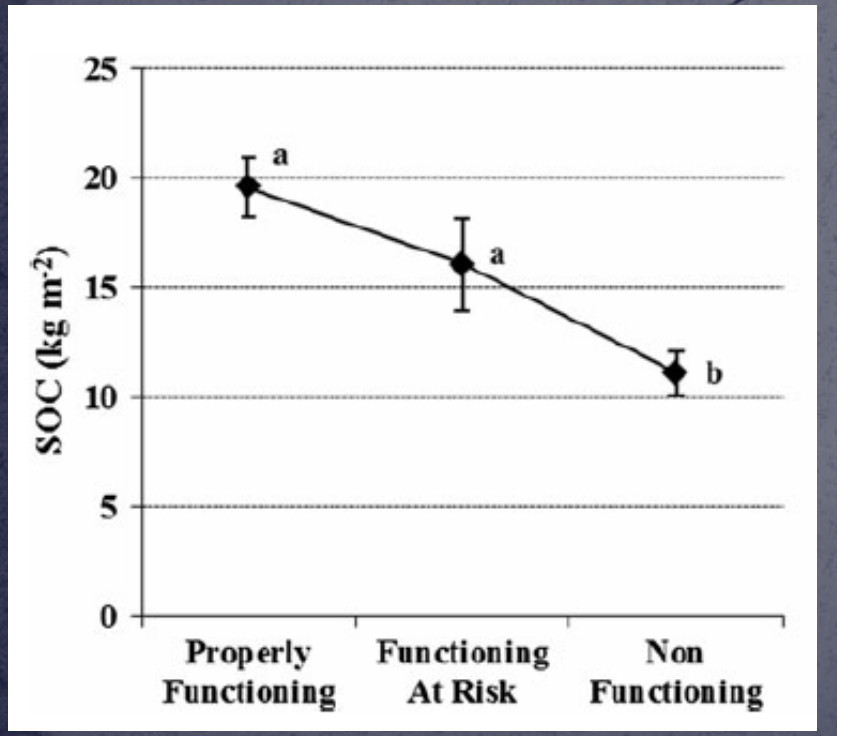

Bonita Meadow, September 2015

Meadows in the Sierra Nevada and S. Cascade

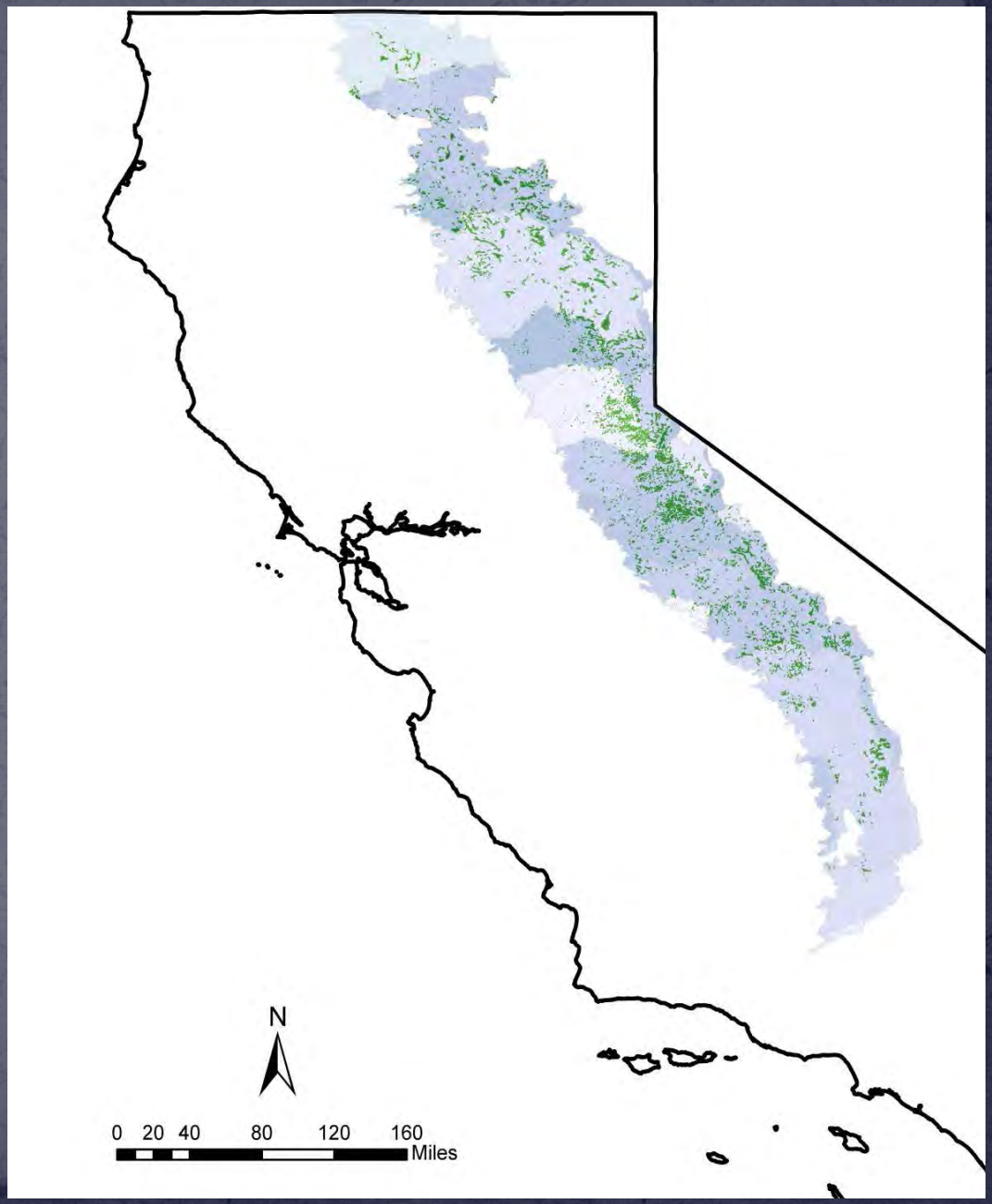
Total Number: >17,000 meadows

Total Acreage: ~200,000 acres

(Veirs et al. 2013)

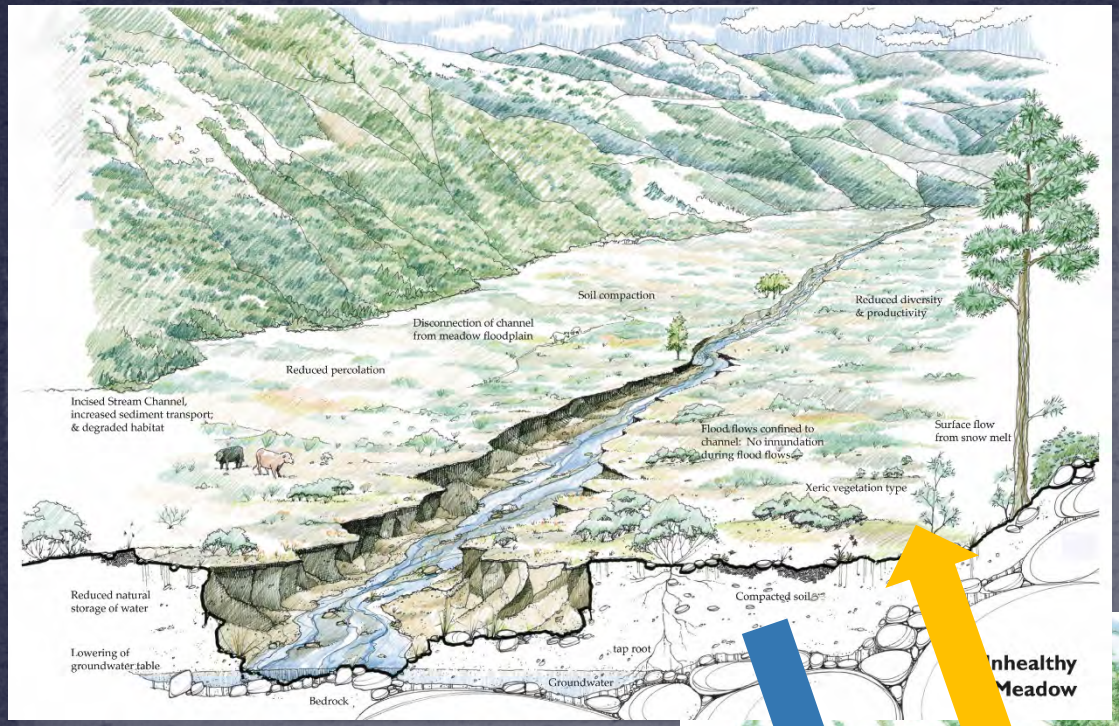


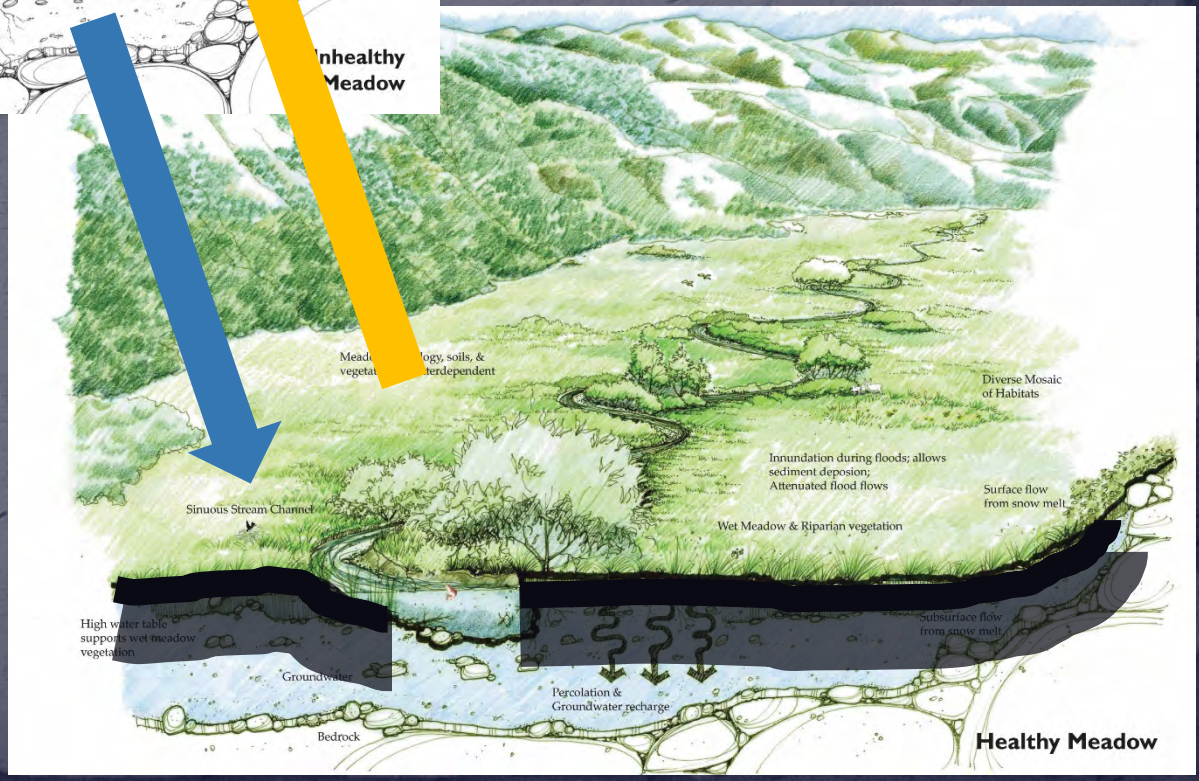
Norton et al. 2011



Protocol for restoration through raising the groundwater level during the growing season.

Many things change with meadow restoration degradation





The Biggest Carbon Reservoir is the Soil

Overarching Question:

Does hydrologic restoration of meadows result in a net increase in carbon sequestration?

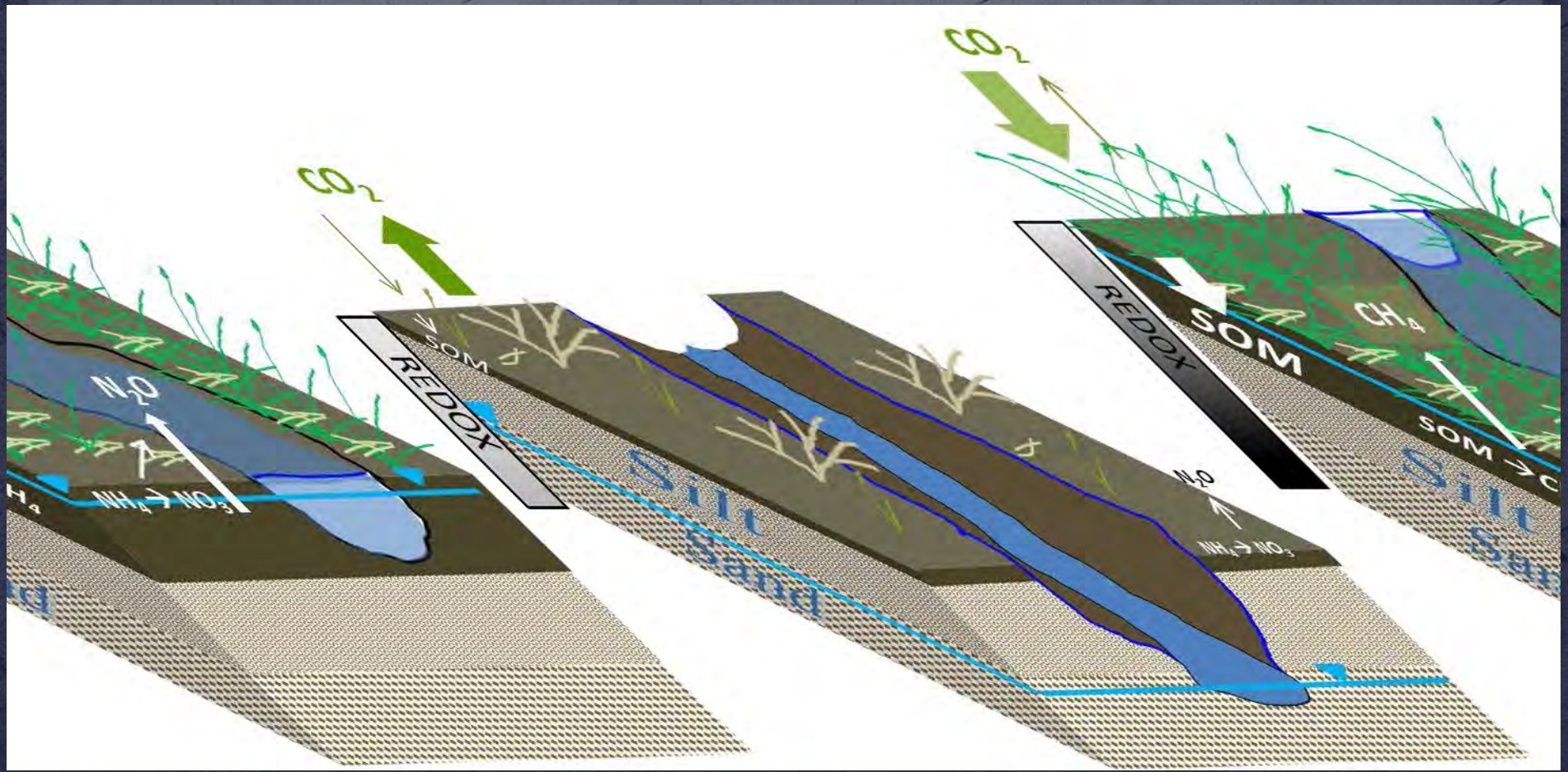
Carbon and GHG Flows

Oxidation

Microbes & Soil

Reduction

Plants, **Microbes & Soil**



Hypotheses

Compared to degraded conditions, hydrologic restoration results in:

1. Increase in net CO_2 input to soil via plant production.

2. Decrease in net CO_2 oxidation from soil via aerobic decomposition.

3. The net increase in N_2O and CH_4 fluxes to atmosphere is small in comparison to the increase in CO_2 input.

Before - After Control - Impact (BACI) Design

7 Impact (restoration)
6 Control
2 Reference
15 Total

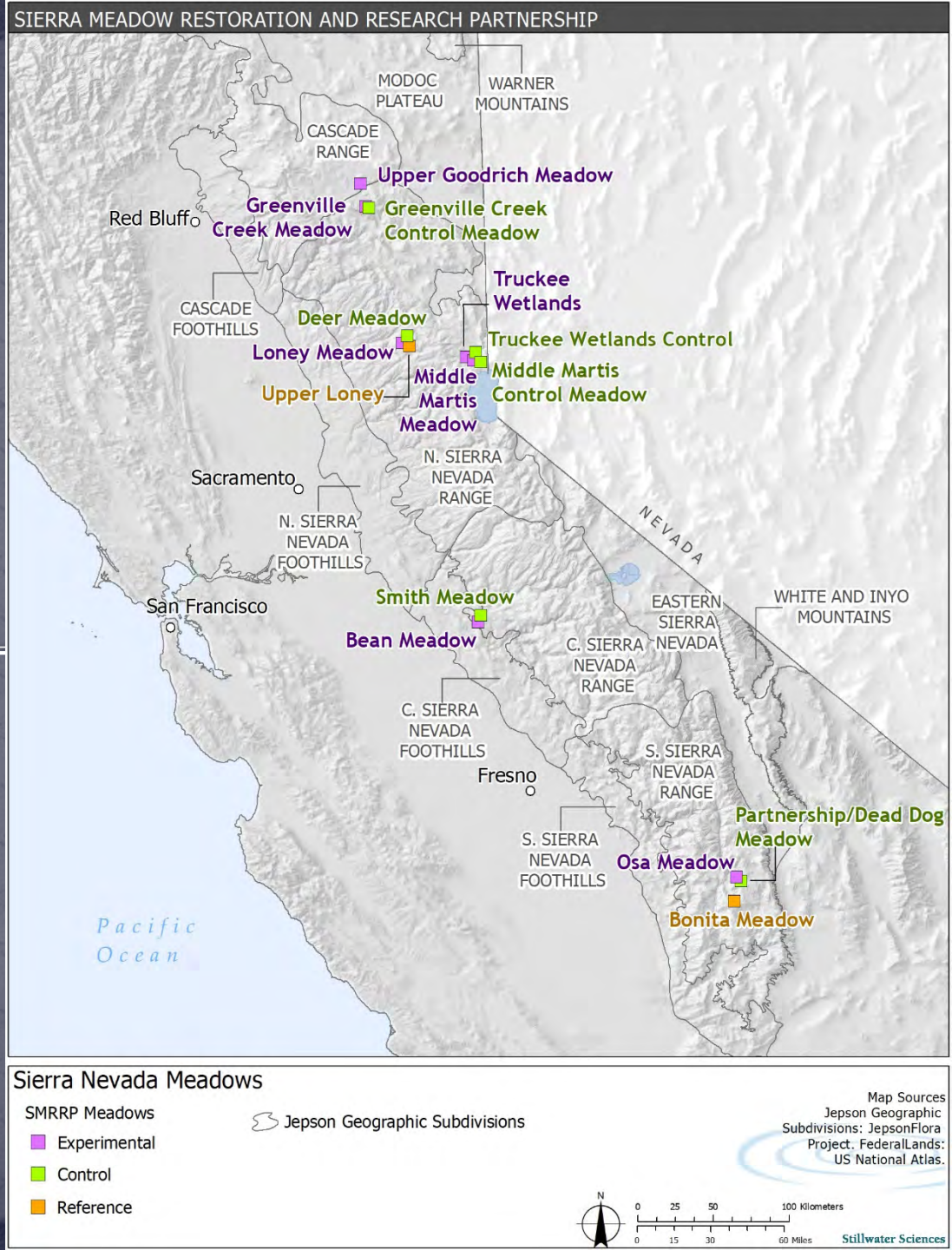
Primary response variables

- CO_2, N_2O, CH_4 flux
- Primary production inputs

Net change in carbon storage

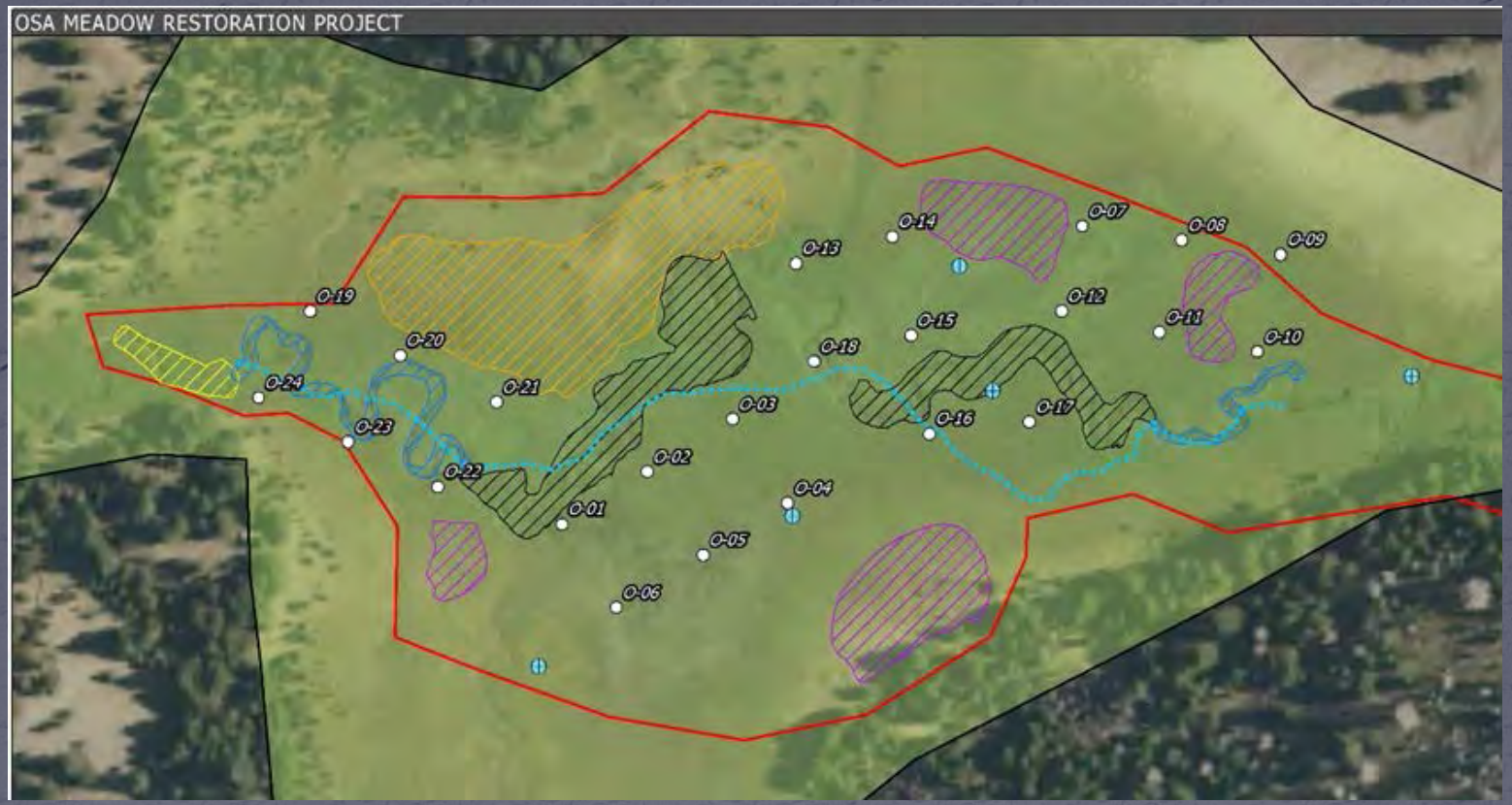
Hypothesized Co-variates

- Soil /Air temperature
- Soil water content
- Vegetation biomass
- Vegetation wetland status
- Groundwater level



Sampling Design

- 24 point grid: 30 m between points

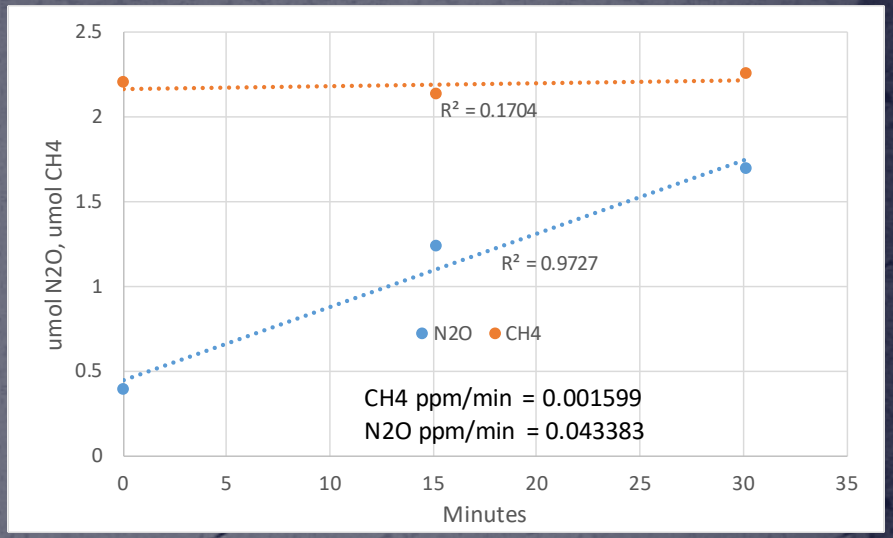


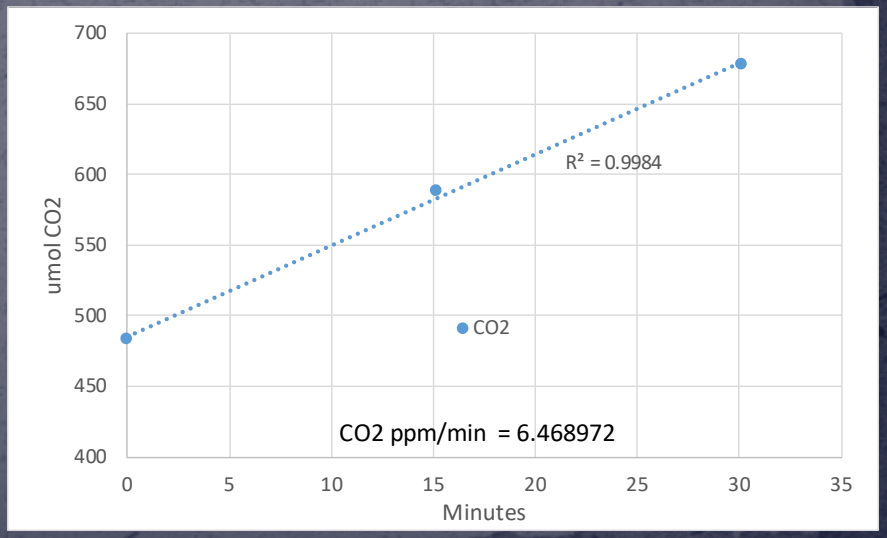
Measurements per Grid Point

- Soil CO_2, N_2O, CH_4 flux
- Monthly to bimonthly
- Aboveground biomass
- Litter Carbon
- Belowground biomass - roots
- Soil C (to 1 m)

How do we measure gas flux?

In Situ Incubation in Static Chambers with 3 time points

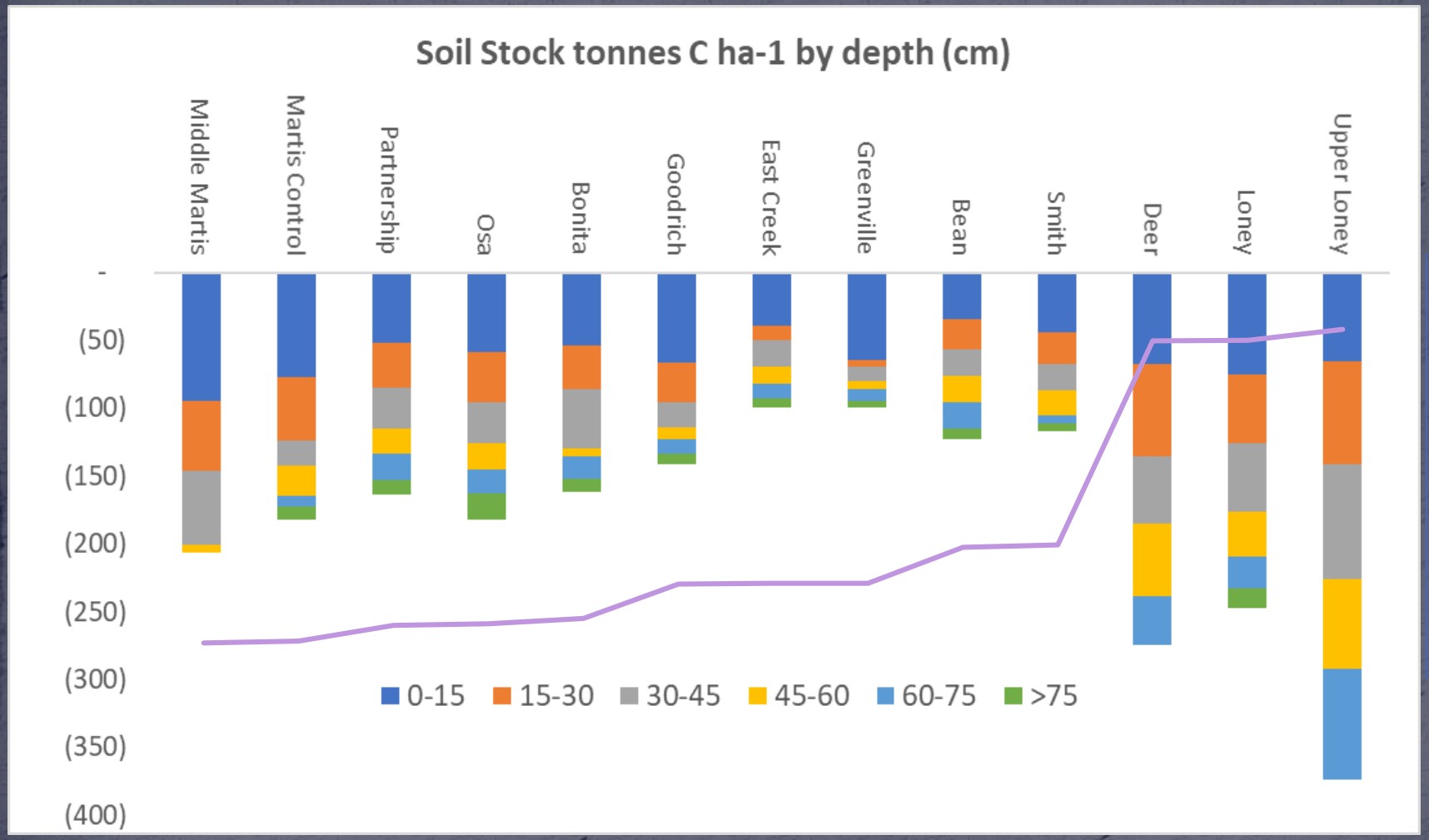




We have had an army of people!!

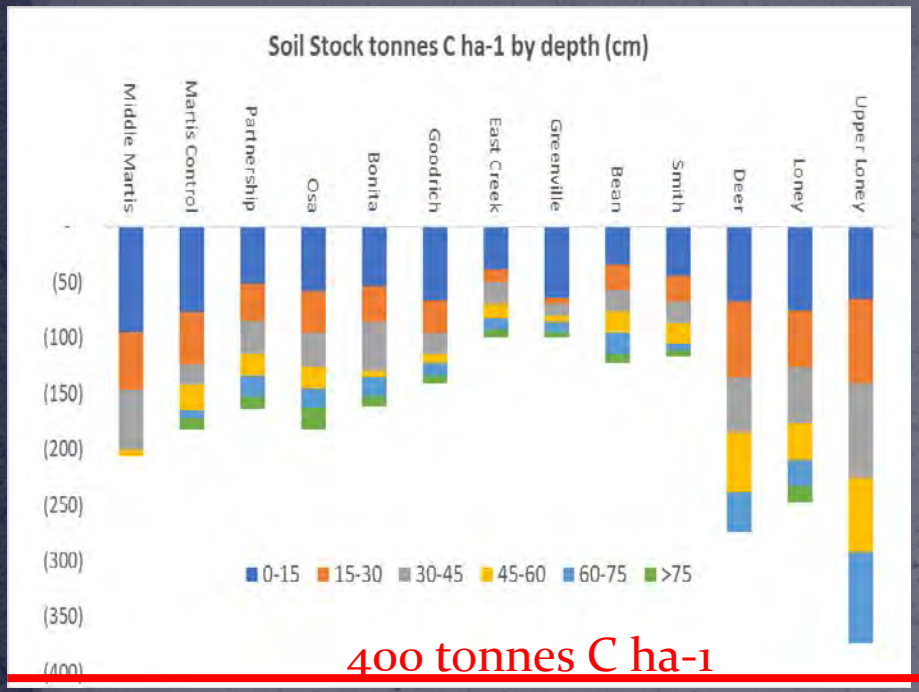
RESULTS

Soil Carbon Pools

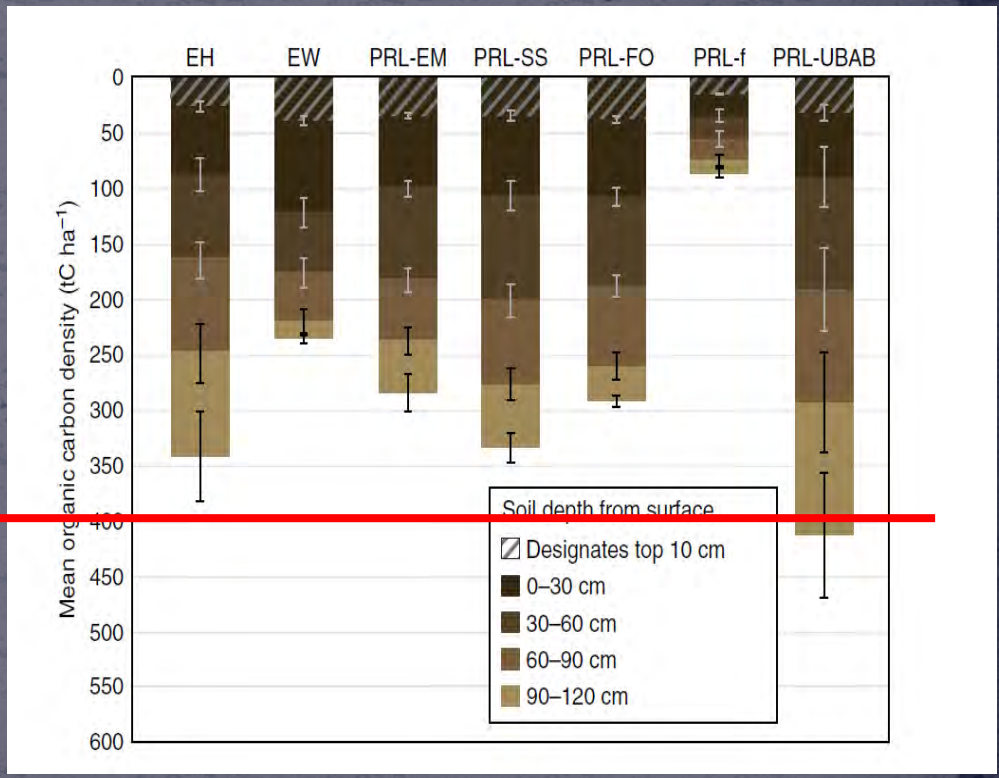


NOTE: Deer, Upper Loney and Middle Martis have no >75 cm measurements, Truckee and Truckee Control are 'under construction'.

Soil Carbon Pools



400 tonnes C ha-1



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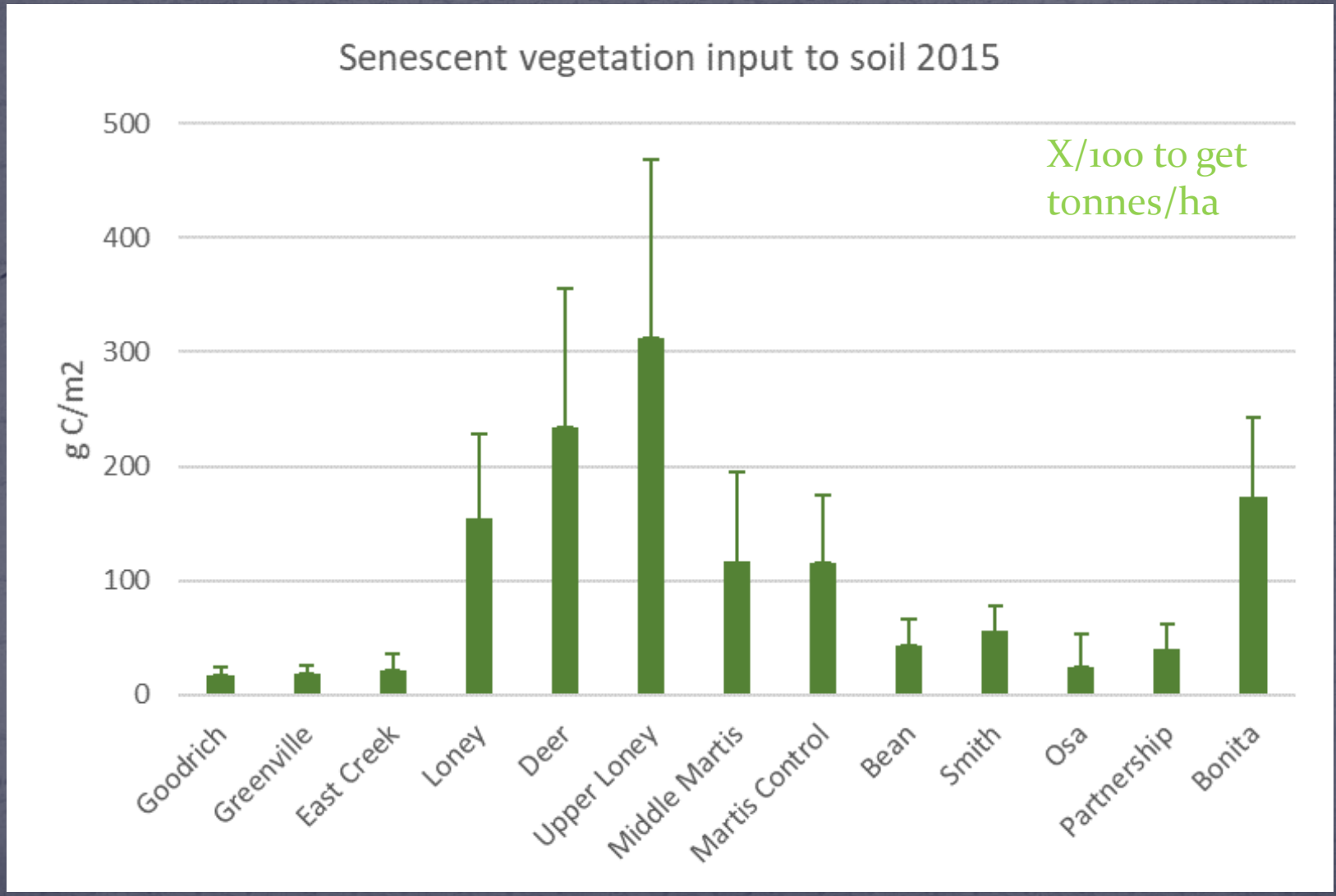
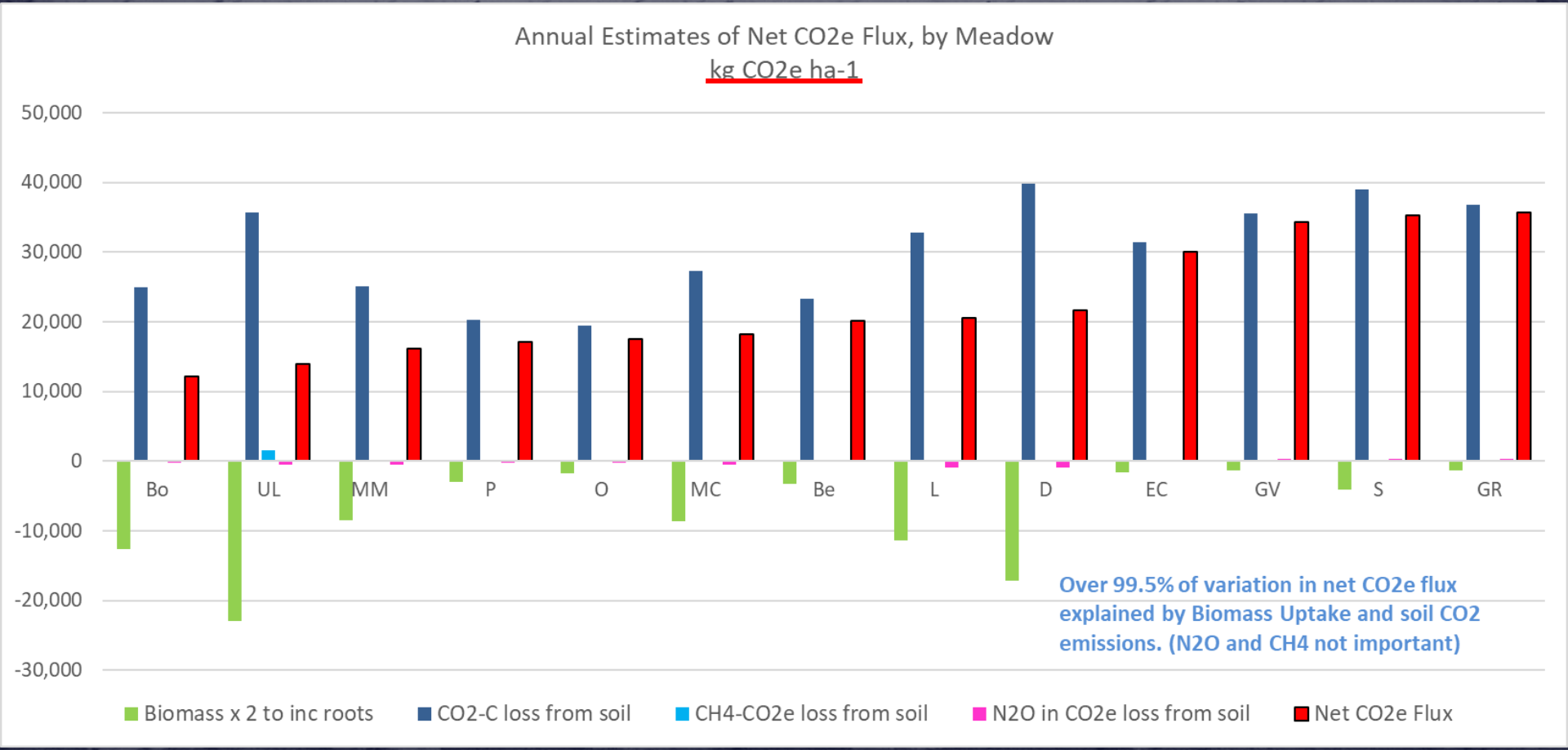
CARBON INPUTS TO SOIL



Net GHG flux

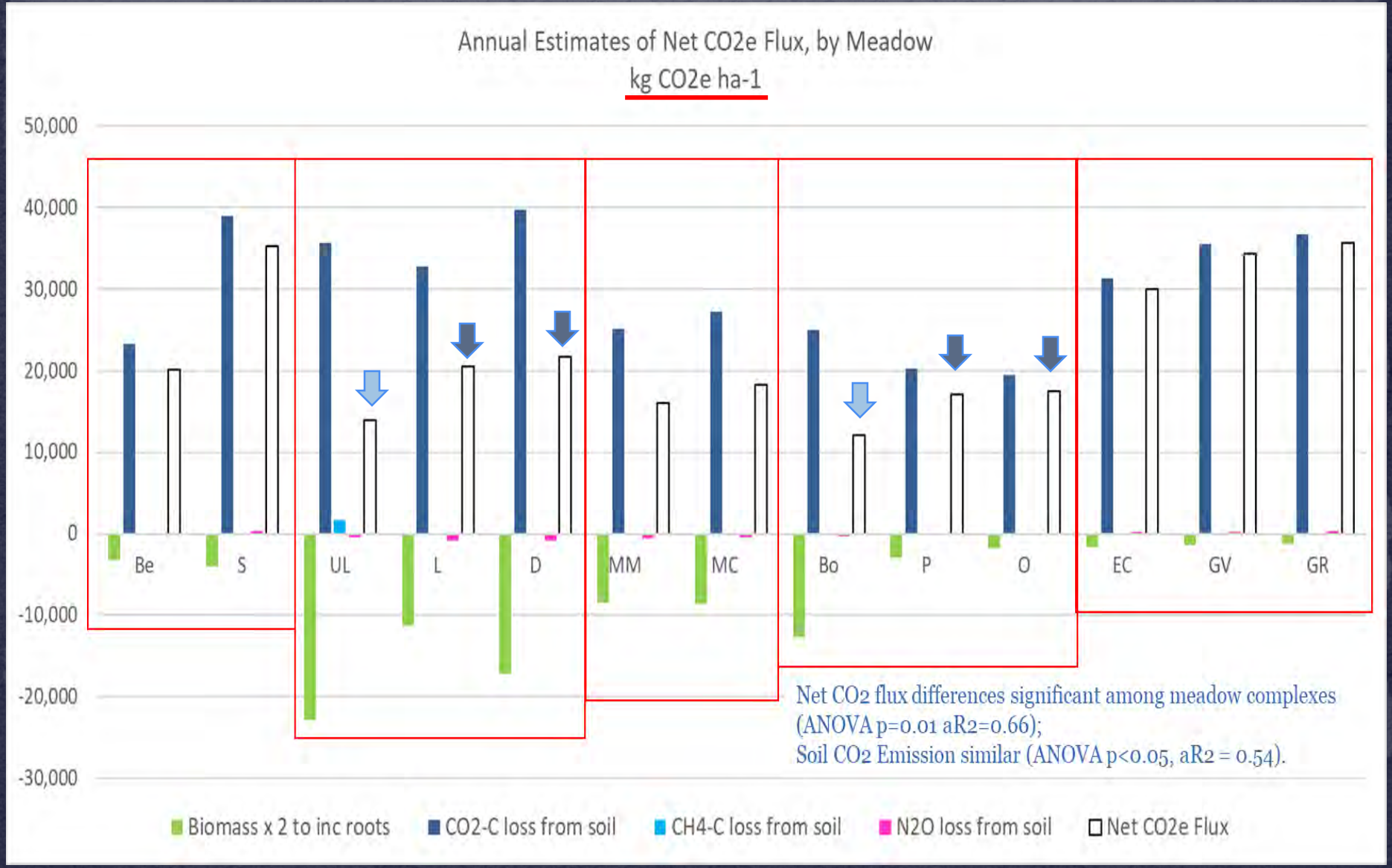
*__Loss__ to atmosphere from meadow

*Dominated by CO_2

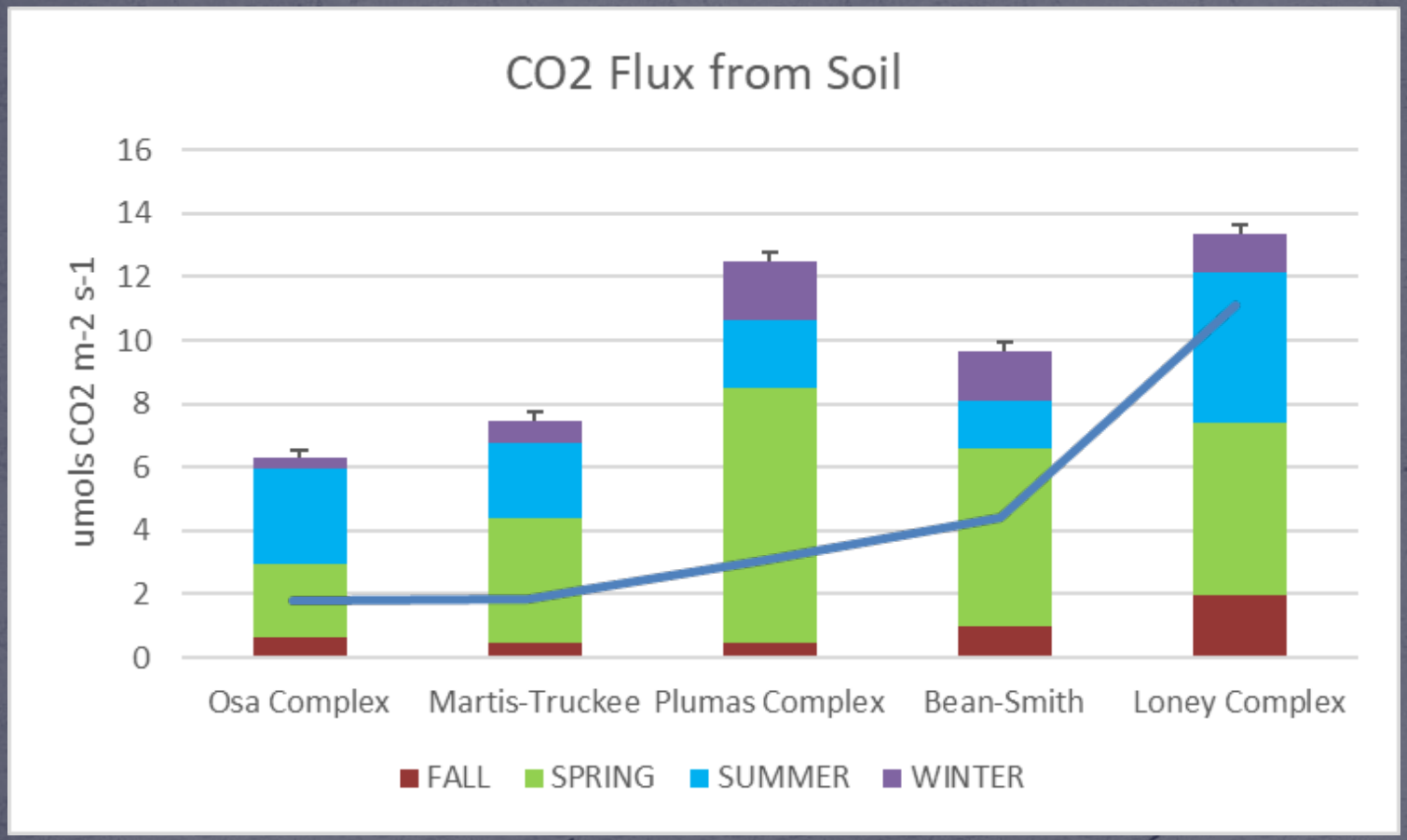


Net GHG flux

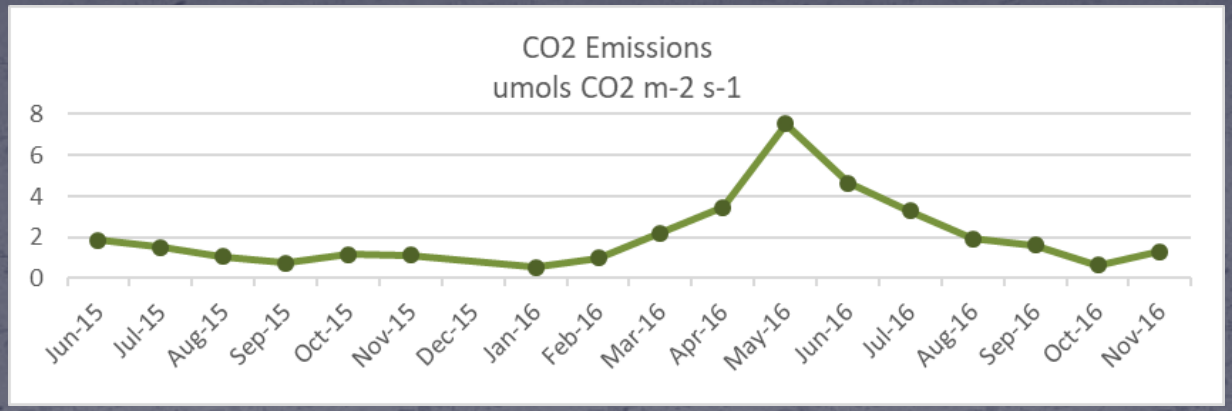
Different among Meadow Sets

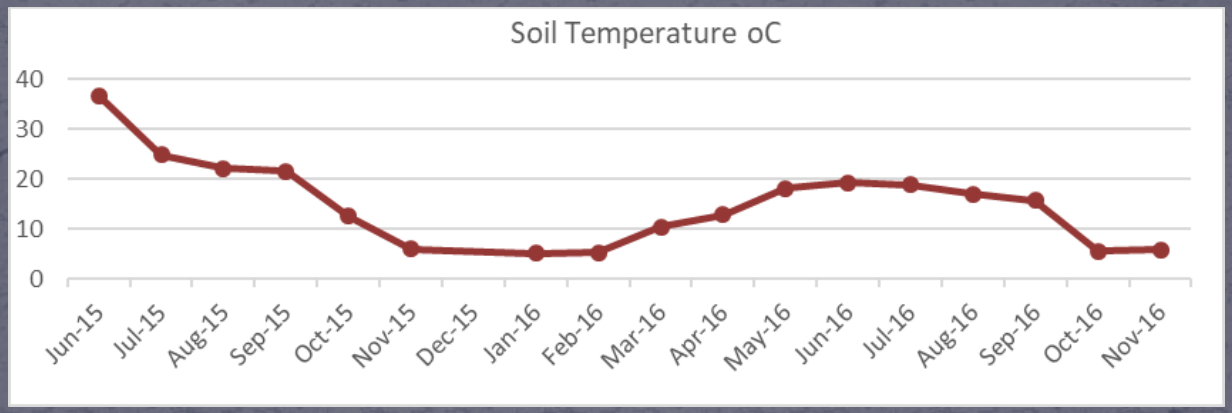


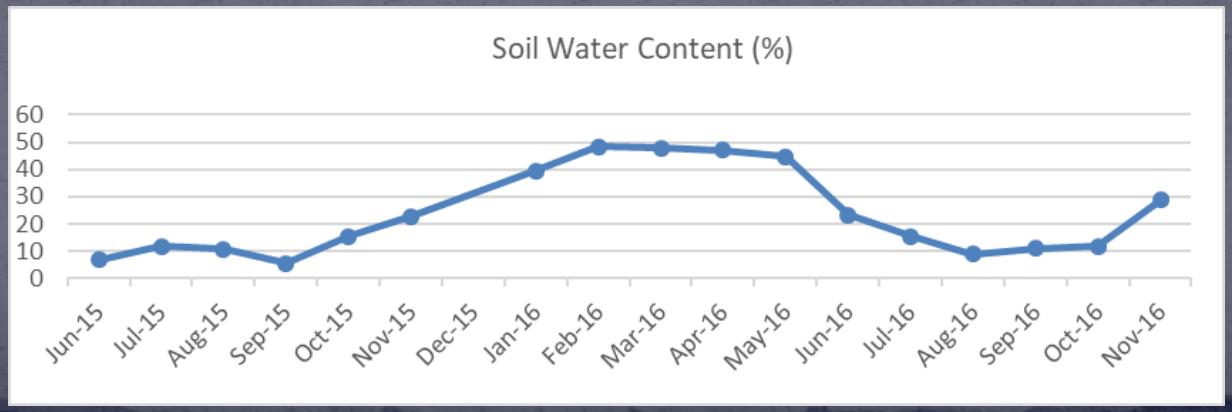
CO_2 LOSS from SOIL



CO_2 LOSS: ALL MEADOWS BY MONTH

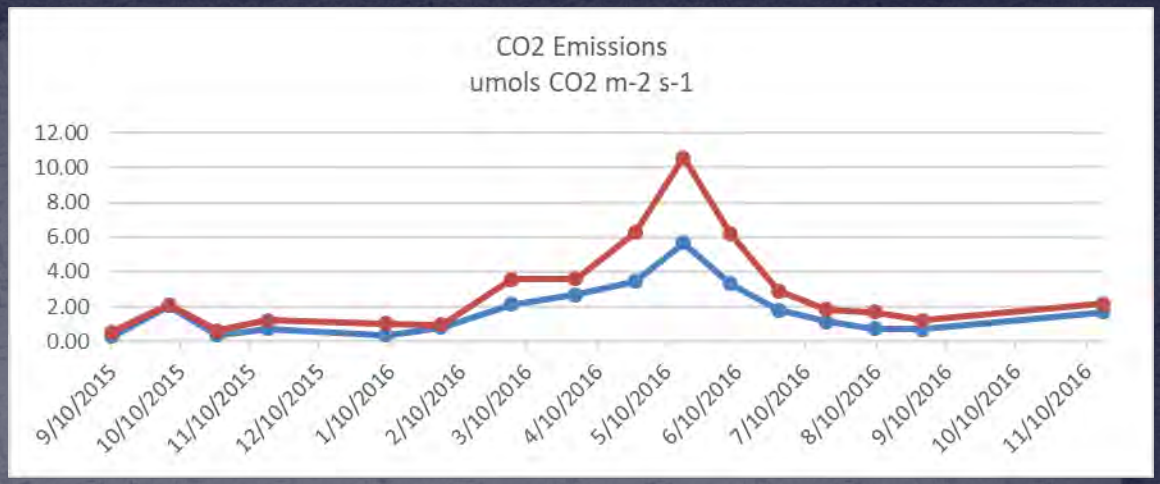


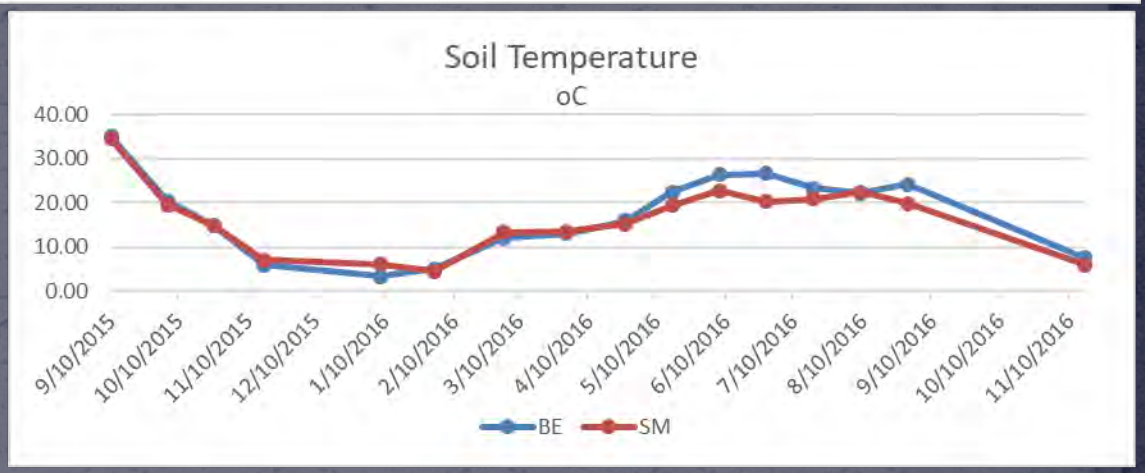


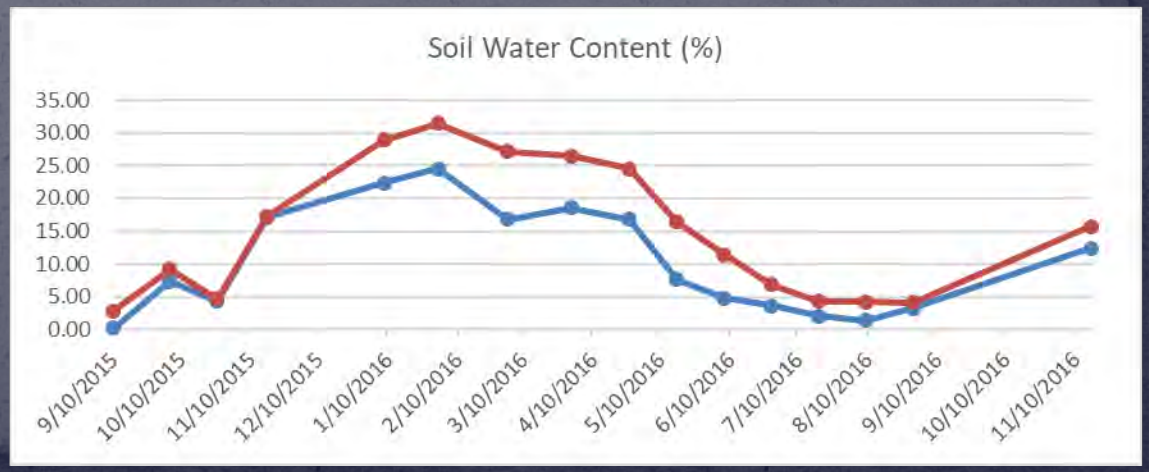


Just Bean and Smith Meadows

ADD PHOTO

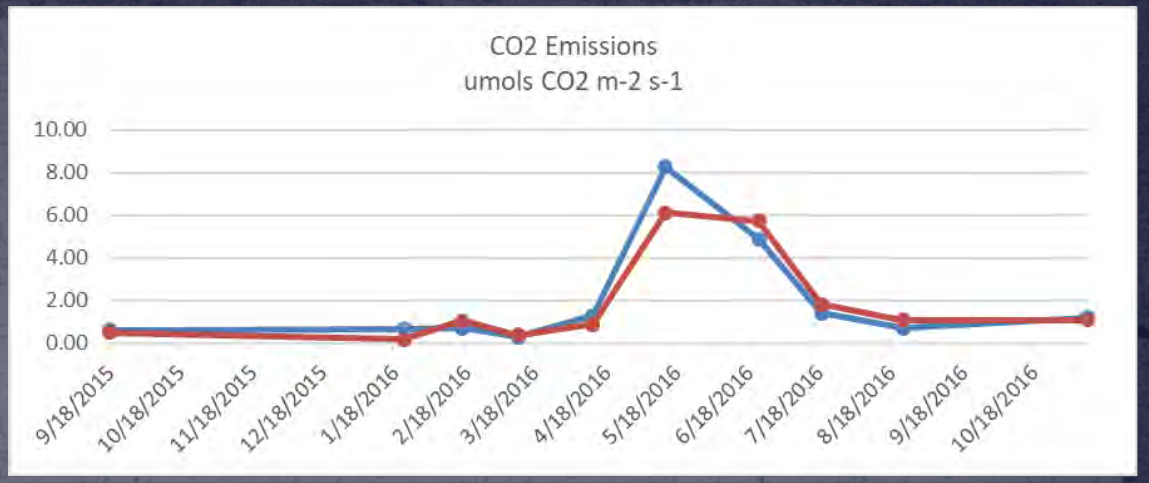


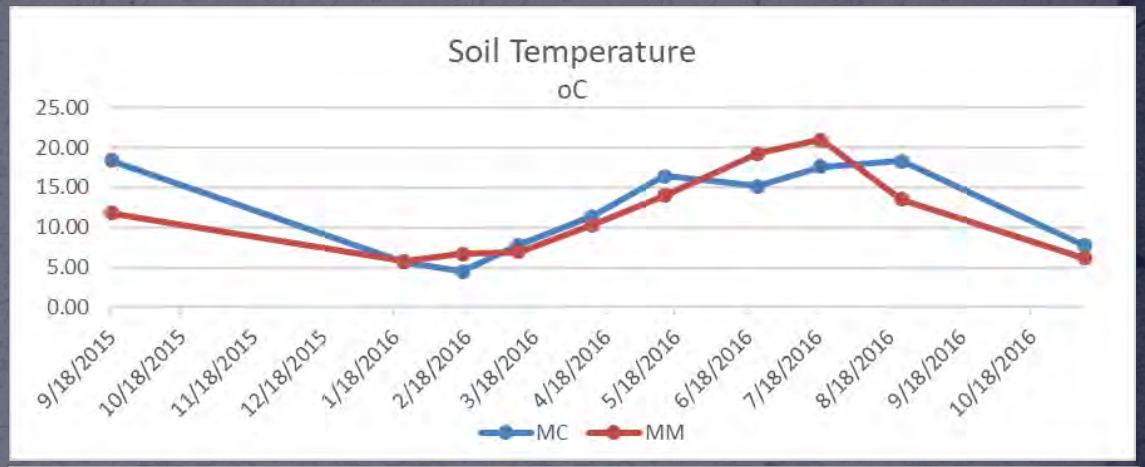


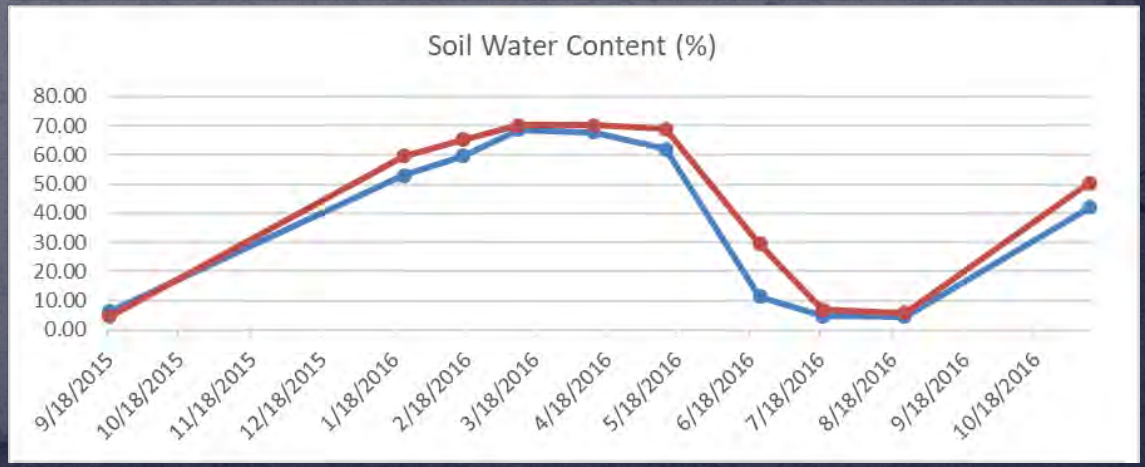


Just Martis and Martis Control Meadows

How well is it predicted here?



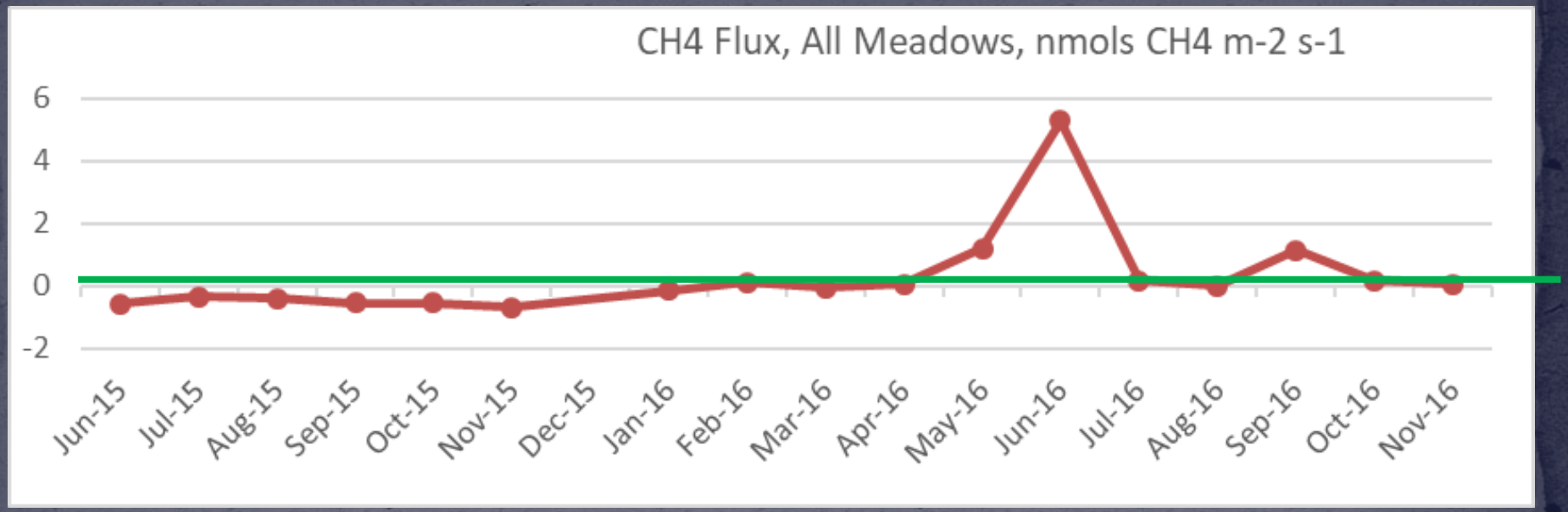


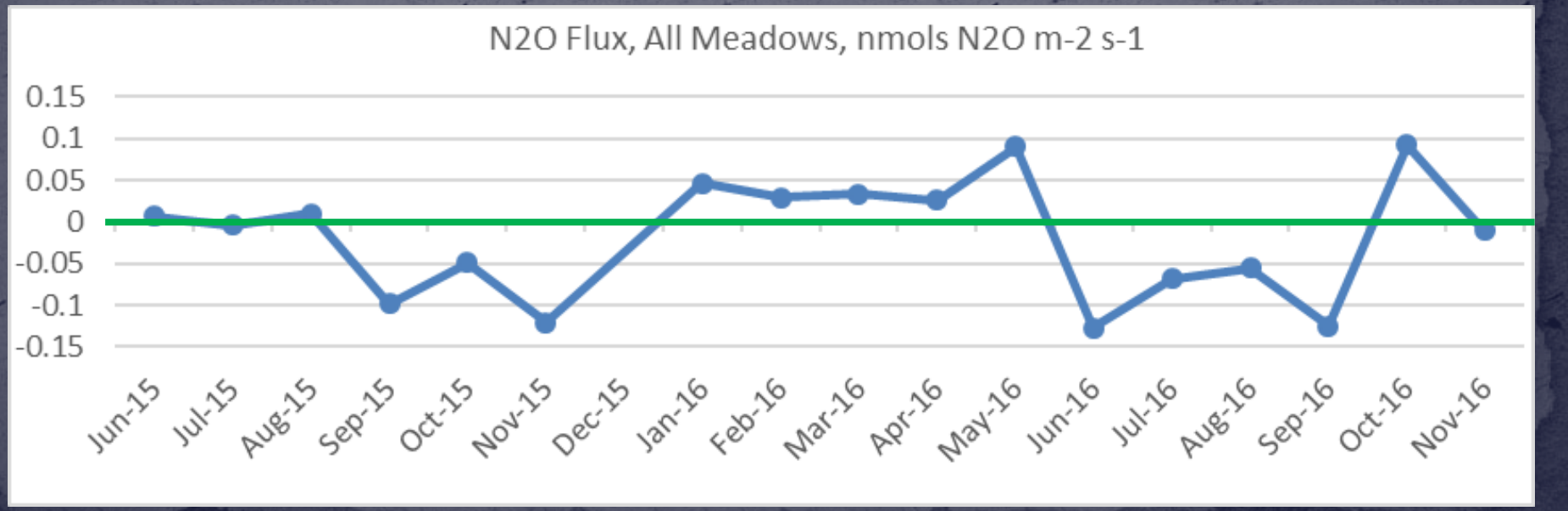


Soil water content and air temperature, used in a multivariate model are significantly and both positively correlated to CO_2 flux from soil.

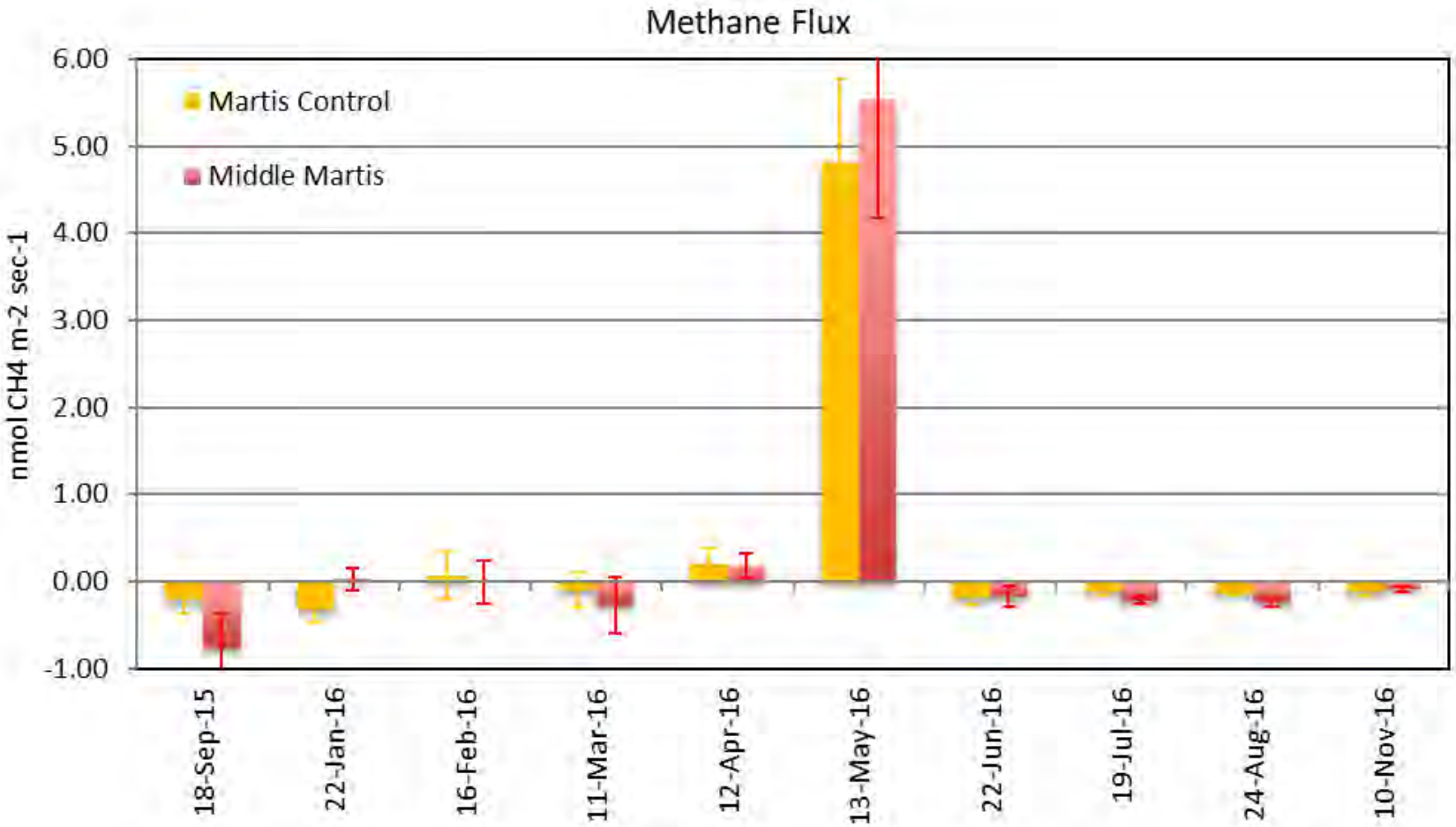
Meadows	All Year		Spring/Summer		Fall/Winter	
	R2	n	R2	n	R2	n
ALL	0.28	3600	0.25	2180	0.10	1420
Plumas	0.47	982	0.47	756	0.31	226
Truckee	0.30	667	0.21	378	0.09	289
Loney	0.38	669	0.25	304	0.25	223
Bean/Smith	0.25	755	0.38	359	0.21	369
Osa Complex	0.38	669	0.13	383	0.16	286

N_2O and CH_4, Seasonal Patterns

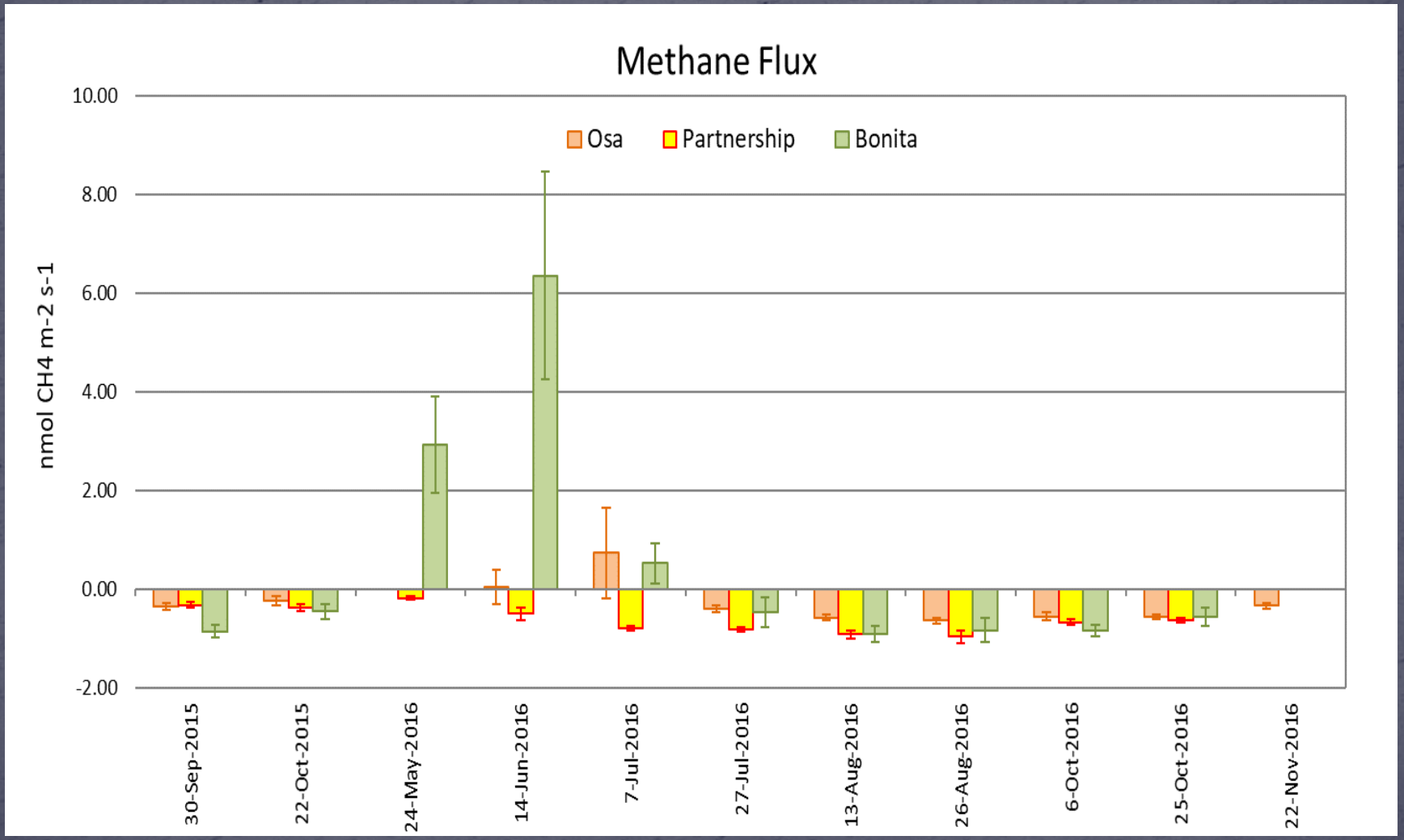




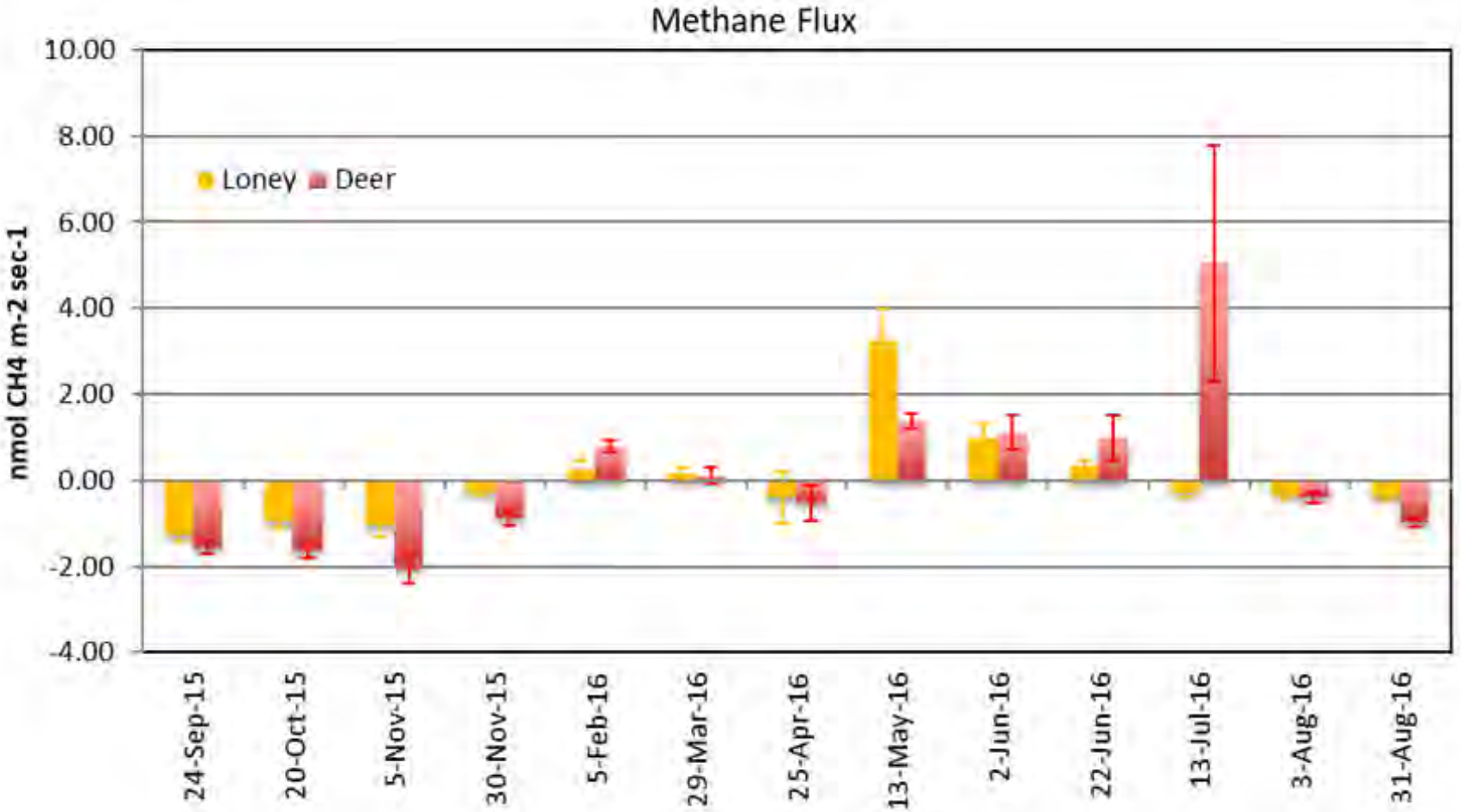
METHANE: MARTIS AND MARTIS CONTROL



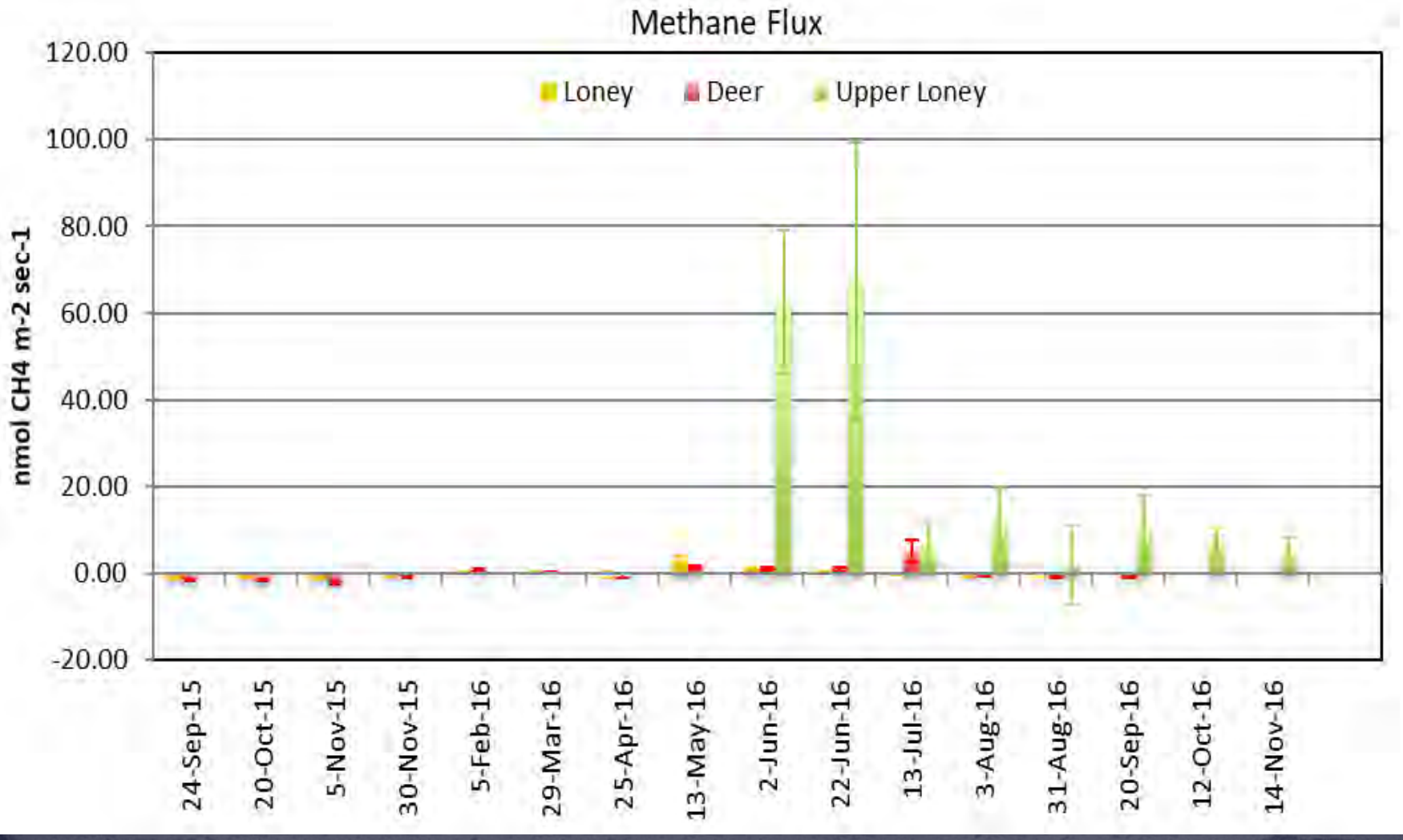
METHANE: OSA COMPLEX



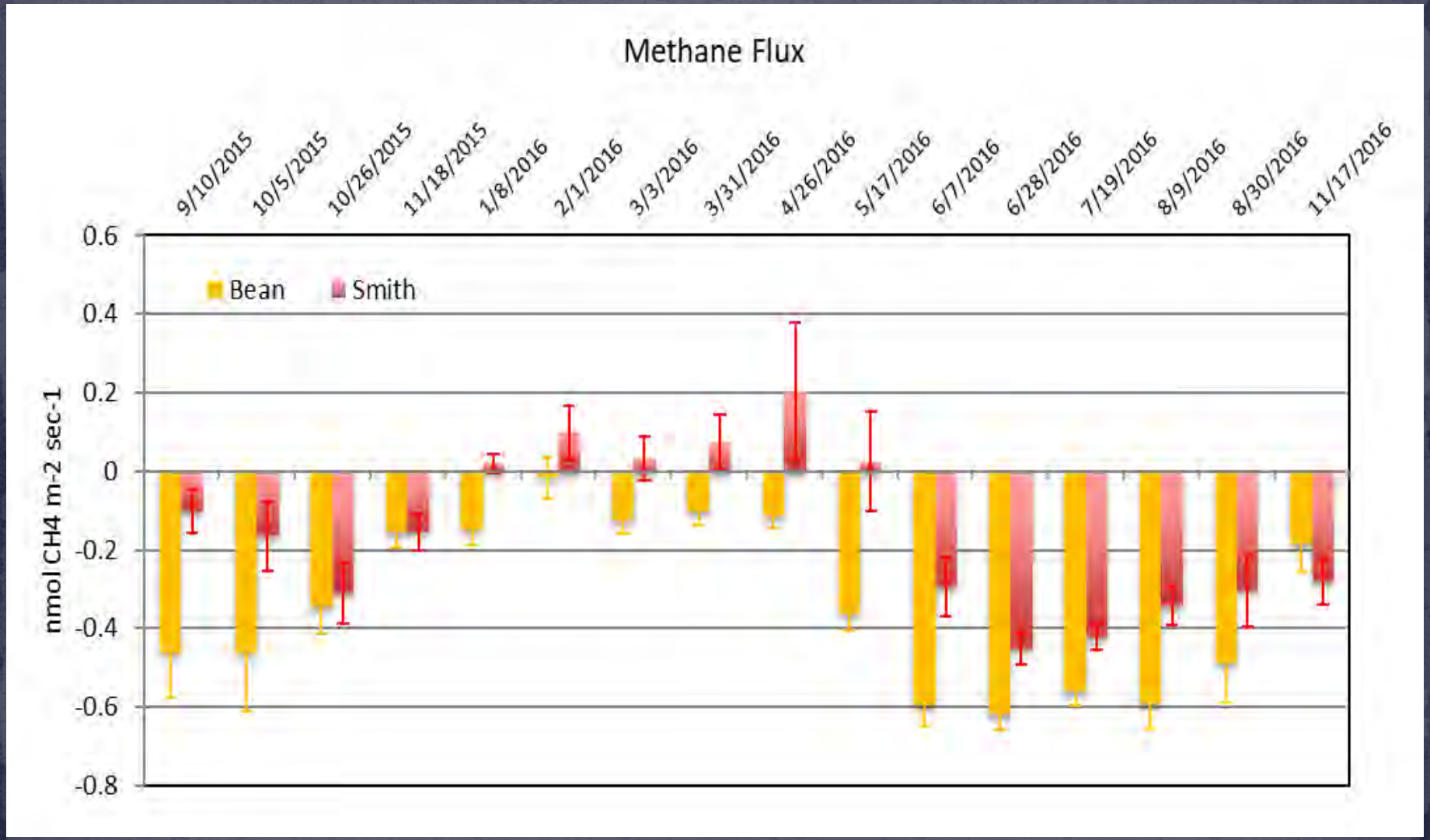
METHANE: LONEY AND DEER



METHANE: UPPER LONEY, LONEY AND DEER



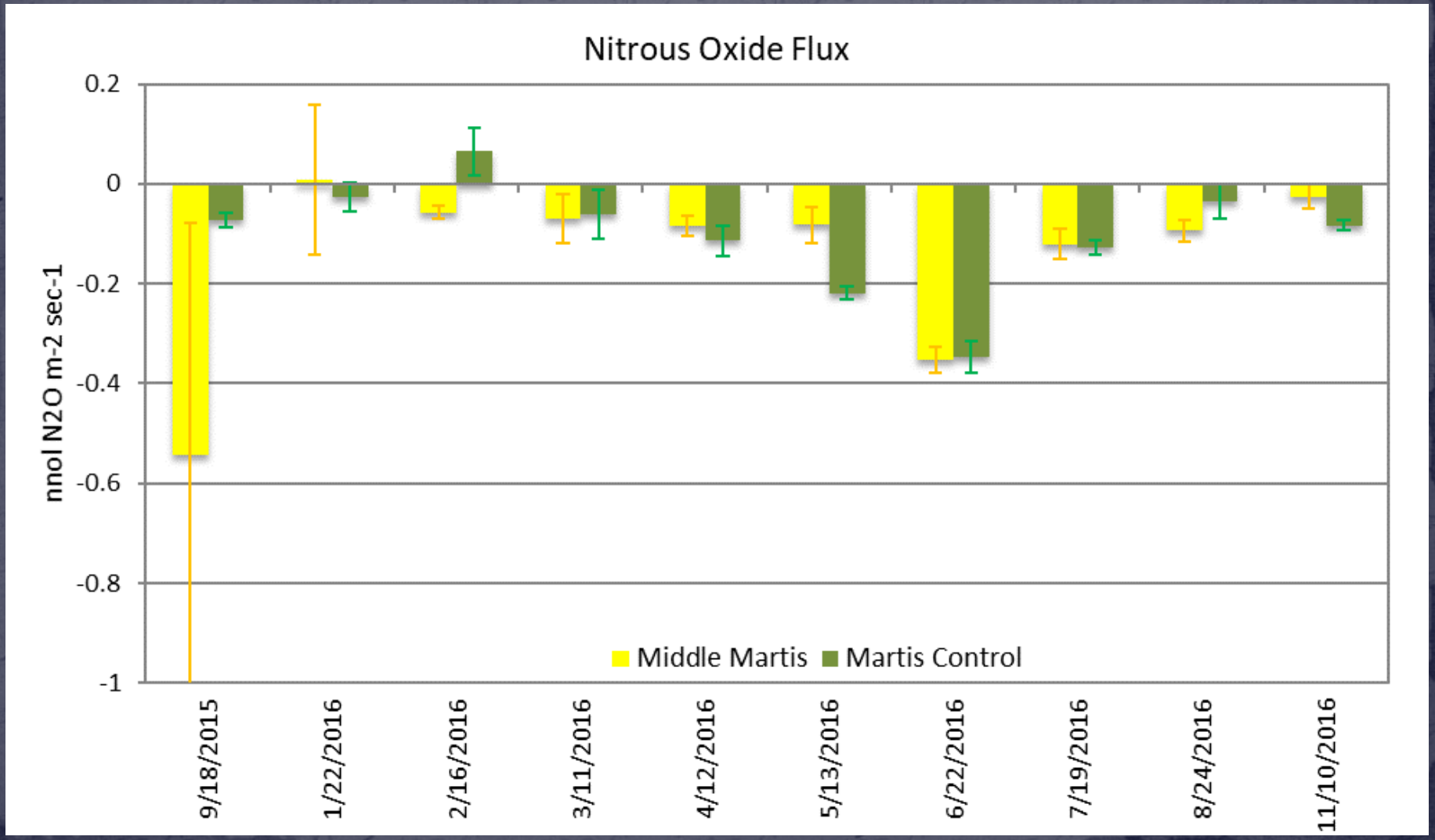
METHANE: BEAN AND SMITH



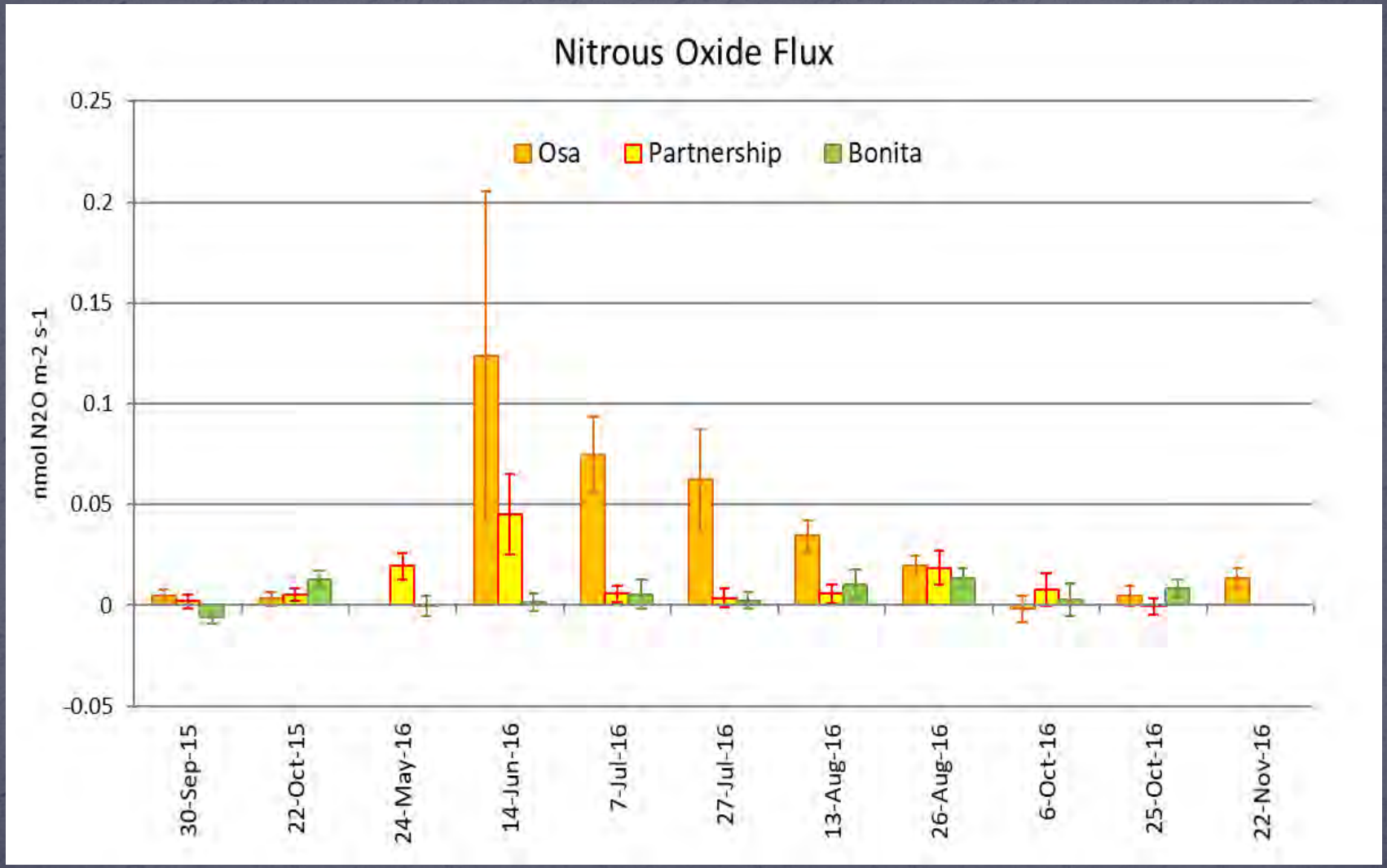
BREATHER

DEER

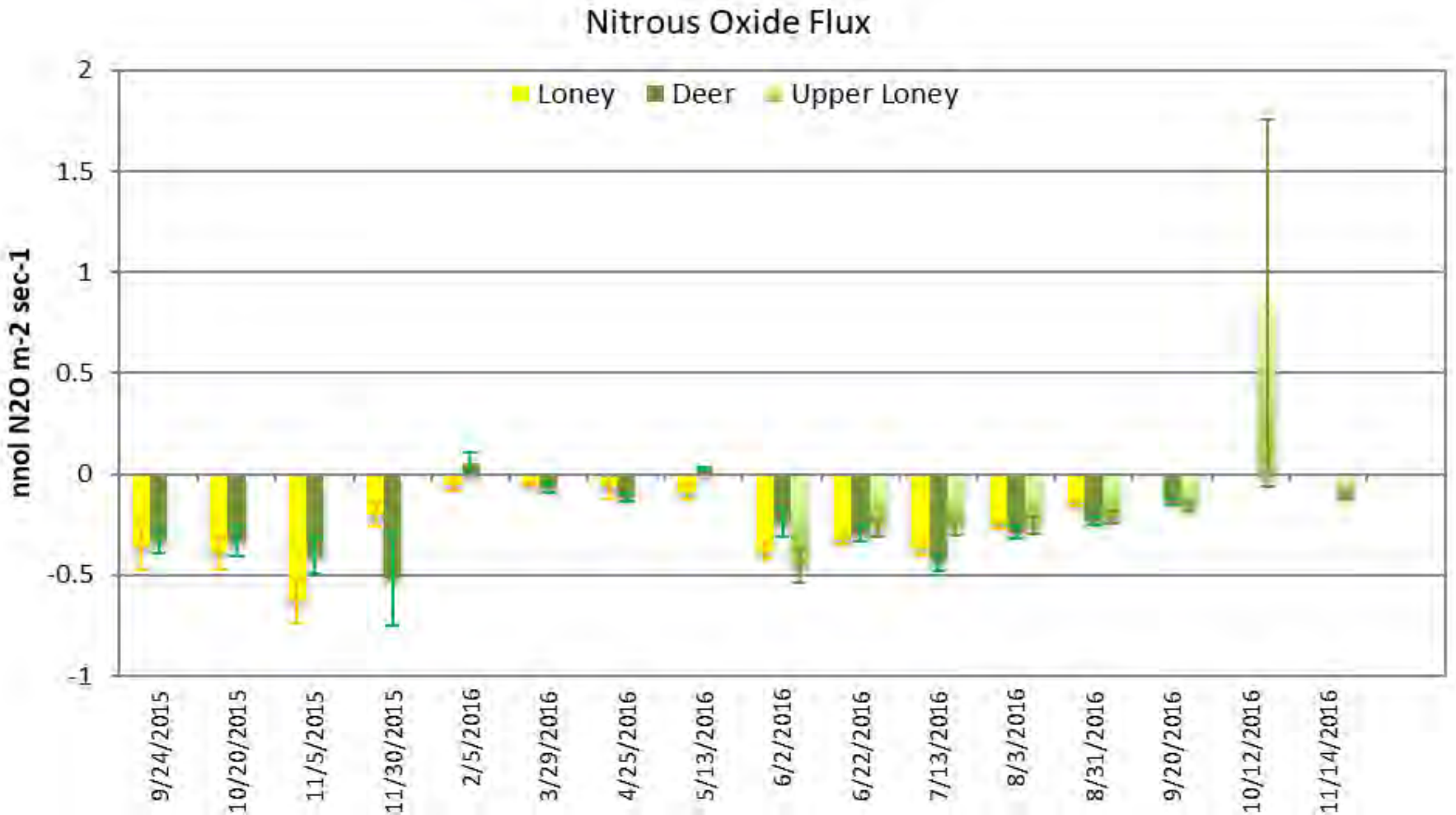
NITROUS OXIDE: MARTIS AND MARTIS CONTROL



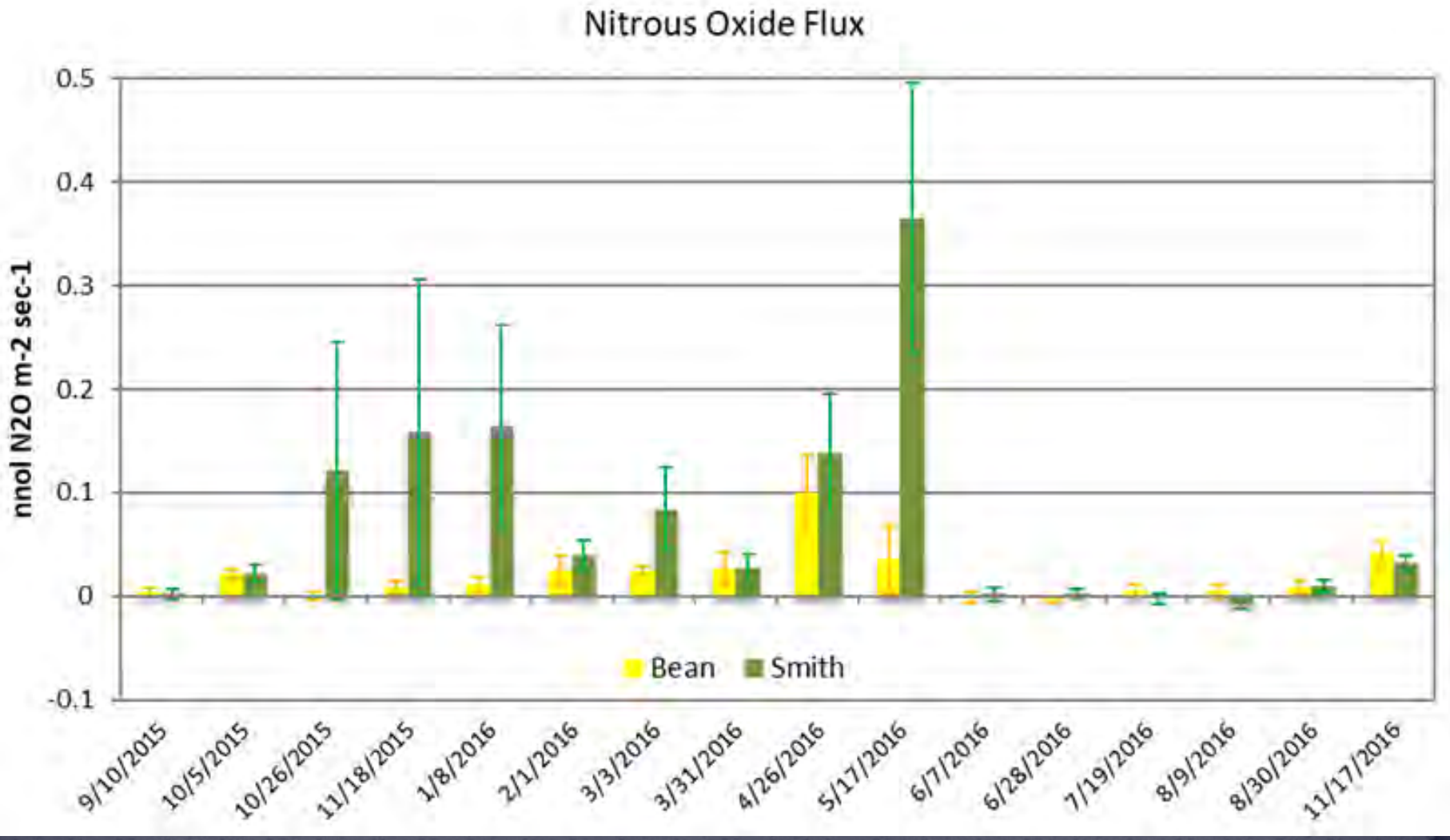
NITROUS OXIDE: OSA COMPLEX



NITROUS OXIDE: LONEY COMPLEX



NITROUS OXIDE: BEAN AND SMITH



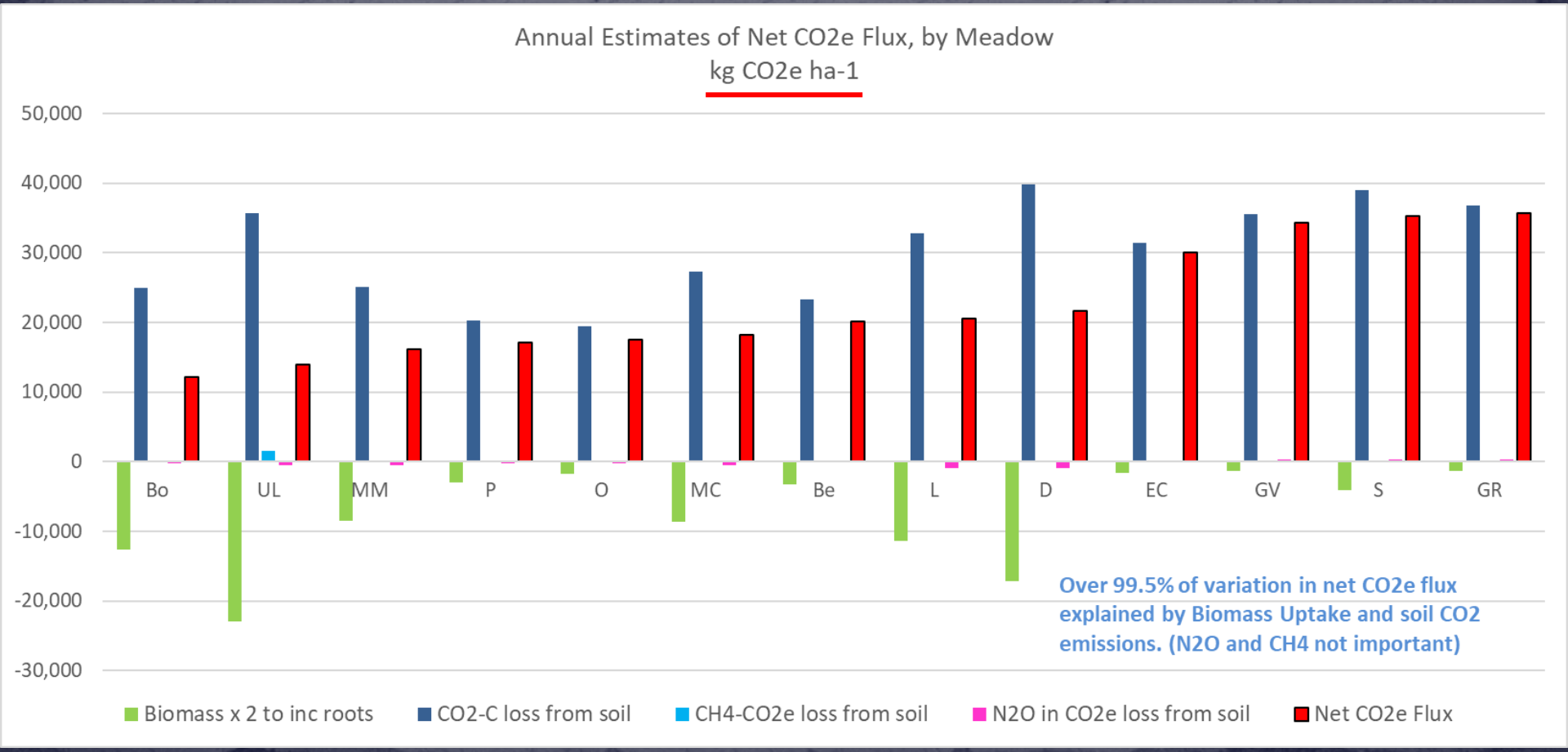
BREATHER

LONEY

Net GHG flux

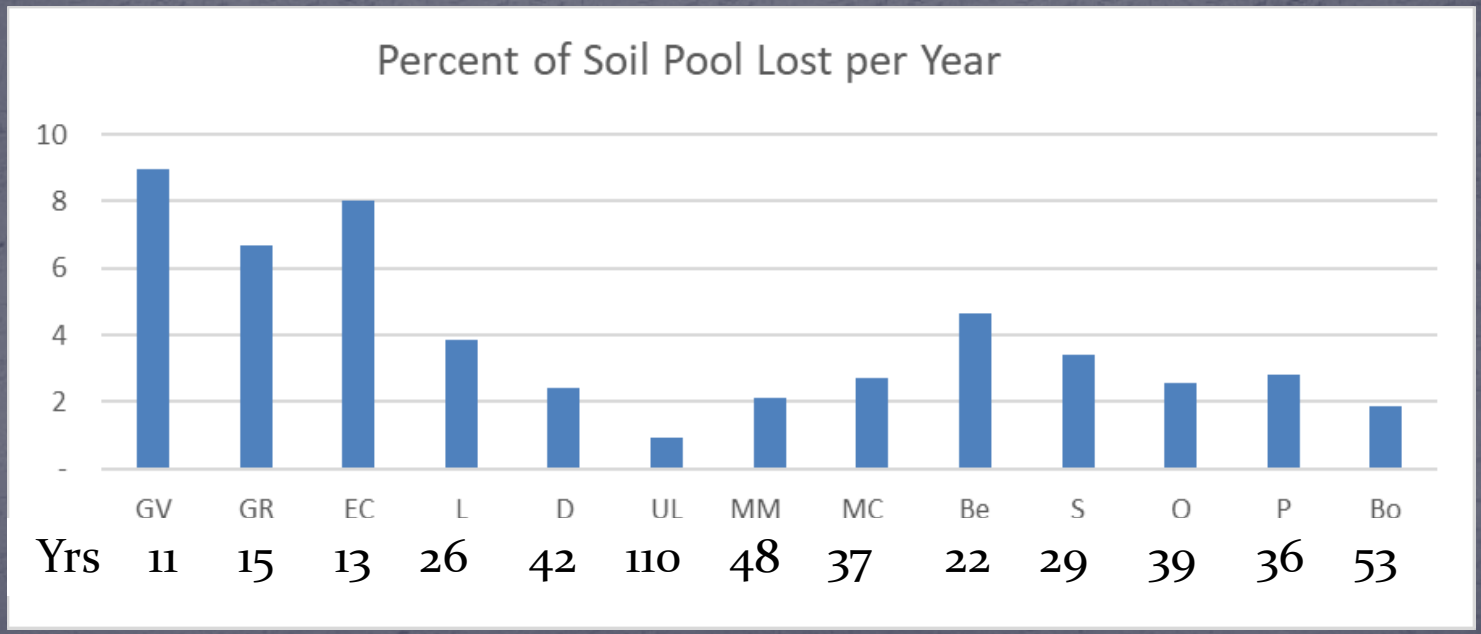
*__Loss__ to atmosphere from meadow

*Dominated by CO_2



SUMMARY

MEADOW	GV	GR	EC	L	D	UL	MM	MC	Be	S	O	P	Bo
C Component	g C m-2 y-1												
Soil and Root Pool	10,356.2	14,426.8	10,114.2	15,246.3	25,667.9	38,837.1	21,601.9	18,627.7	11,788.3	27,886.3	18,840.5	16,797.6	17,964.8
Litter INPUT	38.1	35.0	43.6	308.9	469.1	625.1	232.2	234.2	87.3	111.4	49.1	79.9	346.0
CO2 and CH4 FLUX	(968.5)	(1,002.1)	(856.0)	(893.9)	(1,085.4)	(978.7)	(685.2)	(742.7)	(634.7)	(1,064.1)	(532.0)	(553.5)	(682.4)
NET g C m-2 y-1	(930.4)	(967.1)	(812.3)	(585.0)	(616.4)	(353.6)	(453.0)	(508.5)	(547.4)	(952.6)	(483.0)	(473.6)	(336.4)
Percent of Storage	(9.0)	(6.7)	(8.0)	(3.8)	(2.4)	(0.9)	(2.1)	(2.7)	(4.6)	(3.4)	(2.6)	(2.8)	(1.9)
Years to Depletion	(11.1)	(14.9)	(12.5)	(26.1)	(41.6)	(109.8)	(47.7)	(36.6)	(21.5)	(29.3)	(39.0)	(35.5)	(53.4)



We are losing our soil resource

Summary

- Soil Carbon is the largest C pool -most upper 60 cm
- Oxidation of soil organic material to CO_2- is dominant process
- N_2O and CH_4 "uptake" during much of year
- Greatest GHG activity in spring and summer
- VWC and Temperature are part of the predictive model
- Above ground biomass input less than CO_2+CH_4 loss.
- Many degraded meadows are rapidly losing their soil organic material.
- So far, the wetter, less degraded are not.

Summary

Scaling Up It Takes:

- Someone(s) with a Vision
- A lot of people
- A lot of cooperation
- Multiple skill sets and resources
- Good and fearless leadership

Thanks and Acknowledgements

CalTrout
University of Nevada at Reno
UC Merced
Plumas Corporation
Truckee River Watershed Council
American Rivers
Sierra Foothill Conservancy
SYRCL
US Forest Service
NFWF
CDFW

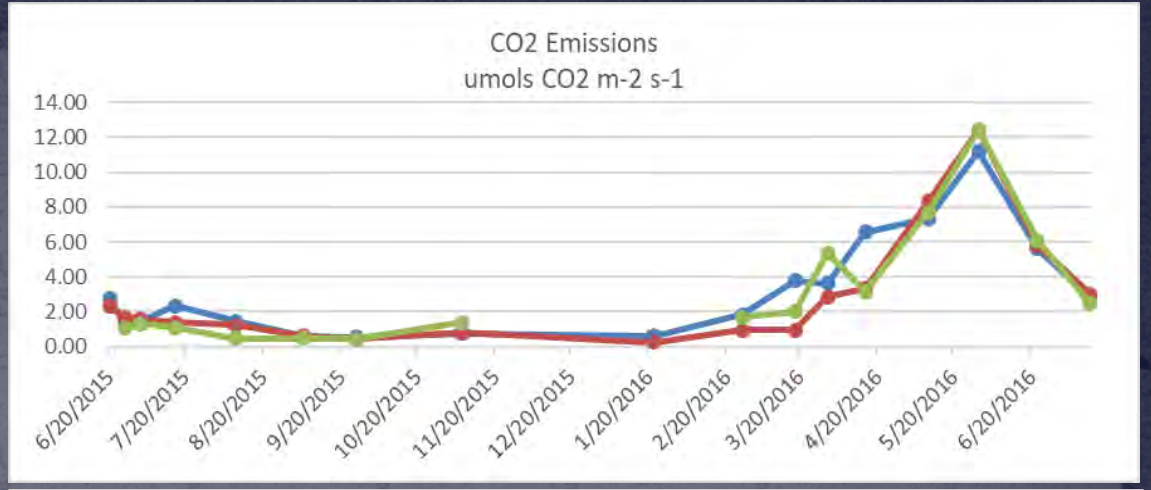
Upper Loney

BEAN

I think this is Osa


Convergence
Meadows Workshop, Calistoga, CA

PLUMAS


CO2 Emissions
umols CO2 m-2 s-1
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
6/20/2015
7/20/2015
8/20/2015
9/20/2015
10/20/2015
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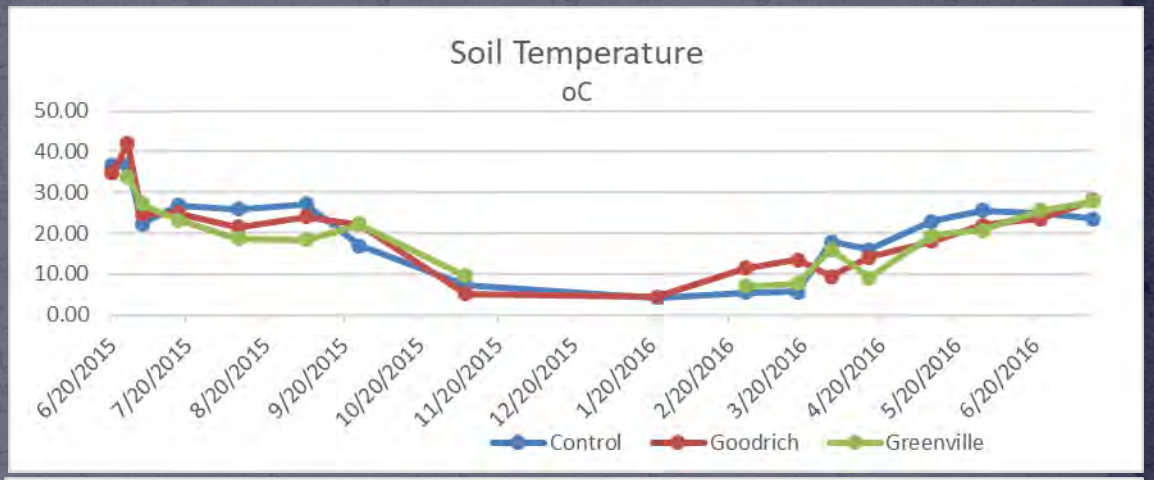
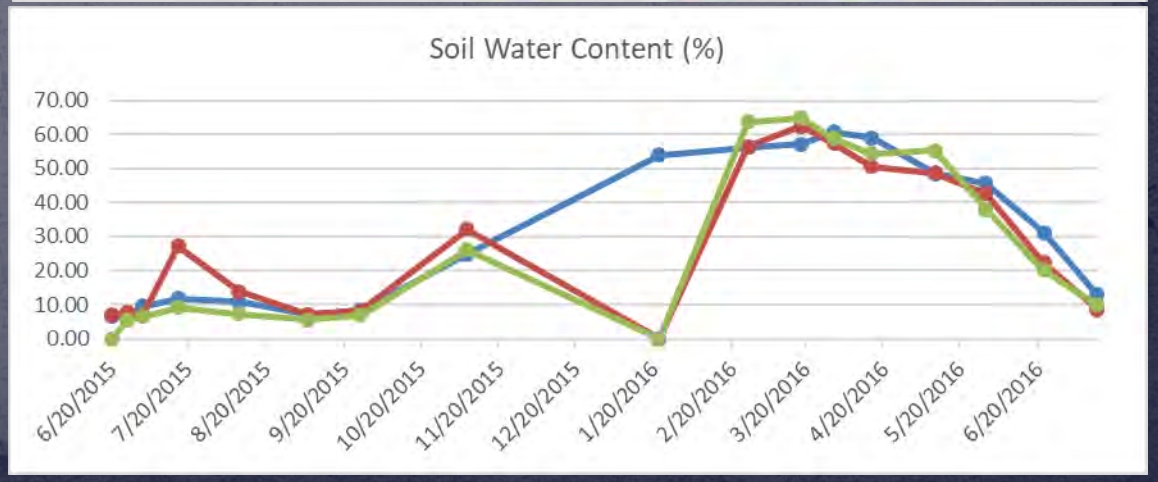
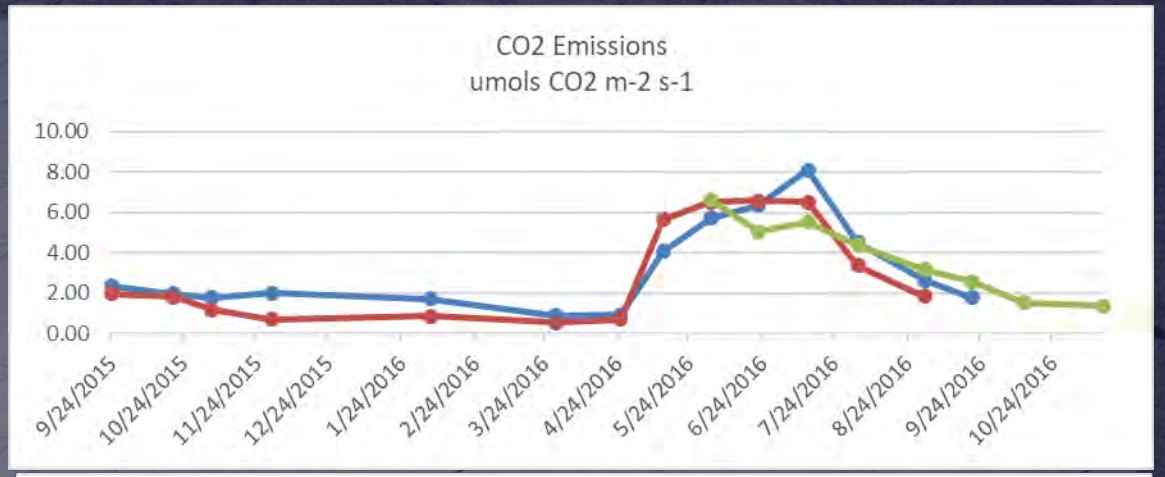
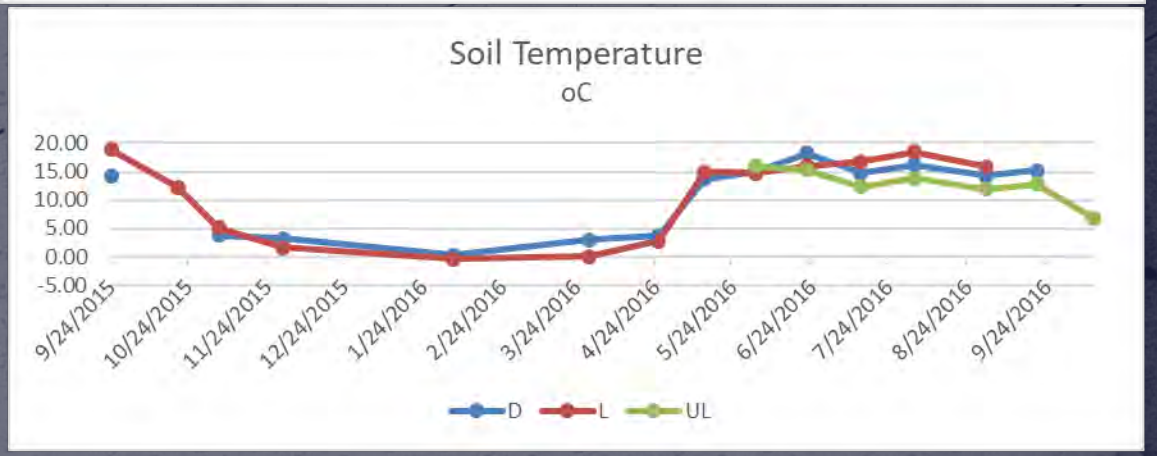
3/20/2016
4/20/2016
5/20/2016
6/20/2016

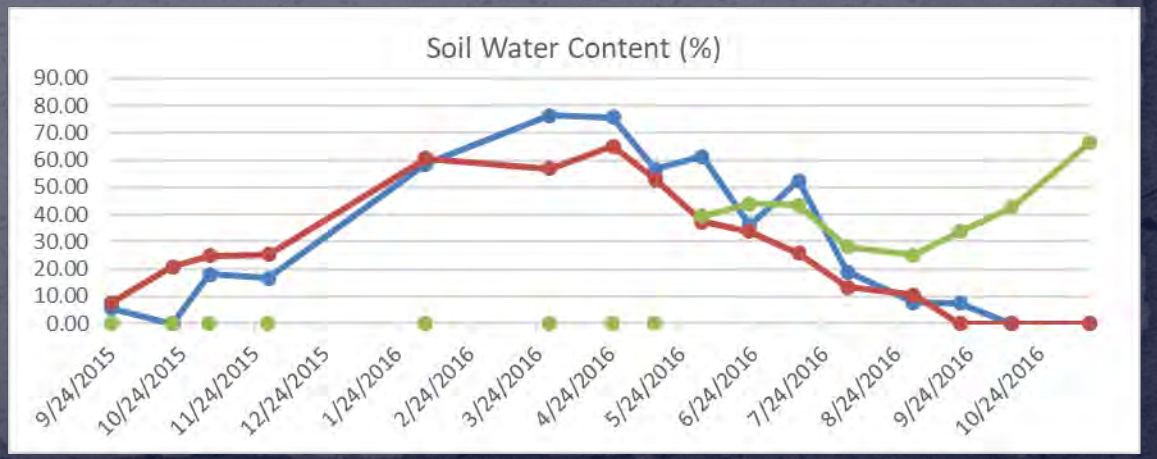

Soil Temperature
oC
50.00
40.00
30.00
20.00
10.00
0.00
6/20/2015
7/20/2015
8/20/2015
9/20/2015
10/20/2015
11/20/2015
12/20/2015
1/20/2016
2/20/2016
3/20/2016
4/20/2016
5/20/2016
6/20/2016
Control
Goodrich
Greenville


Soil Water Content (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
6/20/2015
7/20/2015
8/20/2015
9/20/2015
10/20/2015
11/20/2015
12/20/2015
1/20/2016
2/20/2016
3/20/2016
4/20/2016
5/20/2016
6/20/2016

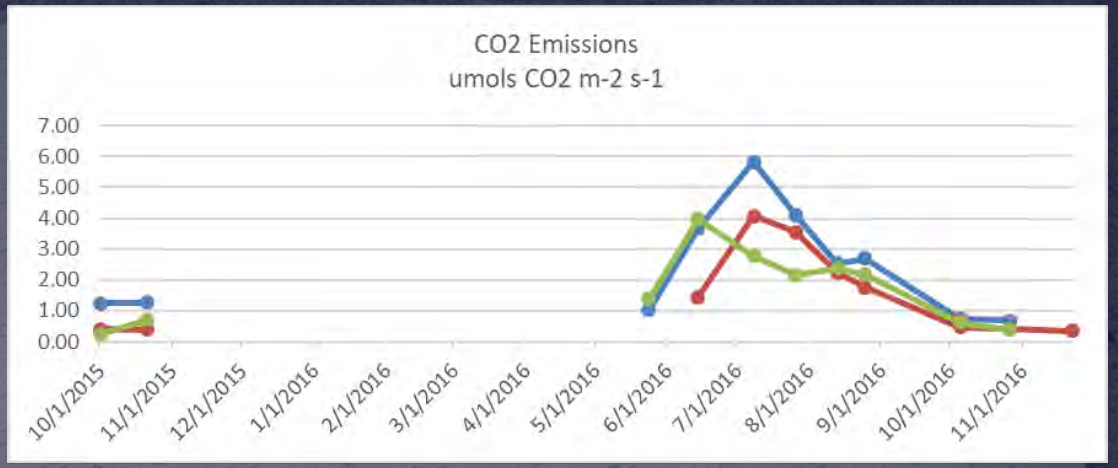
LONEY

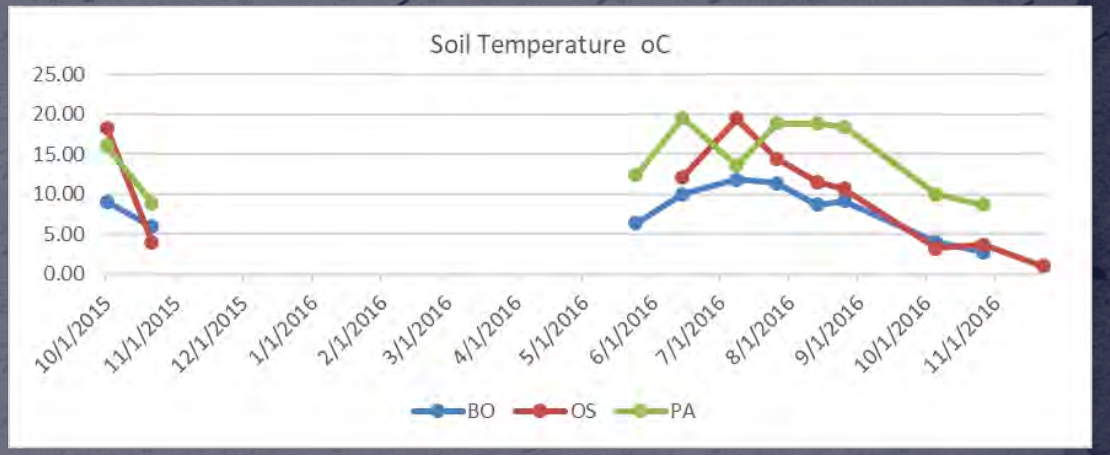

CO2 Emissions
umols CO2 m-2 s-1
10.00
8.00
6.00
4.00
2.00
0.00
9/24/2015
10/24/2015
11/24/2015
12/24/2015
1/24/2016
2/24/2016
3/24/2016
4/24/2016
5/24/2016
6/24/2016
7/24/2016
8/24/2016
9/24/2016
10/24/2016

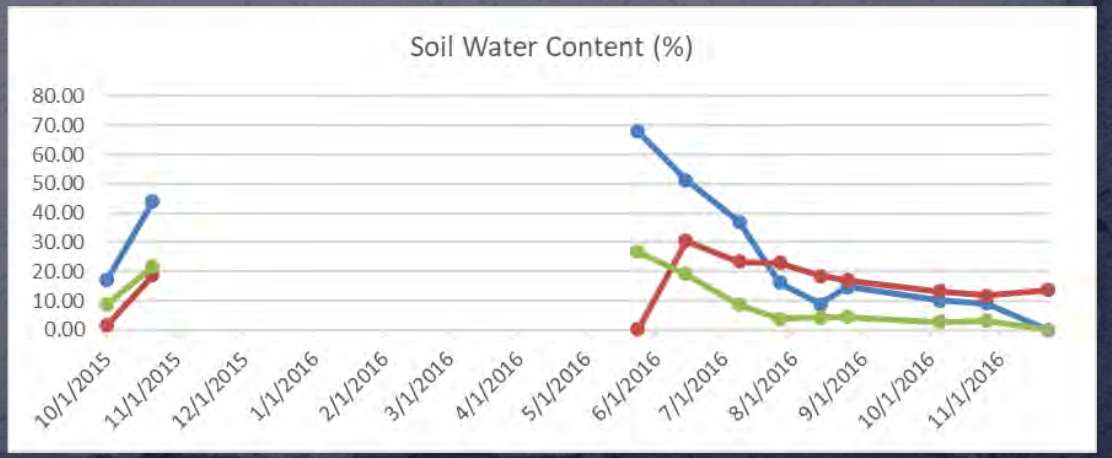

Soil Temperature
oC
20.00
15.00
10.00
5.00
0.00
-5.00
9/24/2015
10/24/2015
11/24/2015
12/24/2015
1/24/2016
2/24/2016
3/24/2016
4/24/2016
5/24/2016
6/24/2016
7/24/2016
8/24/2016
9/24/2016
D
L
UL


Soil Water Content (%)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
9/24/2015
10/24/2015
11/24/2015
12/24/2015
1/24/2016
2/24/2016
3/24/2016
4/24/2016
5/24/2016
6/24/2016
7/24/2016
8/24/2016
9/24/2016
10/24/2016

OSA


CO2 Emissions
umols CO2 m-2 s-1
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10/1/2015
11/1/2015
12/1/2015
1/1/2016
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016


Soil Temperature oC
25.00
20.00
15.00
10.00
5.00
0.00
10/1/2015
11/1/2015
12/1/2015
1/1/2016
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
BO
OS
PA


Soil Water Content (%)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
10/1/2015
11/1/2015
12/1/2015
1/1/2016
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016