How Does 4R Nutrient Stewardship Affect Environmental, Social, and Economic Outcomes?

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4R Nutrient Stewardship Meeting
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Assessment Framework

Identify and define…

… space and time boundaries

… level of detail

… baseline and “treatment” scenarios

Analysis of…

… specific elements that change (scale)

… how these elements impact social, econ, environ

… quantified magnitude and direction

… monetized value

… uncertainty (variability), complexity

Integration necessary (scale and sectors)

Mismatches between management and impact boundaries

- Need to balance farmer needs and societal impacts

Stakeholders have different socio-economic priorities and perspectives

Matrix of effects

	Farm Level	Watershed Level	Regional or National
Environmental	(+) soil quality, long-term productivity (+) reduced NO_3 in drinking water (+) risk management, adaptation	(+) reduced N & P in surface waters (+/-) less climate change	(+) reduced N & P in surface waters (+) healthier ocean (+/-) less climate change
Economic	(-) management time, training, and labour (-) equipment (-) new product (+) lower fertilizer costs	(+) less drinking water treatment needed downstream (+) recreational or tourist income	(+) healthier ocean fisheries
Social	(-) tradition, generational conflict (+) innovation (+/-) need for crop advisors & other experts	(+) recreational benefits: fishing, boating (+/-) relationships between farmers and public	(+) less skin cancer (ozone depletion from N_2O)

Quantify effects (and determine value?)

Data from field sites & literature on environmental impact, equipment, labour

Data or expert opinion on regional baseline practice, applicable cropland area, farm characteristics & demographics

Data or expert opinion on regional water quality issues, farmer/consumer relationships

Note items where quantification or monetization not viable

- Use available indices, social impact assessment tools
- Give decision-makers information

Price Estimates of N Pollution

...the Benefits of Mitigation (per kg N)

	van Grinsven et al. 2013 (European N Assessment; Environ Sci & Tech)	Compton et al. 2011 (U.S. EPA Report; Ecology Letters)	Gu et al. 2012 (China; Environ Sci & Tech)	Kanter et al. 2015 (JEQ) [Average of others]
NO_3	\$8 – 40	\$54 – 57	--	Damage: \$39.40
N_2O	\$10 – 30	\$2 – 4	\$3	Damage: \$8.20

Prices in \$2005 USD (as per Kanter et al.)

\$8.20/kg N_2O-N = \$8.41/tonne CO_2e

Recent market prices (per tonne CO_2e): RGGI (\$5.25); Carbonfund.org (\$10); California/Quebec (\$12.34), Alberta (\$20CAD), BC (\$30CAD)

Higher damages for NO_3

Data needs, questions for field researchers

What data can you provide on environmental and production impacts?

- Synthesize (with other data) to determine central tendency and expected variability

What limitations or barriers exist for farmers in your region for implementing the 4R practices?

- e.g., equipment cost, labour, time management

What water quality topics are important in your region?

- Do you know of plans to upgrade water treatment plants, potential lawsuits, recreational issues?

Relationships between N_2O Emission and Nitrogen Uptake and Use Efficiency in Corn.

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Introduction

IPNI Research Activities:

- Meta-data analysis
  - Hypothesis: increase of NRE leads to decrease of N_2O emission
- Field Experiments
  - Global maize/Ecological intensification (collaborators: Drs. Scott Murrell, Sylvie Brouder, Jeff Volenec)
  - Intentional late split N application (rate and timing)

Objectives:

Assess:

- Relationships between seasonal N_2O and corn N uptake, NRE
- Effects of N management options on these relationships.

Meta-Analysis:

Google Scholar Search: N_2O and N uptake data from same experiment rarely reported.

Data Collection / Structure

- 1316 plot-level (340 mean obs.), across N mgmt.
- 63% rainfed, 37% irrigated systems
- 168 involved 12 N rate comparisons in 7 locations
- 157 involved N source comparisons in 6 locations.

Inclusion Criteria

- N_2O and N uptake data from same experiment
- Conducted for ≥ 2 years, ≥ 3 replicates
- N_2O measured at least weekly, across growing season.

Parameters

- Total and grain N uptake (TNU, GNU)
- Nitrogen recovery efficiency (NRE)
- Nitrogen balance (NB; applied+rotation N).

Meta-Analysis:

Data Analysis

- Data separated by 4R mgmt. systems
- Relationships between N_2O and N uptake dynamics
  - Regression models.

N Rate-focused Management

- Rates grouped 50 kg intervals

N groups (n=7): 0 (n =22), 1-50 (n = 2), 51-100 (n=13), 101-150 (n=19), 151-200 (n=9), 201-250 (n=18), 251-300 (n=2)

Group means: 0, 45, 73, 132, 174, 221, 270 kg N ha^{-1}, respectively for the groups.

(R. Omonode, T. Vyn, A. Halvorson, R. Venterea, and B. Gagnon 2016, in review).

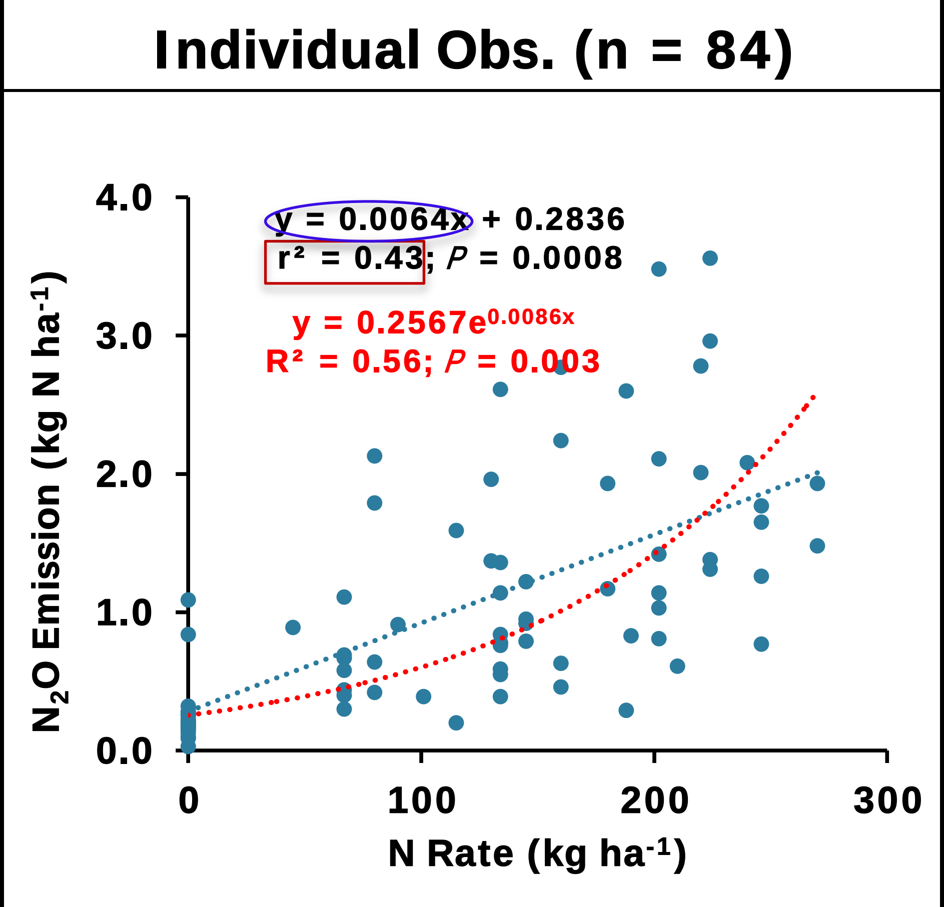
Results and Discussion

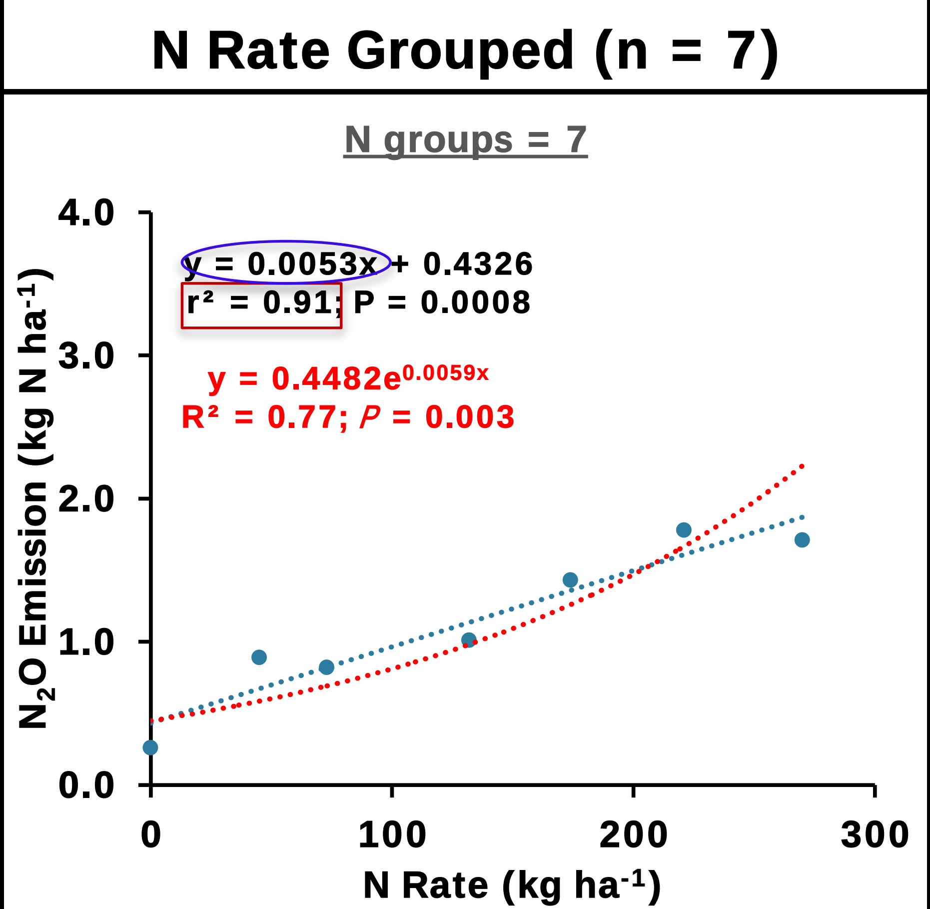
- **Results overview:**
  - N rate and timing influenced the relationships
  - N source and placement tended to confound the relationships.
  - R/ships not improved by yield-scaled or log-transformed N_2O

Mgmt. focused only on N Rate

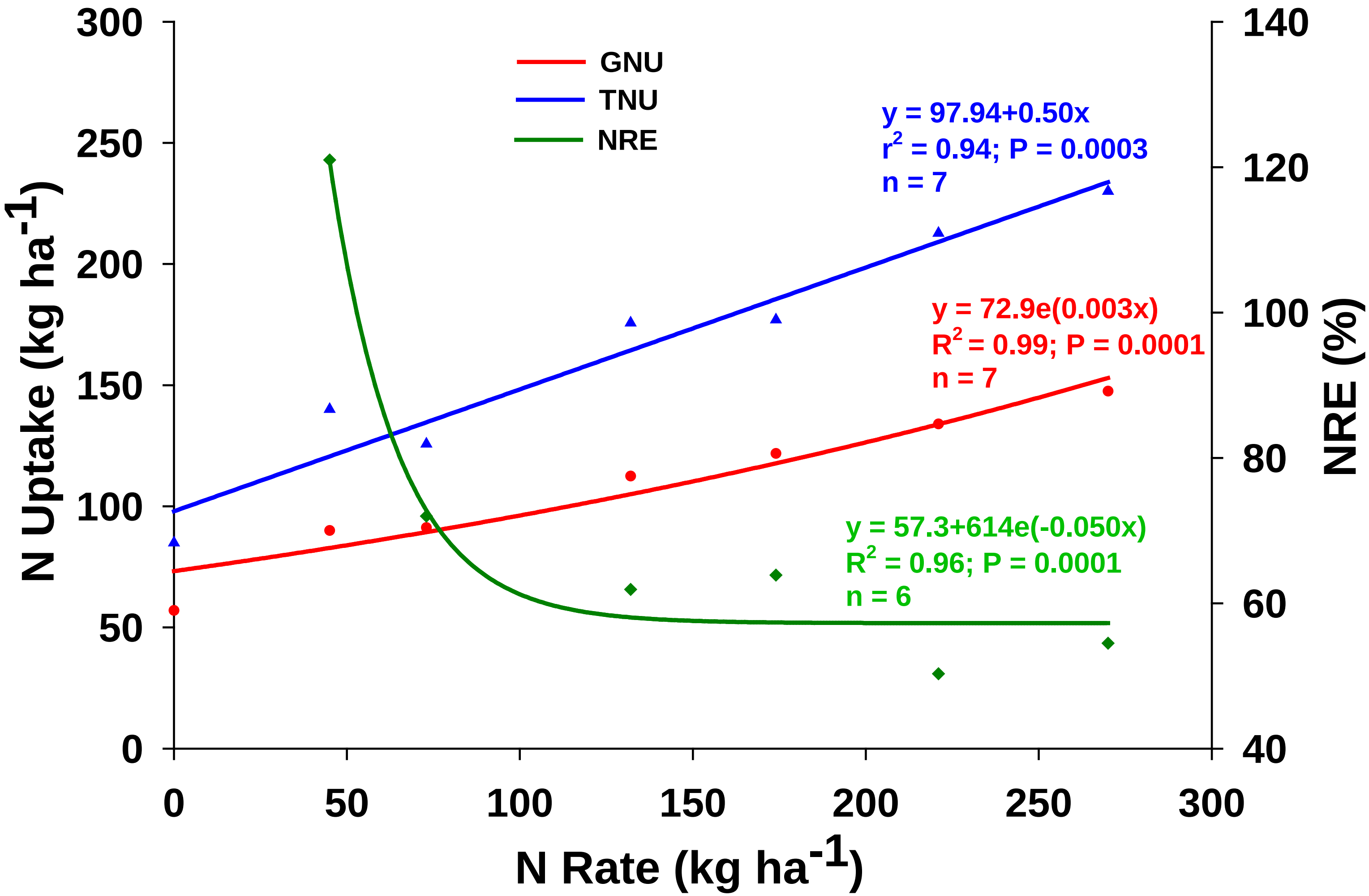
Data structure effect:

Relationship Between N_2O and N Rate.

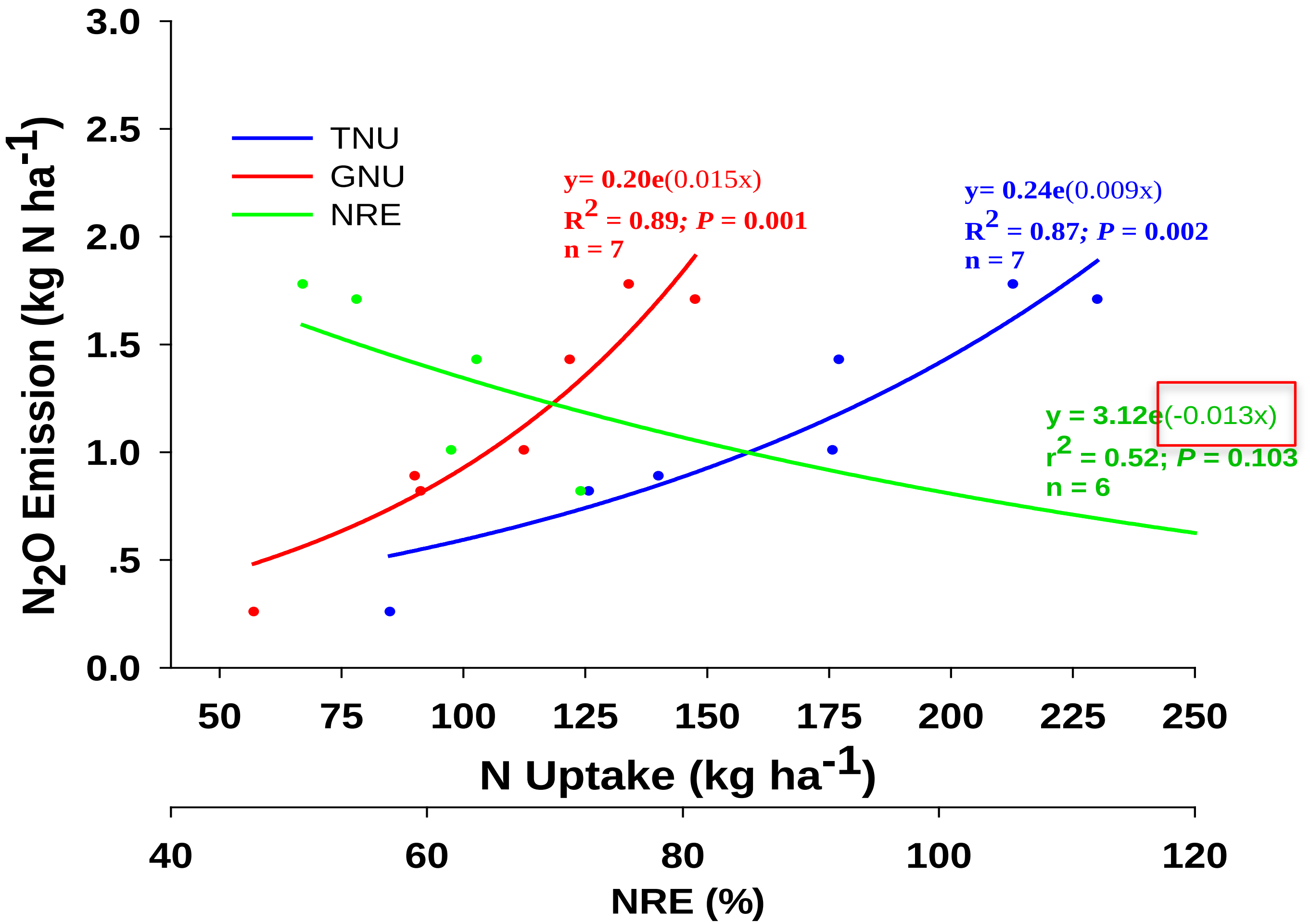




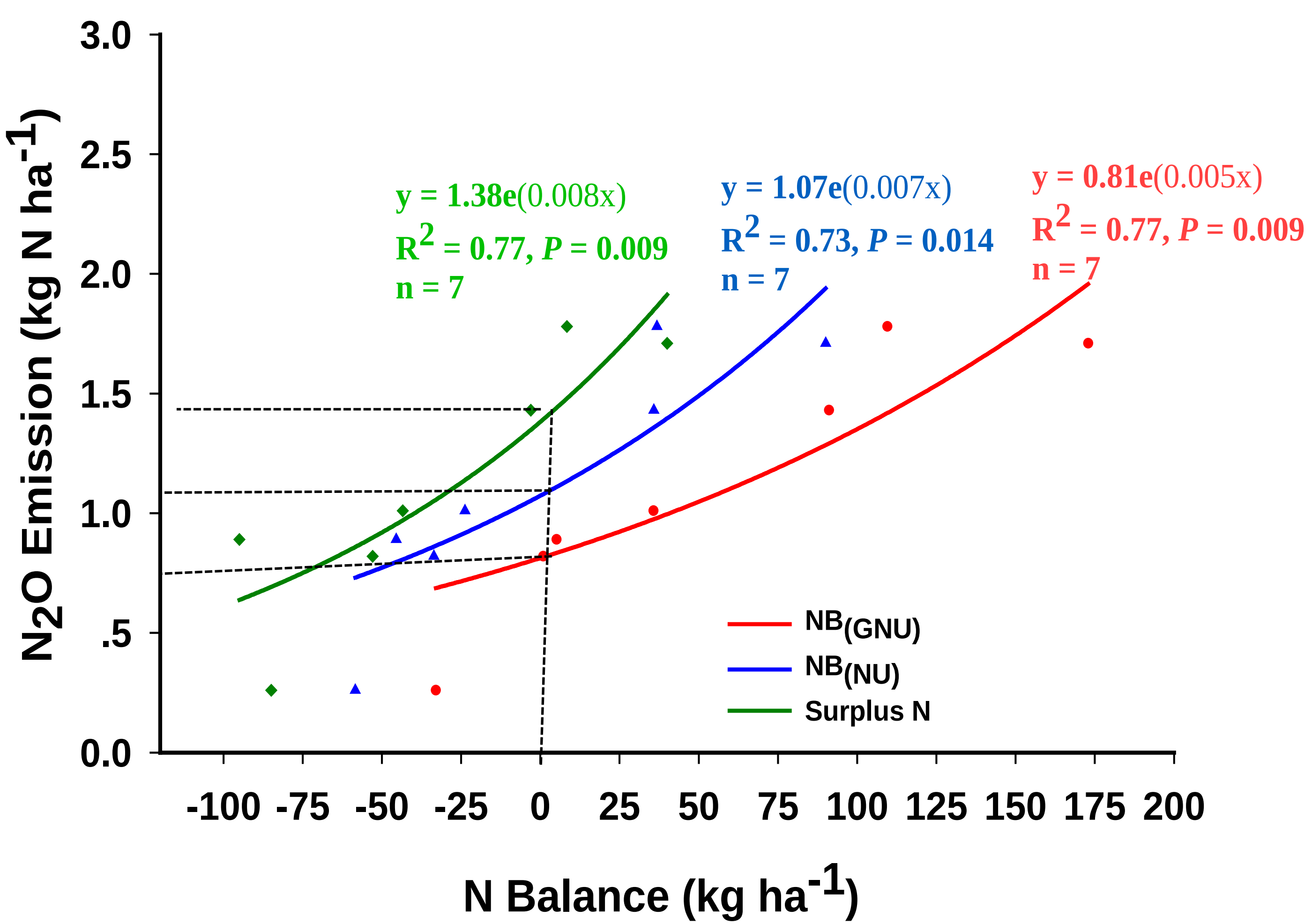
Relationship Between N Rate, N Uptake, and NRE.



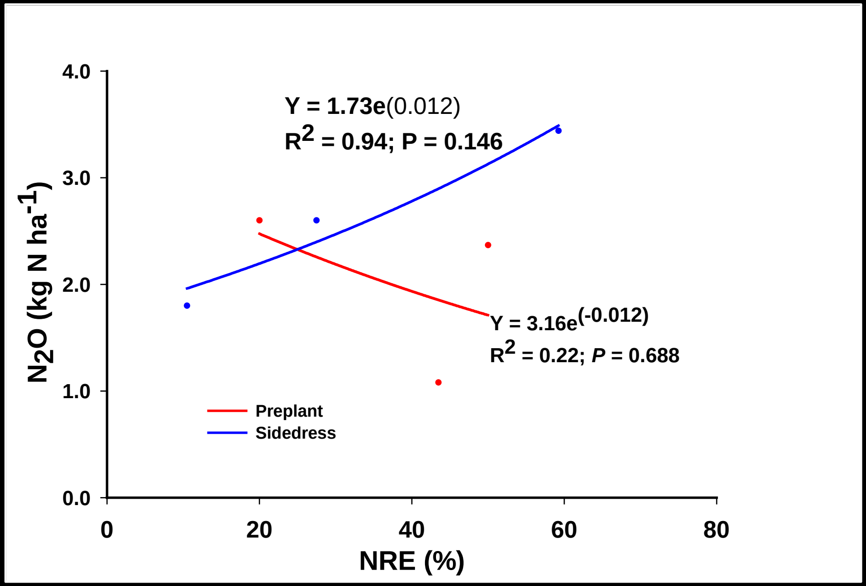
Relationship Between N_2O, N Uptake and NRE.

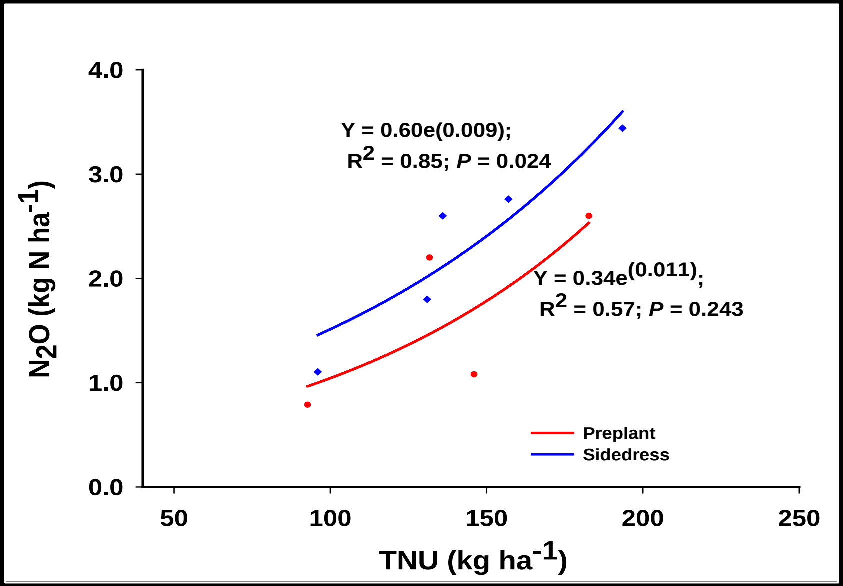


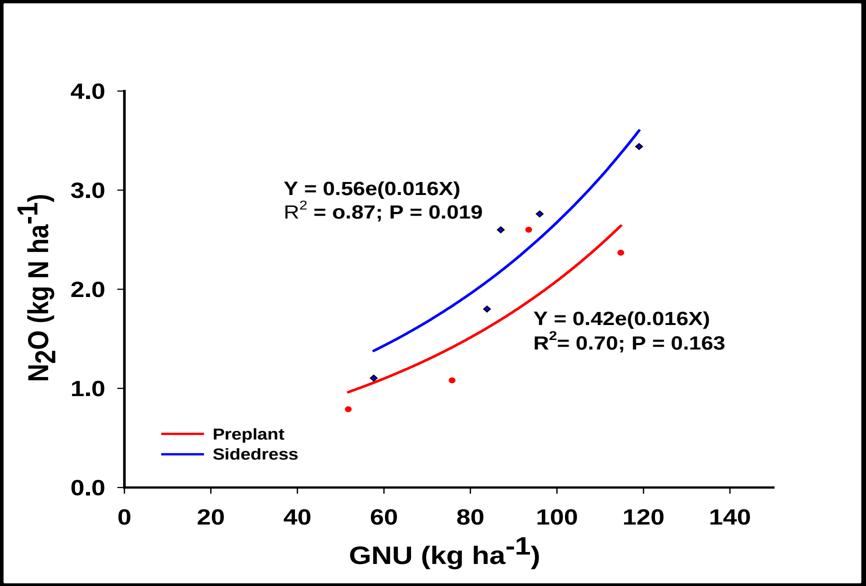
Relationship Between N_2O and Nitrogen Balance.



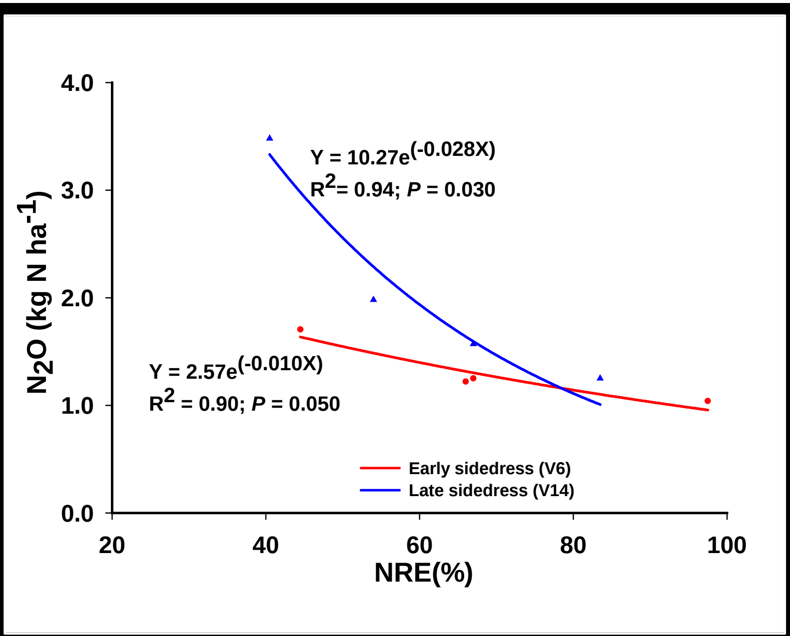
Relationship Between N_2O, N Uptake and NRE (Preplant vs. regular sidedress).

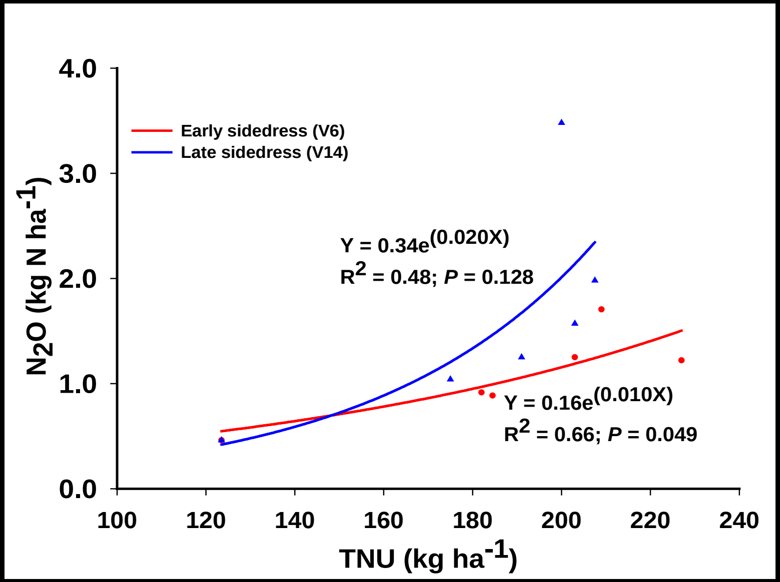


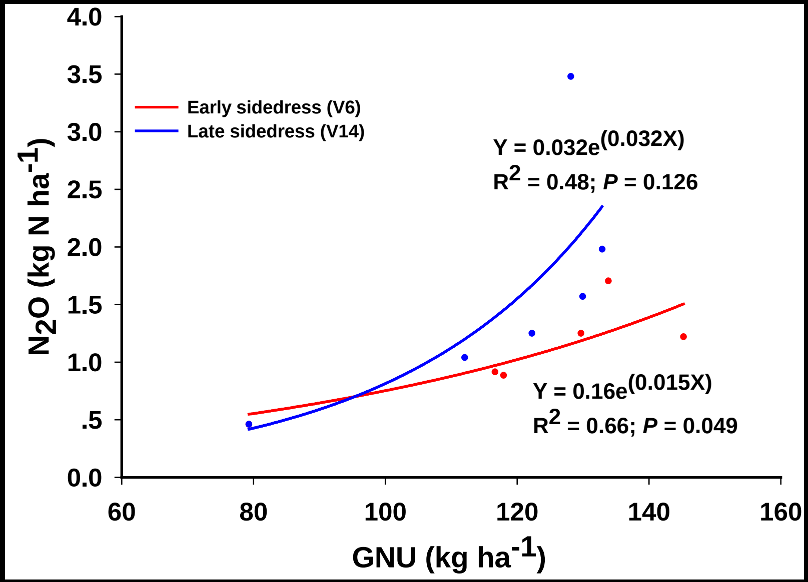




Relationship between N_2O, N Uptake and NRE: (Regular vs late sidedress).







Relative Effect of Nuptake, NRE and N Balance.

- **Multiple Regression:**
  - 40% variability accounted for by all variables
  - $NB_{(TNU)}$ and $NB_{(GNU)}$ accounted for 32 of 40% total variability
    - $N_2O = 0.99+0.006NB_{(TNU)}+0.004NB_{(GNU)}$; $P = 0.0001$

Conclusions

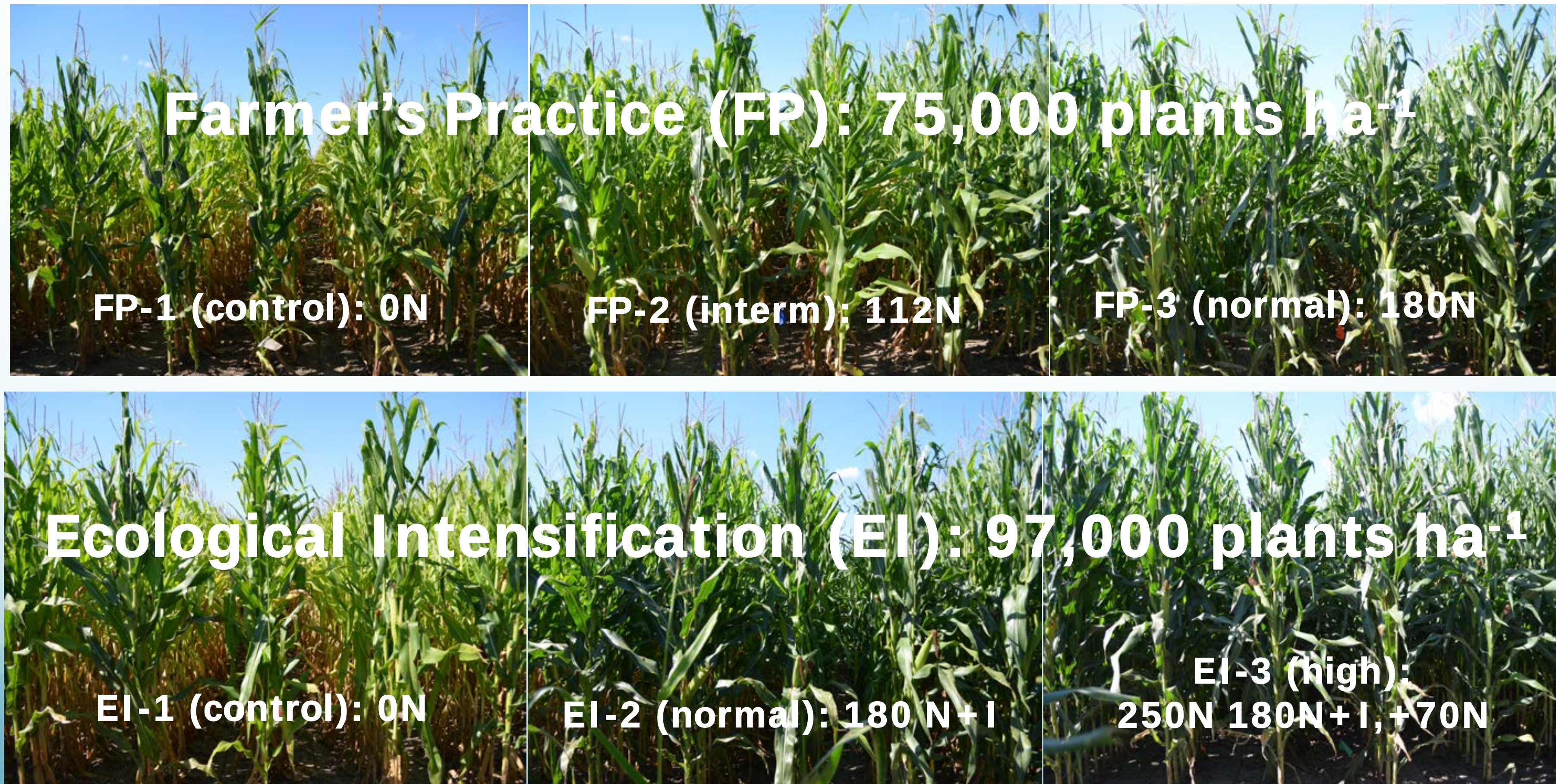
- Weak but significant –ve relationship existed between N_2O and NRE (mgmt.= N rate, rate x timing); N_2O ⇩ by 13 g N ha^{-1} per % ⇧ of NRE under N rate, and by 15 g N ha^{-1} for rate-by-timing treatment comparisons.

- Consistently stronger but significantly positive relationships existed between N_2O and $_{\text{NB(NU)}}$, $NB_{\text{(GNU)}}$ and SN; N_2O increased by 5-8 g N per kg increase of NB, regardless of N rate and timing,

- Benefits from optimum N rate-by-timing practices are likely to be achieved most consistently with systems that reduced NNB (increase of grain N removal or total plant N uptake relative to the total fertilizer N of the system).

Ecological intensification effects on N_2O Emission and N_2O-N uptake dynamics.

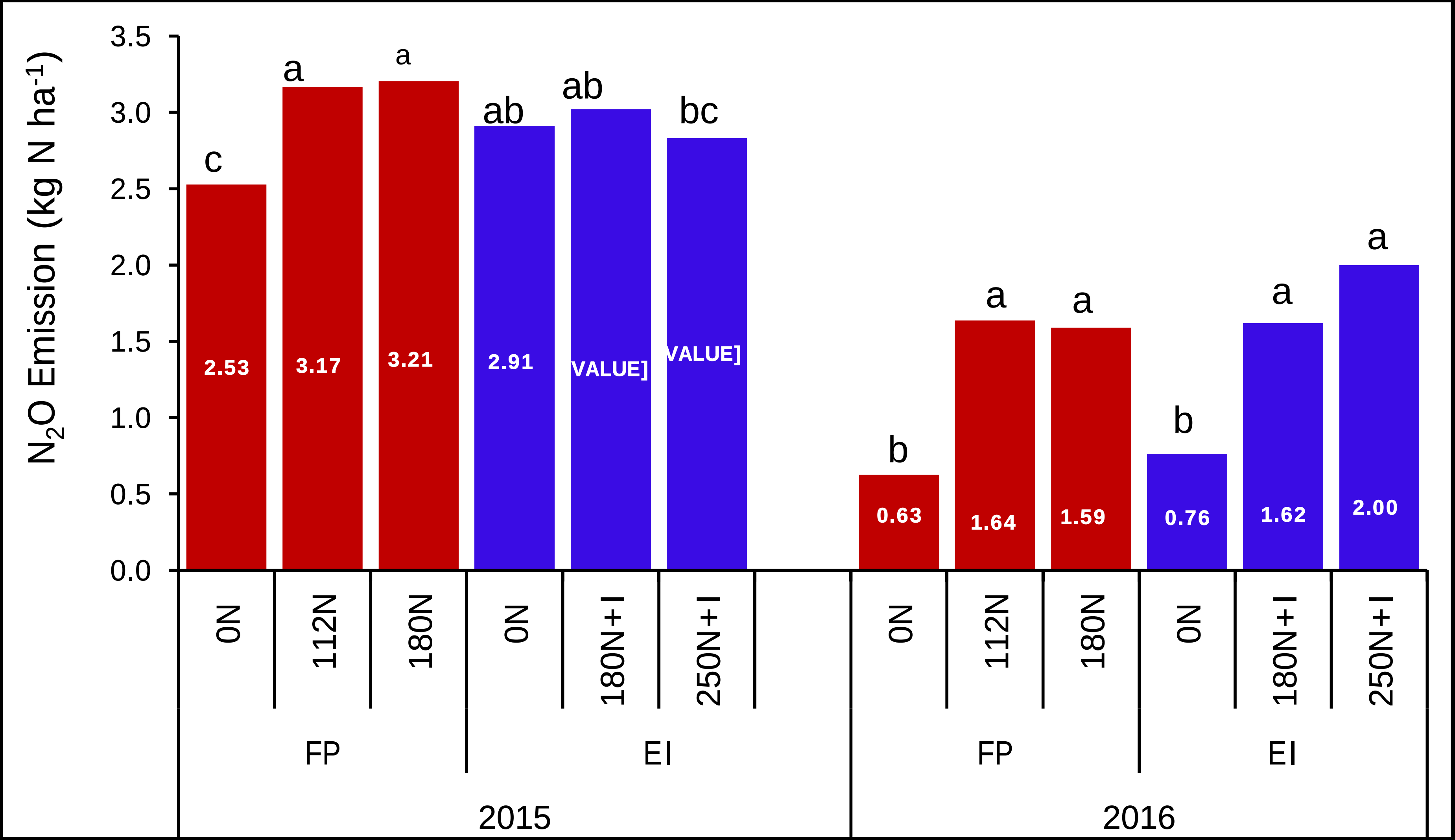
Treatments:



Ecological Intensification and Farmer's Practice Effect on N Uptake & Recovery Efficiency (2015).

Mgmt.	Grain N Uptake (kg ha-1)	Total N Uptake (kg ha-1)	NRE (%)
FP-1 (control)	35.4e	59.5a	-
FP-2 (interm)	82.1d	118.6d	52.8a
FP-3 (normal)	104.7c	146.6c	47.8a
EI-1 (control)	36.1e	62.6e	-
EI-2 (normal)	121.5b	171.0b	59.8a
EI-3 (high)	144.5a	199.6a	55.8a

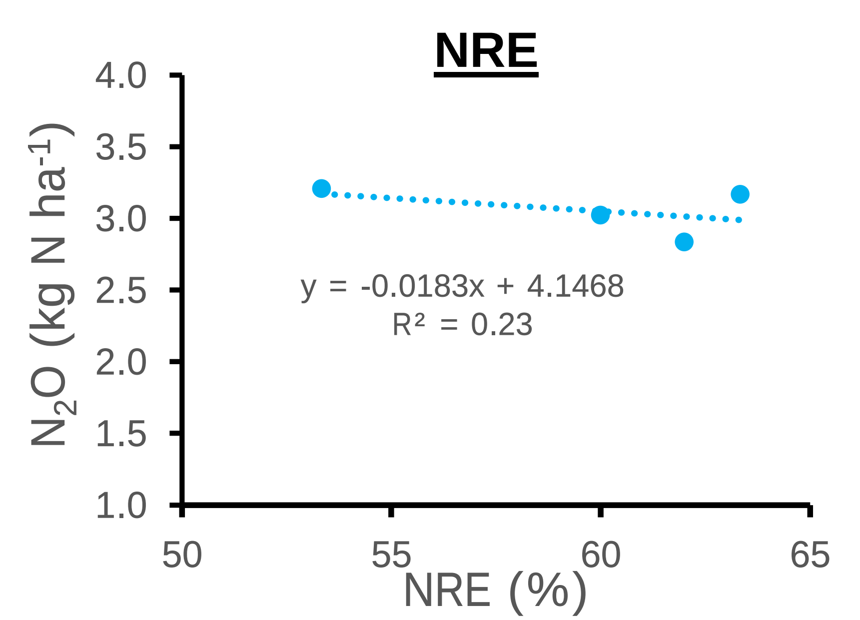
EI and FP Effects on Seasonal Cumulative N_2O Emissions (2015 and 2016).

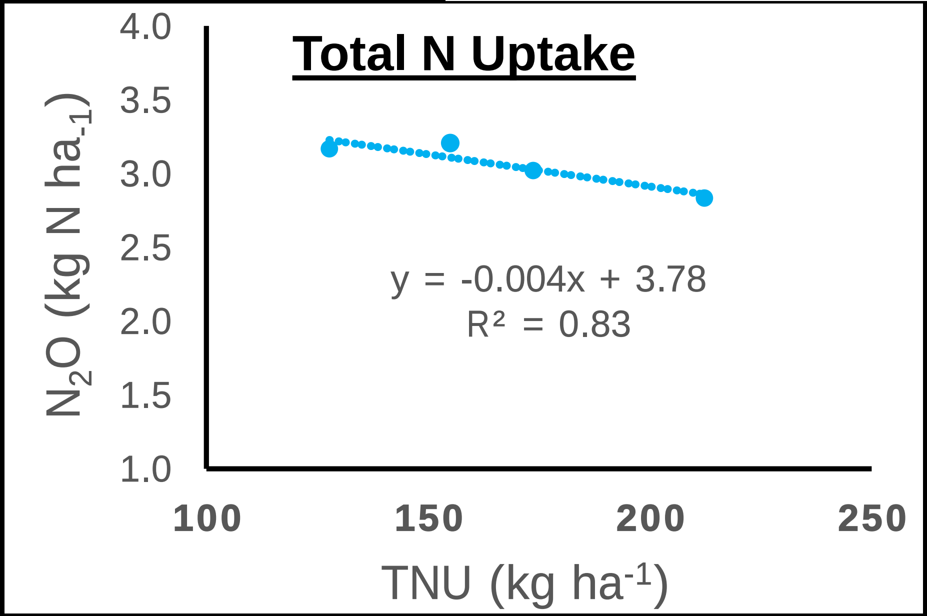


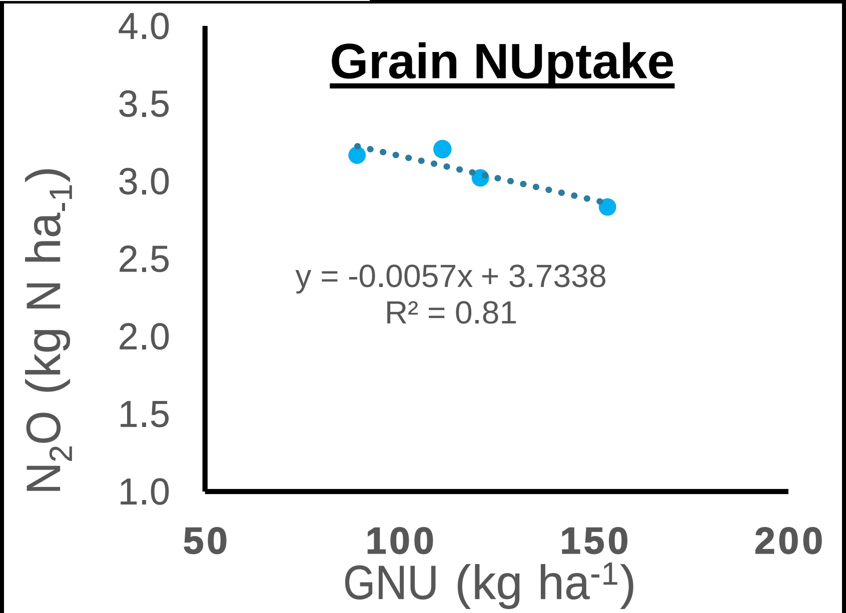
FP and EI Effects on Yield-scaled N_2O and Emission Factor

	2015		2016		Average	
Mgmt.	YS-N_2O	EF	YS-N_2O	EF	YS-N_2O	EF
	(g N MG GY^{-1})	%	(g N MG GY^{-1})	%	(g N MG GY^{-1})	%
FP-2 (Interm.)	346.8a	0.57a	124.9a	0.91a	235.8a	0.73a
FP-3 (normal)	297.0b	0.38a	108.6a	0.53ab	202.8a	0.45ab
EI-2 (normal	260.3c	0.06b	109.9a	0.48b	185.1a	0.27b
EI-3 (high)	215.5d	-0.03b	131.7a	0.49b	172.6a	0.23b

Relationship Between N_2O, NRE, and N Uptake in 2015.







Tentative Conclusions:

- Ecological Intensification (normal; 97000, 250 kg N) likely to increase corn yield without significant increase of seasonal N_2O emission

- Similar general model:
  - –ve relationship existed between N_2O and NRE; N_2O decreased ~18 g N ha^{-1}
  - However, -ve linear relationship also existed between N_2O and Nuptake.

THANKS.

IPNI

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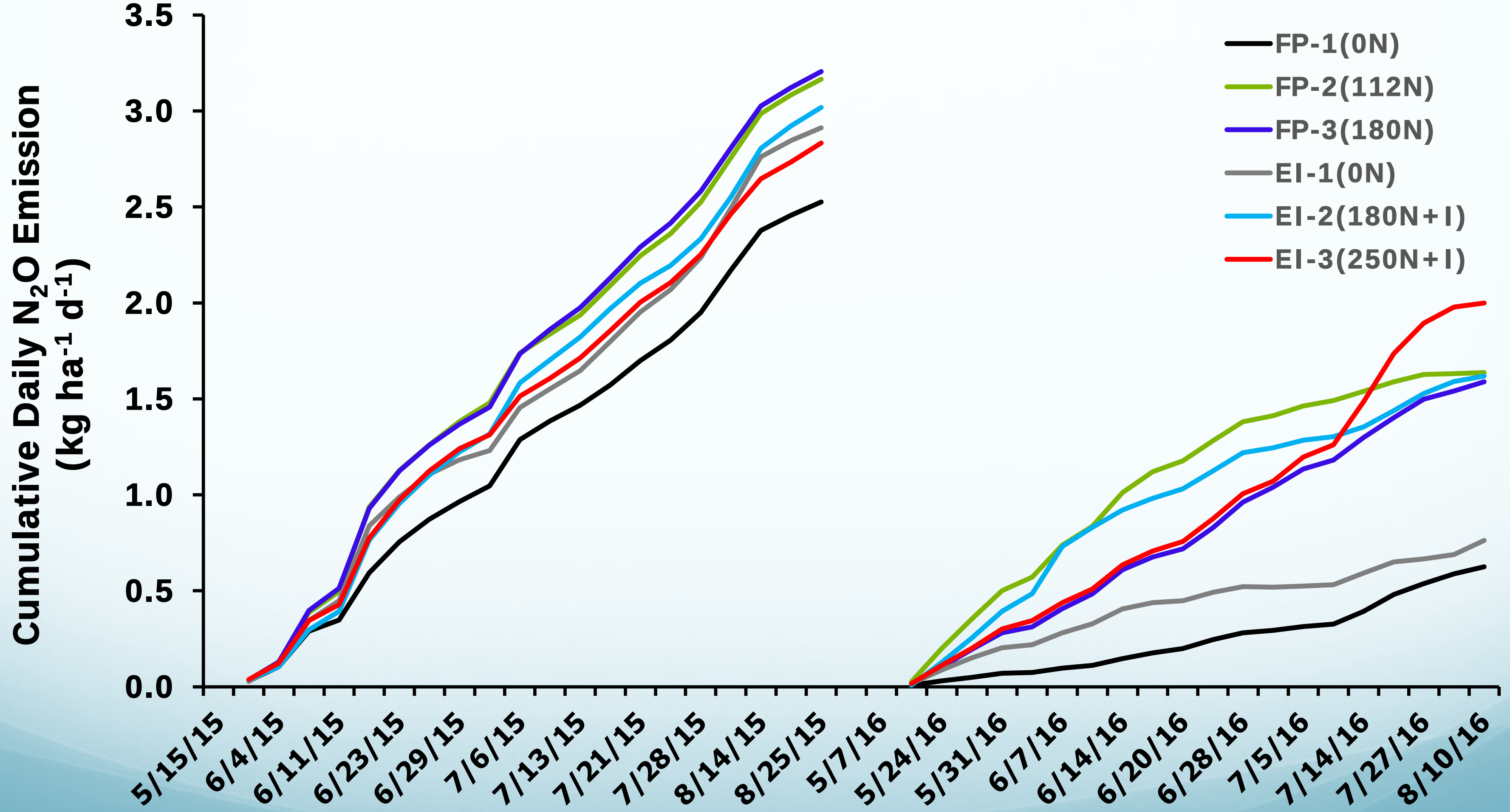
Cumulative Daily N_2O Emissions Under Farmer's Practice and Ecological Intensification (2015 and 2016).



Timing of N Application

Preplant vs sidedress (Indiana

Locations: Indiana (0, 90, 150 180 kg ha-1) & New Brunswick (0, 180 kg ha^{-1});

For Indiana, each N2O and N uptake data point is the mean value of 4 data points (with and without Instinct, over 2 years (i.e., n=4)

Regular vs late/slit sidedress

Location: Minnesota; one year data, N rate = 0, 50, 90, 130, 170, 210 kg ha-1

Calculations:

Calculations:

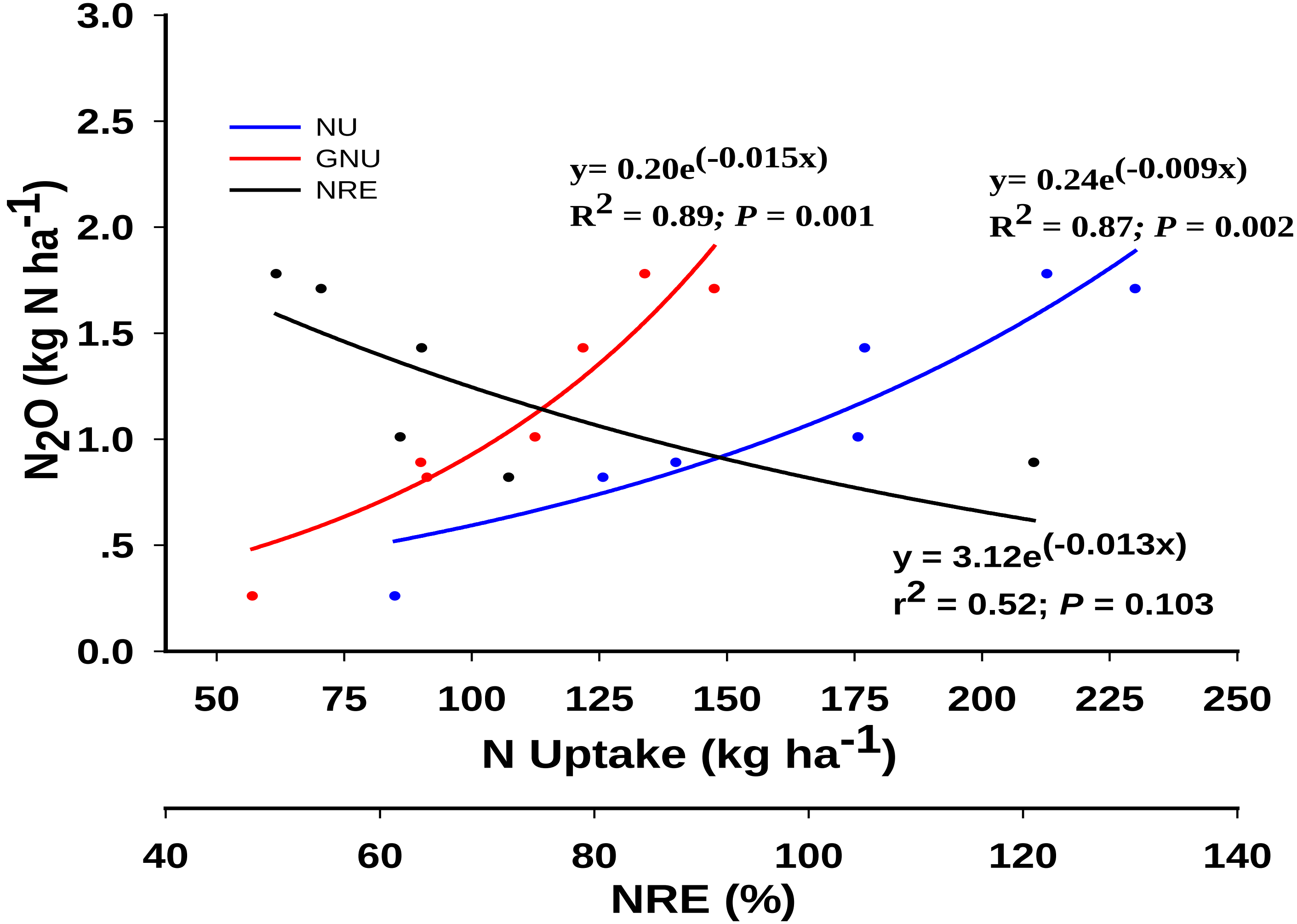
- Total above-ground N uptake (NU) = Grain N uptake, (GNU)/0.64 (N harvest index); Grain N uptake = NU*0.64

- From N rate, GNU and NU data, NRE, net N balance, NNB, surplus N (SN) calculated as:

  - NRE (%) = (NU(NR) - NU (0N))/NR*100;
  - NNB(GNU) (kg N ha-1) = ((NF + NROT) - (GNU))
  - NNB(NU) (kg N ha-1) = ((NF + NROT) - (NU))
  - SN (kg N ha−1) = NF – NU

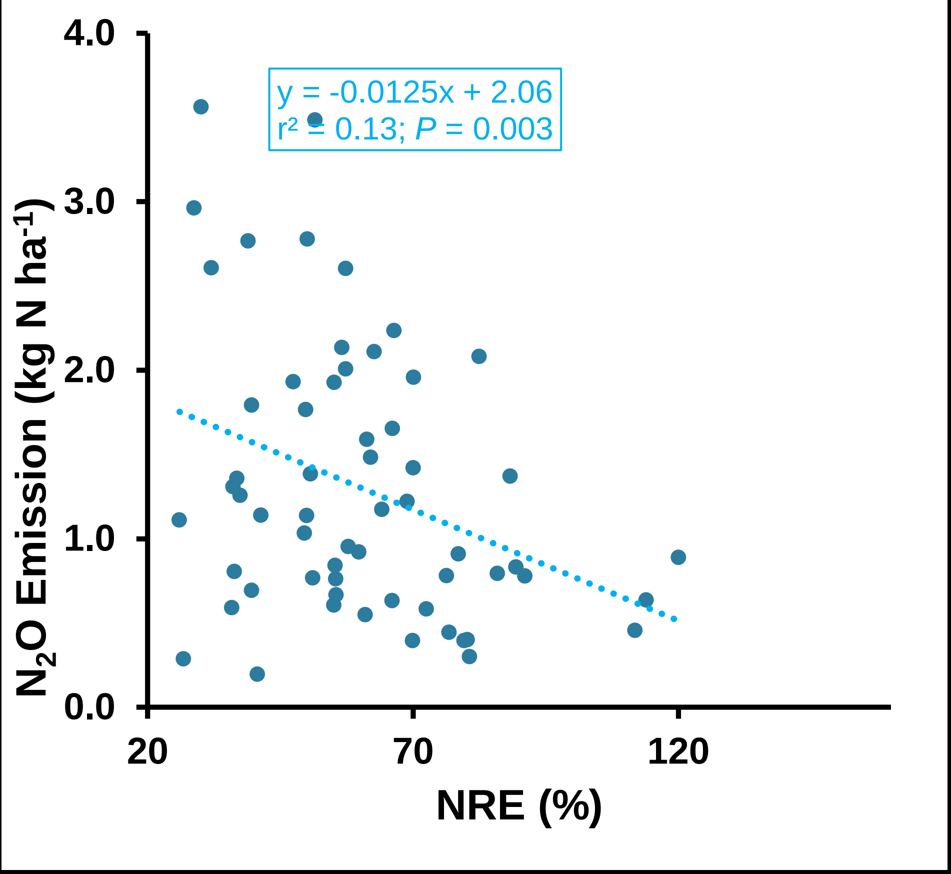
Where NR = N rate (kg N ha-1); NF = applied fertilizer N (kg N ha-1); NROT = N credit (kg N ha-1) due to rotation when corn followed a legume as recommended for the state/region.

Relationship Between N_2O, N uptake and NRE: Mgmt. focused on N Rate.

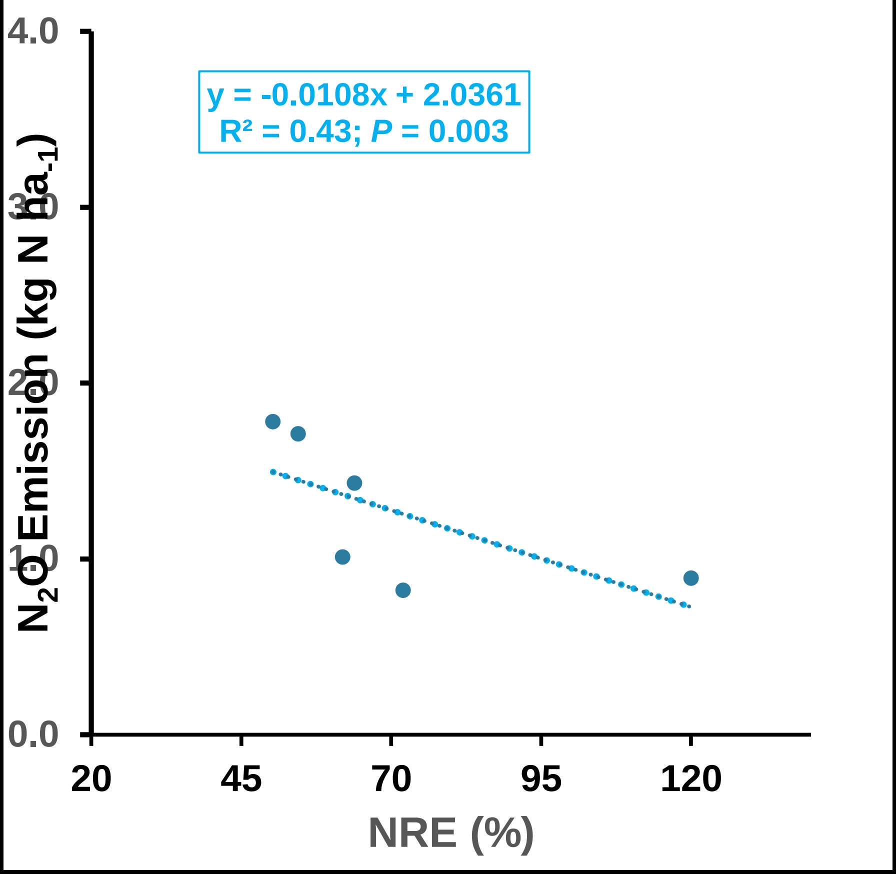


Data structure effect:
Relationship Between N_2O and NRE.

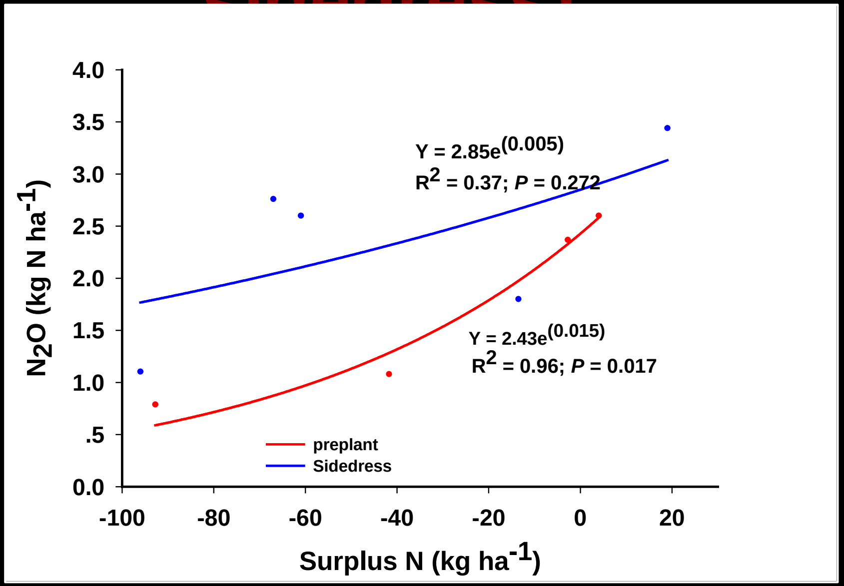
Individual observations (n=62)

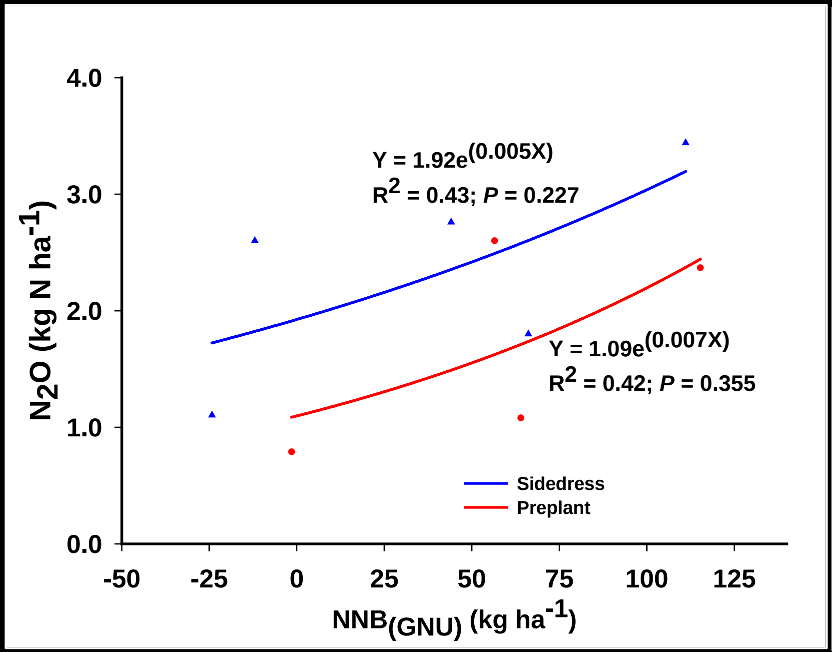


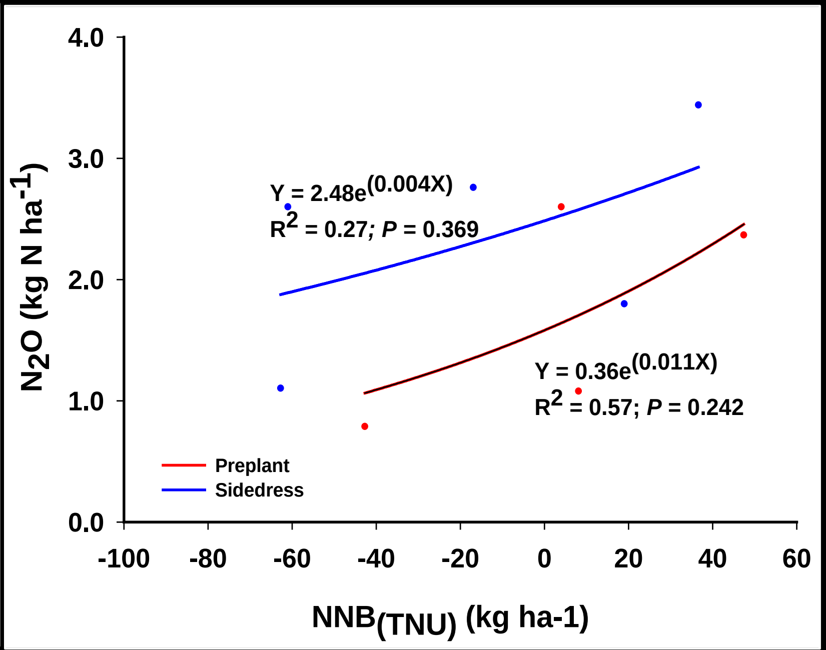
Grouped by 50 kg (n = 6)



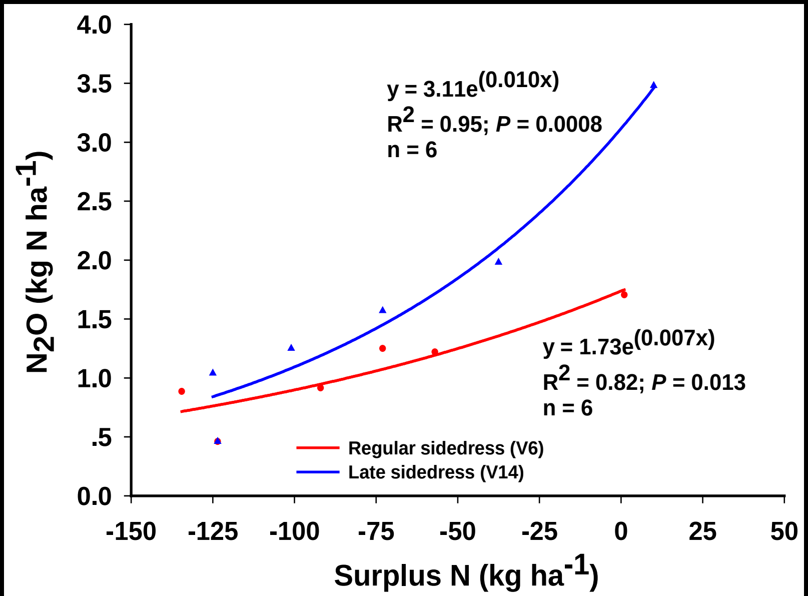
Relationship Between N_2O and Nitrogen Balance (Mgmt. = timing; preplant vs. regular sidedress)

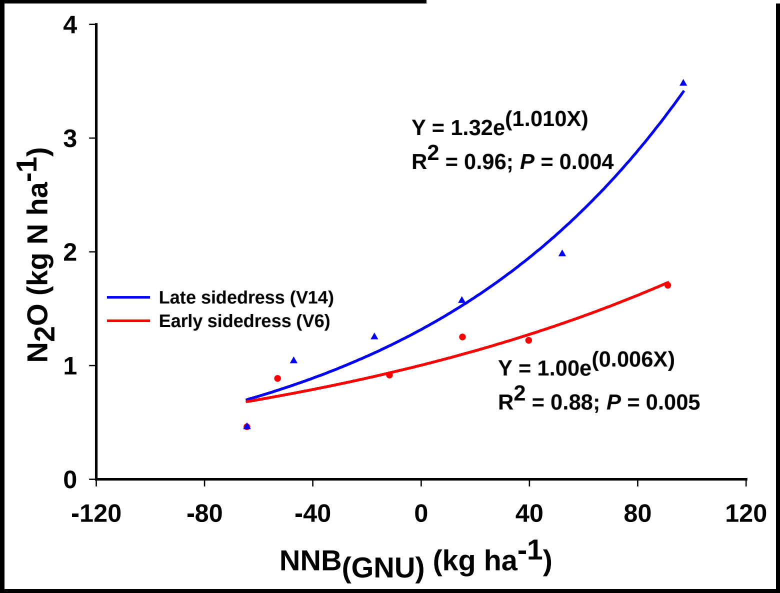


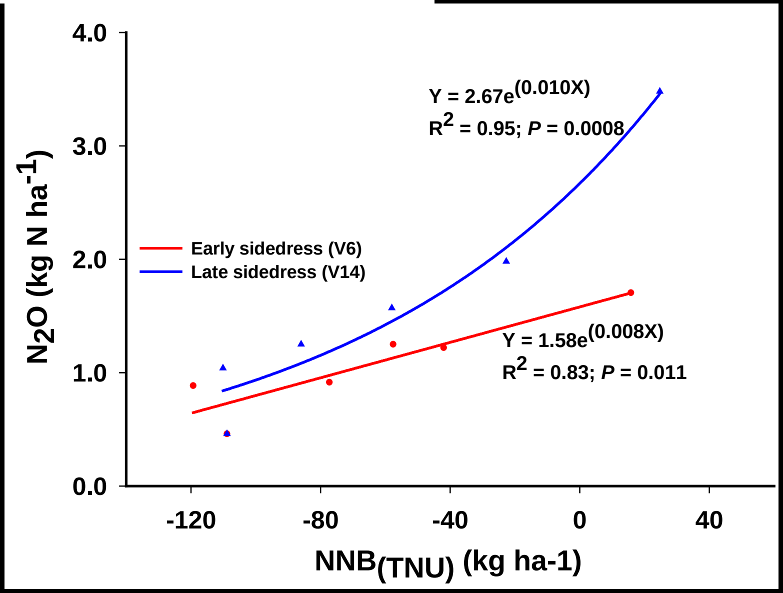




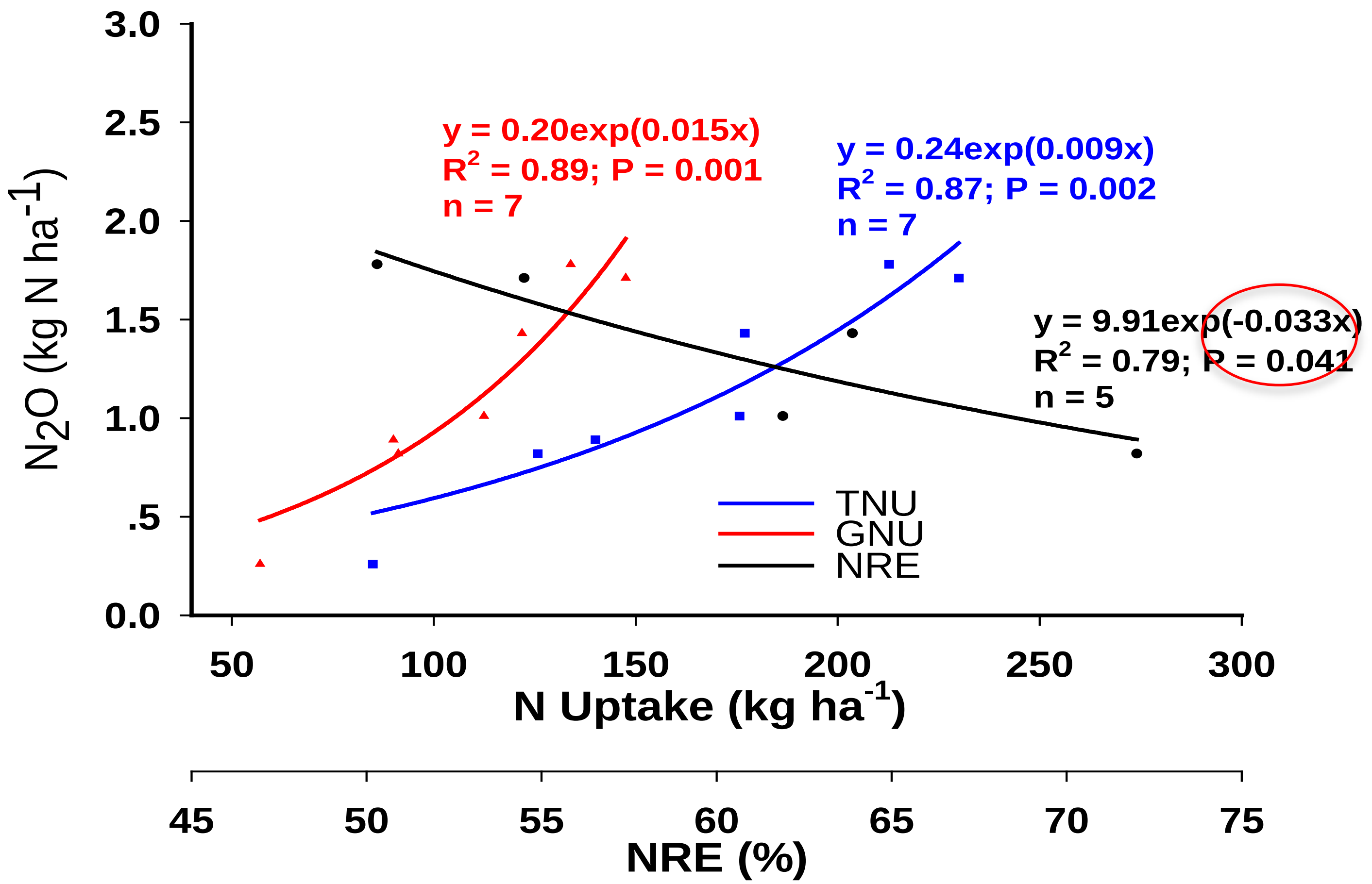
Balance:
(Mgmt. = timing; regular vs late sidedress).



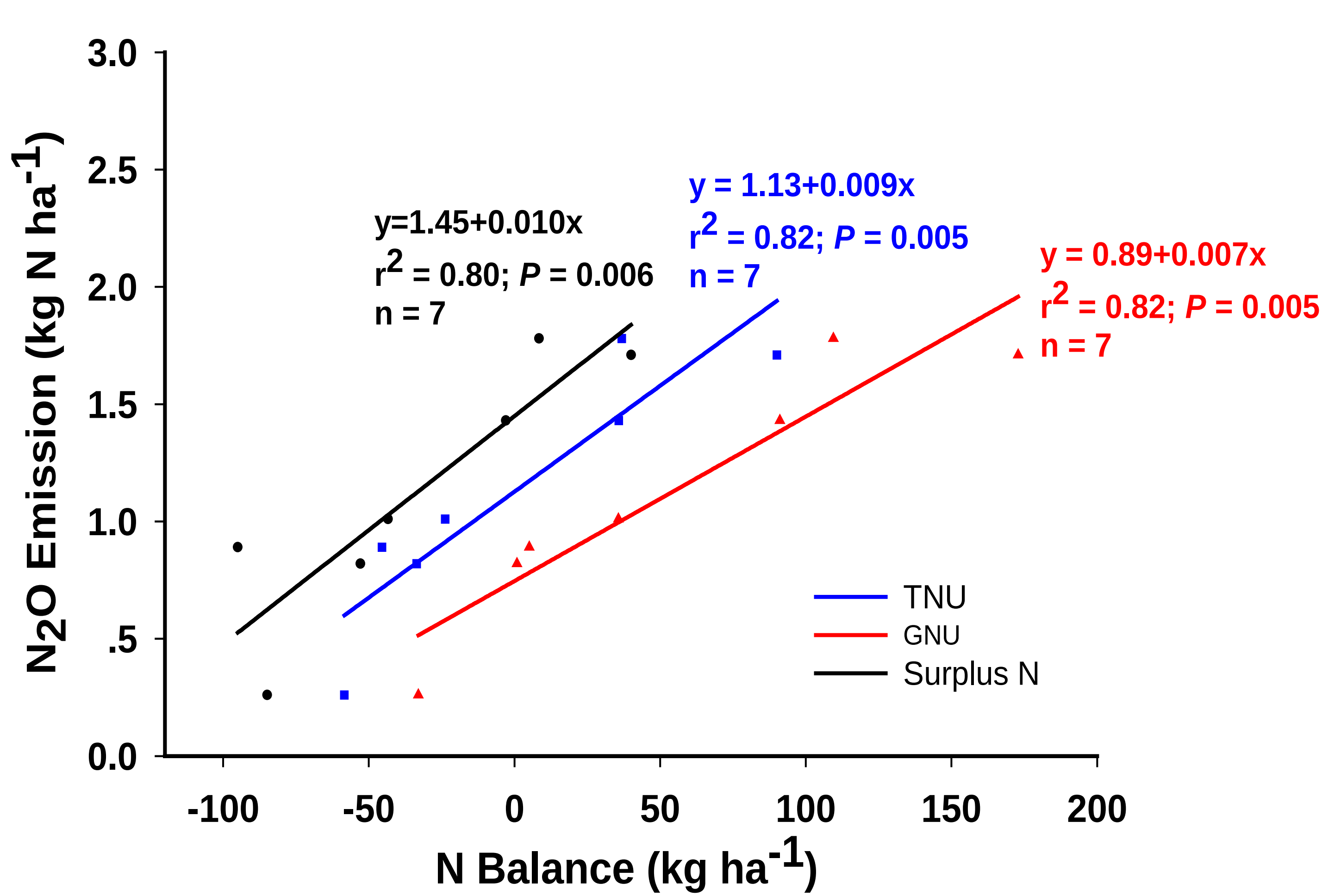


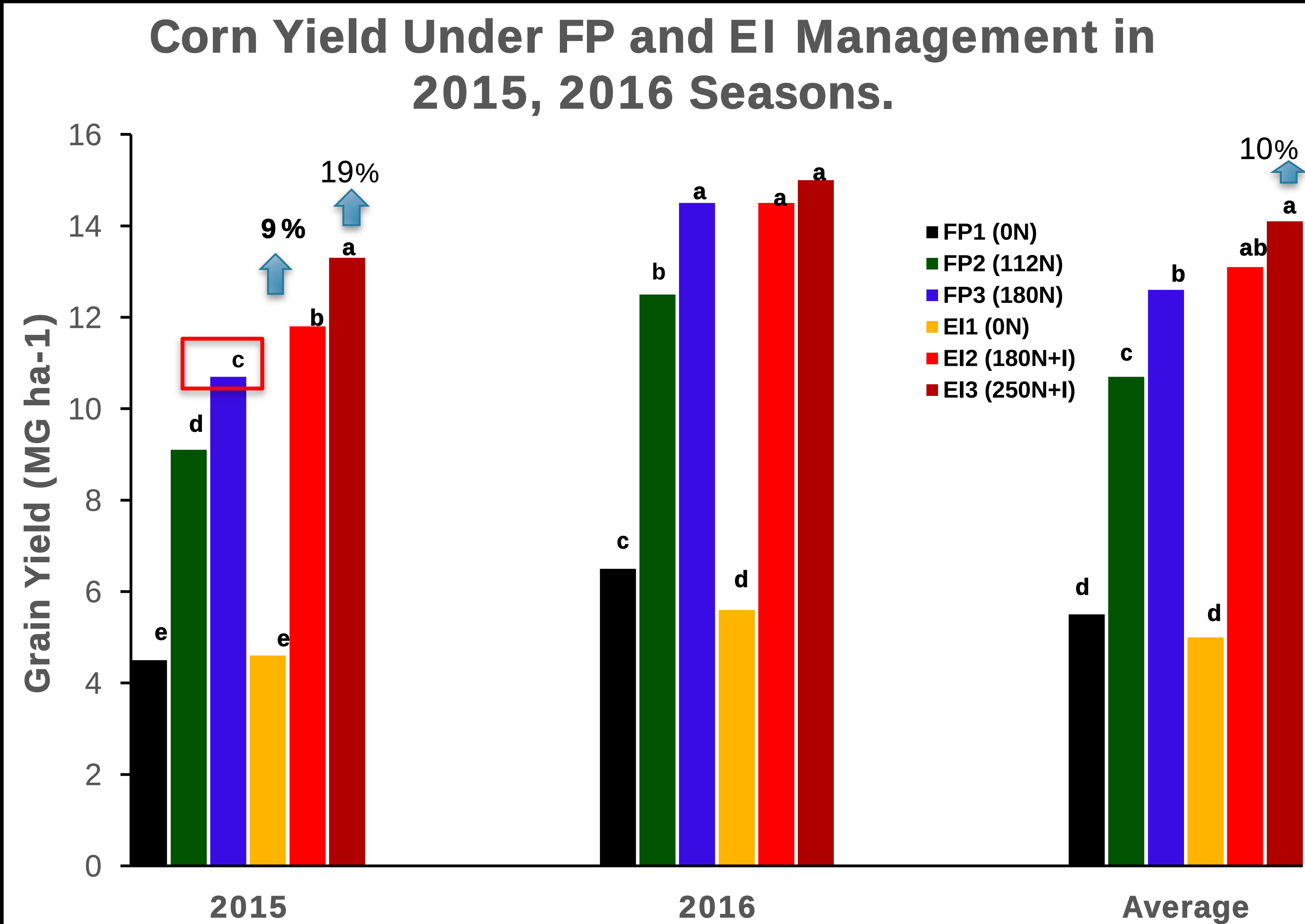


Relationship Between N_2O, N uptake and NRE.



Data structure effect:
Relationship Between N_2O and Nitrogen Balance.




Corn Yield Under FP and EI Management in 2015, 2016 Seasons.
Grain Yield (MG ha-1)
0
2
4
6
8
10
12
14
16
2015
2016
Average
9 %
19%
10%
e
d
c
e
b
a
c
b
a
d
a
a
d
c
b
d
ab
a
FP1 (0N)
FP2 (112N)
FP3 (180N)
EI1 (0N)
EI2 (180N+I)
EI3 (250N+I)